FPE 596 – Culminating Project Final Report

[redacted]

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[redacted] Building

[redacted]

San Francisco, CA

Statement of Disclaimer

Keywords: ASET, RSET, Egress, Fire Dynamics Simulator (FDS), Prescriptive Requirements

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1 EXECUTIVE SUMMARY

The objective of this report is to conduct a thorough analysis and evaluation of the existing fire life safety and fire protection systems in place at the [redacted] Building located in San Francisco, California. The building is classified as a Type II-A building and serves predominantly as office space. The building is six stories tall with a total gross area of approximately 97,170 SF.

The initial portion of this report concentrates on a thorough prescriptive-based analysis, which provides an evaluation of the egress design, fire alarm system, communication systems, fire suppression system, structural and construction design, smoke control, and flammability requirements. The results of this comprehensive analysis demonstrate that the building complies with the requirements of the applicable building and fire codes.

The subsequent portion of this report provides a performance-based analysis, which evaluates two distinct fire and life safety assessments. The first assessment involved the evaluation of the I.T. room located in the basement, with a focus on identifying potential flashover occurrences, the activation times of smoke and sprinkler detection, and the possibility of secondary ignition. The outcomes of this analysis revealed that flashover is unlikely to occur, with smoke detection activation taking approximately 674 seconds, and sprinkler activation occurring approximately 744 seconds after the onset of the fire. Note that the activation times appear relatively long for a room of this size, which is understood to be primarily due to the inclusion of the fire's incipient slow growth phase. The results also indicated that secondary ignition does occur. These results suggest that the room is vulnerable to a fire scenario that could significantly impact the operations of the business and safety of occupants. To mitigate this risk, it is recommended that a fire protection system, such as a clean agent halon system or CO2 system, be installed to suppress fires and minimize equipment damage. Additionally, regular equipment maintenance performed by qualified professionals should be conducted to minimize the risk of ignition. The room should also be regularly inspected to ensure that the space does not contain large amounts of combustible materials to reduce potential fuel sources.

The second fire scenario involves the atrium, which connects the basement level to the second floor. The design fire occurs at the base of the atrium in the basement. The scenario was assessed using Fire Dynamic Simulator (FDS) and Pathfinder to determine the Available Safe Egress Time (ASET) and Required Safe Egress Time (RSET). The primary objective was to determine whether the ASET exceeds the RSET, thus ensuring that the building and its associated life safety systems can maintain a safe and tenable environment for all occupants to evacuate safely. The ASET analysis will specifically focus on the deployment of the fire-rated shutters to assess whether the conditions on the levels above the fire, as well as the areas remote from the fire, will remain safe and suitable for the evacuation of building occupants. Pathfinder was utilized to determine the RSET, and the results indicated a time of 1034 seconds (~18 minutes) which takes into account a 1.5x safety factor.

ASET was calculated by FDS, which simulated and assessed various tenability criteria, including smoke layer descent, heat exposure, visibility, and carbon monoxide dosing. The results indicated that the ASET could be maintained for 18 minutes for floors and areas remote from the fire. This is primarily due to the activation of fire-rated shutters, which compartmentalized the basement from the floors above. It should be noted that the atrium complies with all applicable prescriptive code requirements. The analysis emphasizes the crucial role of fire safety equipment functioning properly to ensure the safety of occupants within the building. The primary recommendation is to minimize potential ignition sources and fuel sources near the atrium. Additionally, regular equipment inspection and maintenance from qualified professionals should be conducted to ensure that the fire alarm system, automatic sprinkler system, and fire-rated shutters operate properly.

2 INTRODUCTION (BUILDING OVERVIEW)

2.1 Overview of the [redacted] Building

The [redacted] building is a six-story low-rise building located in the SOMA district of San Francisco, California. [redacted]. [redacted]. [redacted]. However, the façade of the building was required to be retained. This tenant improvement initiative involved upgrading the building to meet the latest California Building Code 2016, ensuring compliance with current codes and standards at the time. The building is considered a San Francisco landmark and is registered/classified as a historic building.

[redacted]t. Notably, the building is situated next to public ways ensuring that firefighters have ample access to the property. Refer to Figure 1 for a site map.

[redacted]

Figure 1 - Site Map

The building is classified as a Type II-A. The building is fully equipped with an automatic sprinkler system, dry standpipes, fire alarm system, emergency responder radio communication system, two-way communication system, and HVAC systems. The building is approximately 93,170 SF and is primarily used as office space. Table 1 below provides a summary of the general building information.

Table 1 - [redacted] Building, General Building Information

General Building Information	
Project Address	[redacted]
Construction Type	Type II-A
Building Area	93,170 SF
Stories	6 Stories & 1 Basement
Sprinkler Protection	Protected by Automatic Fire Sprinklers according to NFPA 13
Fire Alarm System	Addressable Fire Alarm System with Horn Audible Notification according to NFPA 72

Other Fire/Life Safety Equipment	Two-Way Communication & Emergency Radio Responder Radio Communication System (ERRCS); Dry Standpipes

2.2 Applicable Codes

The [redacted] Building will be evaluated using the 2019 edition of the California Building Code (CBC) and the California Fire Code (CFC) and the appropriate San Francisco local amendments.

In addition to the previously listed codes, the following National Fire Protection Associate (NFPA) technical codes, among others, apply:

- NFPA 13, Standard for the Installation of Sprinkler Systems, 2016 Edition
- NFPA 14, Installation of Standpipe and Hose Systems, 2016 Edition
- NFPA 25, Standard for Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems, 2017 Edition
- NFPA 72, National Fire Alarm and Signaling Code, 2016 Edition

2.3 Floor Plans

The floor plans included in this section of the report offer a comprehensive overview of the building, color-coded to highlight the different occupancy classifications on each floor, and provide important information on the fire rated assemblies installed throughout the structure. In addition, the plans offer a detailed representation of the vertical exits and shaft locations. Refer to Figure 2 to Figure 8, in the subsequent pages, for the [redacted] Building floor plans.

2.3.1 Basement

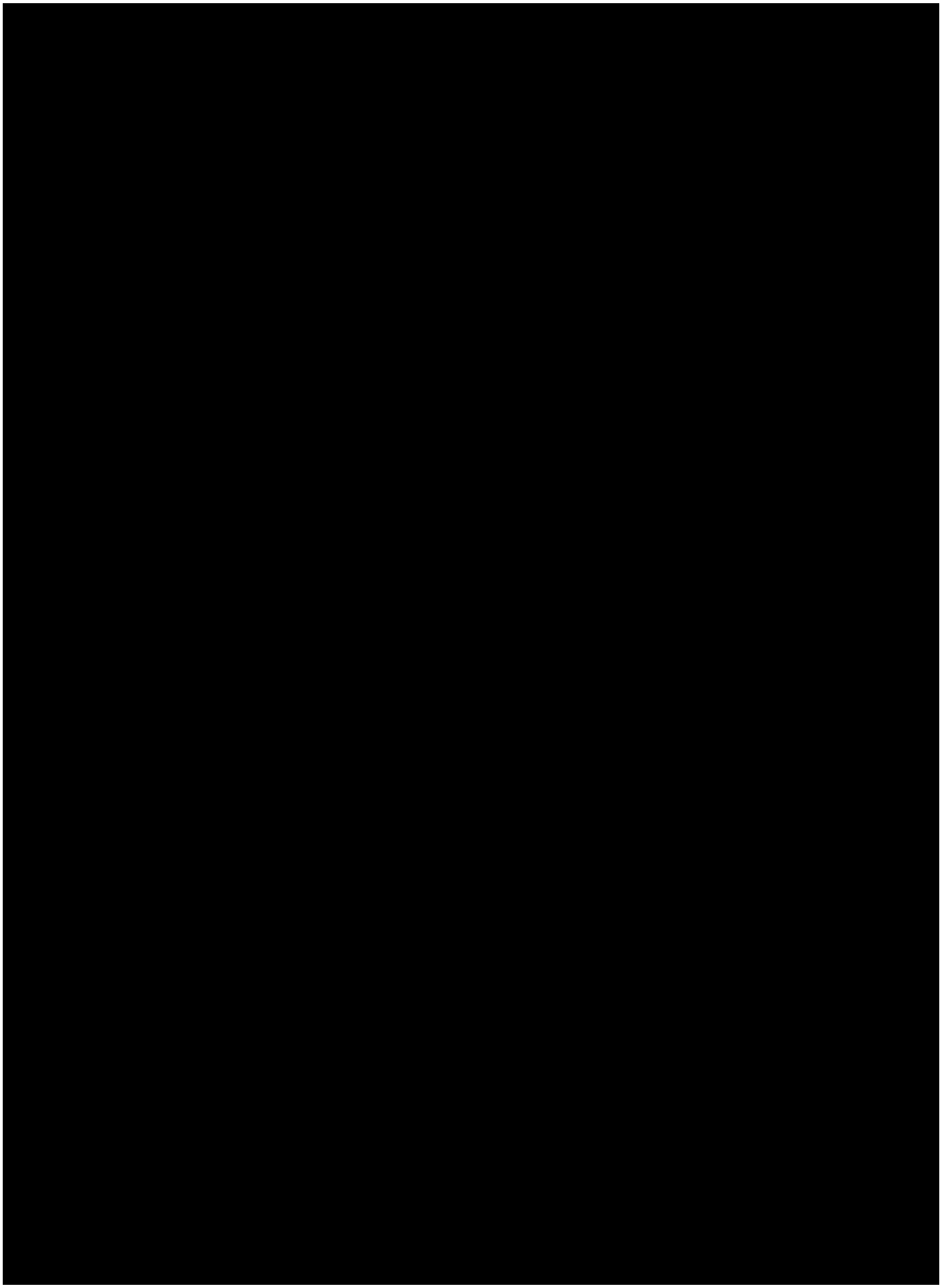

Figure 2 - Basement Floor Layout

2.3.2 Ground Floor

[redacted]

Figure 3 - Ground Floor Layout

2.3.3 Second Floor

[redacted]

Figure 4 - Second Floor Layout

2.3.4 Third Floor

[redacted]

Figure 5 - Third Floor Layout

2.3.5 Fourth Floor

[redacted]

Figure 6 – Fourth Floor Layout

2.3.6 Fifth Floor

[redacted]

Figure 7 - Fifth Floor Layout

2.3.7 Sixth Floor

[redacted]

Figure 8 - Sixth Floor Layout

3 EGRESS

Egress refers to the ability to exit a building safely and efficiently in case of an emergency. It is an essential component of building safety, providing appropriate means for occupants to evacuate the premises swiftly and securely in case of an emergency. For the [redacted] building, the egress requirements are primarily dictated by Chapter 10 of the California Building Code. Section 3 of this report provides a summary of these requirements and evaluates whether the [redacted] building meets them.

3.1 Occupancy Classifications

The [redacted] building is primarily utilized for office space and therefore primarily classified as a Group B occupancy. However, there are other spaces that are considered accessory within the building that have different occupancy classifications. Per the CBC, section 508.2.3, accessory occupancies cannot occupy more than 10 percent of the floor area of the story in which they are located. Some of the other classifications include unconcentrated assembly (A-3), electrical/data rooms (F-2), storage (S-2). The building does not contain any control areas for hazardous materials or conducts operations that put additional risk towards the safety of the tenants. Table 2 below provides a summary of the different occupancy classifications in the building. Some of the other classifications include unconcentrated assembly (A-3) and storage (S-2). Since these spaces are considered accessory occupancies, they are not required to have a separation with the main occupancy. Floor plans of the [redacted] building are provided in Section 2.3 of this report. The floor plans are color-coded to distinguish between the different occupancy classification from the intended use of each portion of the building.

Table 2 - [redacted] Building Occupancy Classifications

Occupancies	Classification
Community spaces, conference/meeting rooms with an occupant load of 50 or more people (Accessory)	A-3
Offices, conference/meeting rooms with an occupancy load not over 49 people, miscellaneous back-of-house areas	B
Electrical, mechanical, and data rooms	F-2
Low-hazard storage	S-2

3.2 Means of Egress

Means of egress consists of 3 phases to develop an order of safety as explained in Figure 9 and explained in Table 3:

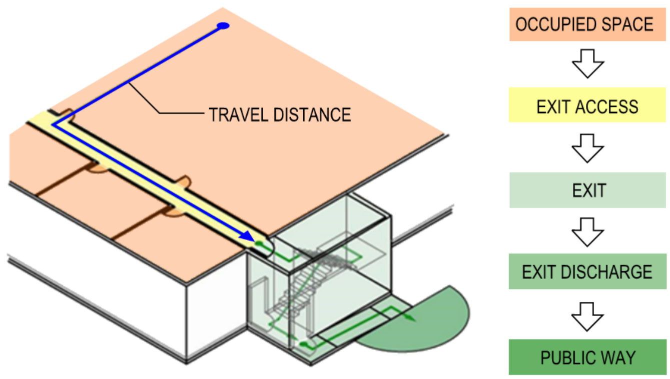

Figure 9 - Means of egress elements.

Table 3 - Egress Components

Component	Definition	Examples
Exit Access	That portion of a means of egress system that leads from any occupied portion of a building or structure to an exit.	Rooms, corridors, exit access stairs
Exit	That portion of a means of egress system between the exit access and the exit discharge or public way.	Exterior exit doors, interior or exterior exit stairways, horizontal exits and exit passageways.
Exit Discharge	That portion of a means of egress system between the termination of an exit and a public way. Exit discharge must be sufficiently open to outside and cannot re-enter a building.	Egress courts, safe dispersal area,

The egress components of this building include exterior exit doors, interior exit stairways, and exit discharge.

3.3 Occupant Load Factors

The occupant load used in calculating the number of occupants in a space is based on the CBC Table 1004.5, which specifies the maximum floor area allowed per occupant according to the space's classification/function. To calculate the occupant load for a given space, we need to determine its function, measure its area (in square footage), and divide it by the appropriate occupant load factor.

Calculating the occupant load is essential in determining the means of egress requirements for each building and floor. For the load factors used to calculate the occupant load across the entire building, refer to Table 4.

Table 4 - Occupant Load Factors

Occupancy Uses	Floor Area Per Occupant (sf)
Storage areas, mechanical spaces, electrical rooms, etc.	300 gross
Assembly spaces	15 net
Business areas	150 gross

Refer to Table 5 for the occupant load for the calculated occupant load from each floor and the total occupant load of the entire building. For a more detailed assessment into how the occupant loads were calculated for each floor, refer to Section 12 of this report for the egress/occupant load floor plans.

Table 5 -Building Occupant Load Calculations Per Floor

Floor	Occupant Load Per Floor
Basement	150
Ground	156
Second	158
Third	202
Fourth	221
Fifth	224
Sixth	265
Total	1376

3.4 Exit Capacity

The clear width of the stairways and exit access doors are evaluated to determine the egress capacities for each floor. CBC Section 1005.3.1 & 1005.3.2 indicate the egress capacity factor for the stairways and exit access doors as being 0.3 inches per occupant and 0.2 inches per occupant, respectively. These factors are used because the building is equipped with an automatic system but is not equipped with an EVAC system. To calculate the exit capacities for each floor, divide the width of the stairways by a 0.3 egress factor and the width of the exit doors by 0.2 egress factor for stair 1 and stair 2. The egress capacity will be determined by the lower value between the stairway and exit access doors for either stair 1 or stair 2, as it is the more limiting factor. Refer to Table 6 for a summary of the exit capacity factors utilized for the [redacted] Building.

Table 6 - Egress Width per Occupant

Egress Element	Clear Width per Occupant
Stairs	0.3 inches per occupant
Ramps	0.2 inches per occupant

Egress Element	Clear Width per Occupant
Doors and other level egress components	0.2 inches per occupant

Refer to Table 7 for a summary of the exit capacity factor calculations per floor. Note that clear width measurements were utilized for the exit doorways.

Table 7 - Exit Capacity Calculations

Floor	Stairway Width (in.)		Exit Capacity (Occupants)	Exit Doorway (in.)		Exit Capacity (Occupants)
Basement	Stair 1	45	150	Stair 1	34	170
	Stair 2	48	160	Stair 2	34	170
Ground	Not Applicable			Stair 1 Exit Discharge	34	170
	Not Applicable			Stair 2 Exit Discharge	34	170
Second	Stair 1	45	150	Stair 1	34	170
	Stair 2	48	160	Stair 2	34	170
Third	Stair 1	45	150	Stair 1	68	340
	Stair 2	48	160	Stair 2	34	170
Fourth	Stair 1	45	150	Stair 1	68	340
	Stair 2	48	160	Stair 2	34	170
Fifth	Stair 1	45	150	Stair 1	68	340
	Stair 2	48	160	Stair 2	34	170
Sixth	Stair 1	45	150	Stair 1	68	340
	Stair 2	48	160	Stair 2	34	170

If the occupant load per floor is lower than the exit capacity per floor, it means that the exit capacities are sufficient to support the occupant load of the building. To see a comparison of the calculated occupant load per floor and the corresponding exit capacity, refer to Table 8. It is evident that the exit capacity of each floor of the [redacted] building has enough exit capacity to accommodate the occupant load.

Table 8 - Exit Capacity Per Floor

Floor	Occupant Load	Exit Capacity (Occ.)	Compliancy
Basement	150	310	Adequate
Ground	156	340	Adequate

Floor	Occupant Load	Exit Capacity (Occ.)	Compliancy
Second	158	310	Adequate
Third	202	310	Adequate
Fourth	221	310	Adequate
Fifth	224	310	Adequate
Sixth	265	310	Adequate

The CBC 1005.5 states, "Where more than one exit, or access to more than one exit, is required, the means of egress shall be configured such that the loss of any one exit, or access to one exit, shall not reduce the available capacity of width to less than 50 percent of the required capacity or width." For all floors of the [redacted] building, this requirement is satisfied. The exit capacity for all floors is much greater than the occupant load. If either stair 1 or stair 2 became unavailable, the other exit would sufficiently hold more than 50 percent of the required capacity.

3.5 Number of Required Exits

CBC Table 1006.3.2 specifies the number of exits or access to exits required depending on the occupant load per floor. If the occupant load is between 1 and 500, a minimum of two exits or exit accesses are required per floor. A minimum of three exits are required if the occupant load is between 501 and 1000 per floor and a minimum of four exits are required if the occupant load is above 1000 per floor. Based on the occupant load per floor from Table 5, each floor is required to have a minimum of two exits and is fulfilled by two exits provided. Refer to Table 9 for more details.

Table 9 - Exits Provided Per Floor

Floor	Occupant Load	Exits Provided	Exits Required
Basement	150	2	2
Ground	156	2	2
Second	158	2	2
Third	202	2	2
Fourth	221	2	2
Fifth	224	2	2
Sixth	265	2	2

3.6 Exit Arrangements

The CBC Section 1007.1.1 requires that exits or exit access doorways be separated by a certain distance. The intent of this code is to reduce the probability that multiple exits or exit access doorways become unavailable in a single event (such as flame spread) due to proximity. Because the [redacted] building is equipped with two exits or exit access doorways per floor and is equipped with an automatic sprinkler system, the separation distance shall not be less than one-third of the length of the maximum overall diagonal dimensions of the area served.

All floors have an overall diagonal dimension of 197', which means that the exit separation will not be less than 66' (one-third of the overall diagonal dimension). All measurement points are compliant with CBC 1007.1.1.1 and can be seen on the floor plans in Section 12 of this report. Refer to Table 10 which confirms that the [redacted] building satisfies the requirement for exit separation distance, as all floors have greater distances than what is required by CBC section 1007.1.1.

Table 10 - Exit Arrangement

Floor	Overall Diagonal Dimension of the Building (Ft.)	Exit Separation Distance Required	Exit Separation of Floor Served
Basement	197	66	141
Ground	197	66	142
Second	197	66	142
Third	197	66	138
Fourth	197	66	138
Fifth	197	66	138
Sixth	197	66	138

3.7 Common Path of Travel

Common path of egress travel is defined in CBC Section 202 as, "That portion of exit access travel distance measured from the most remote point of each room, area or space to that point where the occupants have separate and distinct access to two exits or exit access doorways."

According to CBC Table 1006.2.1, the maximum common path of egress travel for all occupancies in the [redacted] building (excluding Group A-3 assembly spaces) is 100 feet. Assembly spaces in Group A-3 are required to have a common path of travel distance of 75 feet. Since all floors in the [redacted] building have an occupant load of over 30 and the building has an automatic sprinkler system installed, it is fully compliant with the egress travel distance requirement specified in CBC Table 1006.2. Refer to Table 11 for a summary of the common path of travel requirements for all of the occupancies within the [redacted] building.

Table 11 - Common Path of Travel Distance

Occupant Classification	Common Path of Travel Distance w/ Sprinkler System (Ft.)
A-3	75
B	100
F-2	100
S-2	100

3.8 Dead-End Corridor

According to CBC Section 1024.4, "Where more than one exit or exit access doorway is required, the exit access shall be arranged such that dead-end corridors do not exceed 20 feet in length." However, exception 1 of this code sections allows Group B, F, and S occupancies to have dead-end corridors that do not exceed 50 feet as long as the building is protected by an automatic sprinkler system in accordance with Section 903.3.1.1.

Considering that the [redacted] building is primarily utilized as an open office space, the current configuration of the building does not create any dead-end corridor conditions that are non-compliant with CBC Section 1020.4.

3.9 Exit Access Travel Distance

Exit Access is defined in CBC Section 202 as, "That portion of a means of egress system that leads from any occupied portion of a building or structure to an exit." The intent of this code is to place limitations on the distance that occupants must travel before entering an exit access.

From CBC Table 1017.2, the maximum exit travel distance is 300 feet considering that the building is primarily utilized as office space. However, it is important to note that the accessory occupancies in the building must meet their required exit travel distance requirements as well. The floor plan in Section 12 demonstrate examples of exit travel distances and routes using dashed lines on all floors. Although there are instances in those figures where occupants may have to traverse the entire floor to reach an exit, the distances are still within the code limits. Hence, the [redacted] building is fully compliant with the exit travel distance requirement specified in CBC Table 1017.2. Refer to Table 12 for a summary of the exit travel distance requirements per occupancy classification within the [redacted] building. Table 12 – Exit Travel Distance

Table 12 - Exit Travel Distance

Occupant Classification	Exit Access Travel Distance w/ Sprinkler System (Ft.)
A-3	250
B	300
F-2	400
S-2	400

3.10 Exit Signs

CBC Section 1013 has specific requirements for exit signs including the following:

- Exit signs must be placed above the exits and exit access doors.
- The path of egress travel to exits and within exits be marked by readily visible exit signs to clearly indicate the direction of egress travel.
- Exit signs are required in rooms or areas that require one exit or exit access.
- Exit sign placement shall be such that any point in an exit access corridor or exit passageway is within 100 feet or the listed viewing distance of the sign, whichever is less.

- Exit and exit access doors are required to be clearly marked by exit signs readily visible from any direction of egress travel. Access to exits is to be marked by additional exit signs if the egress paths to exits and exit access doors are not immediately visible. Exit signs in corridors are required to be placed so that there is a visible exit sign within 100 feet.
- Exit signs will not be required in areas that require only one exit and from inside the dwelling units.
- Main exterior exit doors that are obvious and clearly identifiable will not be provided with exit signs.
- Tactile exit signs stating EXIT are required to be provided adjacent to each door to an exit stairway and the exit discharge.
- Exit signs need to be internally or externally illuminated at all times. Upon primary power loss, the exit signs will maintain continuous illumination for at least 90 minutes.

The floor plans in Section12 of this report provides proposed locations of exit signs to comply with the requirements of CBC Section 1013. All exit and exit access doors in the [redacted] building have exit signs placed above them. The path of egress travel to exits is clearly marked with exit signs that indicate the direction of the nearest exit. Most of the rooms in the building have only one exit, except for conference room 515 on the 5th floor, which has two exits. Exit signs are placed above both exits. It is worth noting that the [redacted] building does not have any exit access corridors or exit passageways.

3.11 Egress Summary

Upon evaluation of the prescriptive requirements outlined in Chapter 10 of the California Building Code, it is evident that the [redacted] building has been designed to meet the general egress requirements. The building has been constructed with the minimum egress standards in mind, ensuring that the occupants have adequate means of exiting during an emergency. However, it is essential to recognize that compliance with prescriptive requirements does not necessarily equate to optimal safety for building occupants. As such, it is the responsibility of building owners and managers to periodically review and update their egress plans and systems to ensure they are effective and efficient in the event of an emergency.

4 FIRE SPRINKLER SYSTEM

The [redacted] building is fully equipped with an automatic wet sprinkler system and a manual wet standpipe as required by Section 903 and 905 of the California Building Code. These fire protection systems are designed according to the requirements of NFPA 13 and NFPA 14. An automatic sprinkler system is generally considered the standard and most used form of fire suppression in modern buildings. Sprinkler systems are a network of water-filled pipes and strategically spaced sprinkler heads located throughout a building or structure. The sprinkler heads include frangible bulbs filled with a liquid that, when heated, expands causing the bulb to break and allow the seal to fall out and release water. Each sprinkler head is designed to cover a limited area, but sprinkler systems are comprised of multiple heads that are strategically placed throughout buildings to provide adequate coverage as required by the applicable Codes and Standards. In the event of a fire, when a predetermined temperature has been exceeded, the sprinkler head will detect it and discharge water. Automatic sprinkler systems are considered as one of the most effective and reliable forms of fire protection as they can detect and control/suppress fires without the need for human activation/intervention. Section 4 of this report provides insight into the fire protection equipment present in the [redacted] building. The section also provides a detailed summary of the applicable code requirements and evaluates the building's compliance with these regulations.

4.1 Overview of Fire Protection Equipment and Water Supply Information

4.1.1 Fire Department Connections

On the east side of the building, there is also an existing and independent 5” Dry Class I Standpipe. Fire fighters can pump water through their fire trucks to connections shown below through the dry standpipes. Typically, these independent dry standpipes are used as another means to supply additional water to fight fires in adjacent buildings.

4.1.2 Manual Wet Standpipe

CBC Section 905.3 details the requirements for standpipes. Since the [redacted] building is more than 30 feet above the lowest level of fire department vehicle access, it is required to be equipped with at minimum a Class III standpipe. However, since the building is protected by an automatic sprinkler system, Class I standpipes are allowed to be utilized in the building.

The San Francisco Fire Department local amendments (AB-4.19) requires, at minimum, a manual wet standpipe be provided. The manual wet standpipes must have a 4 inch width, at minmum, and be included in the hydraulic sizing calculations.

The [redacted] Building is provided with a 6 inch manual standpipe located in each stairway and complies with all applicable requirements of the CBC, NFPA 14, and the SFFD local amendments.

4.1.3 Dry Standpipe

Per CBC Section 905.8, the installation of dry standpipes is prohibited due to concerns regarding their reliability when compared to alternative options such as manual wet and automatic wet standpipes. However, the [redacted] building is currently equipped with an existing and independent 5” Dry Class I Standpipe that was originally installed in the late 1970s. The San Francisco Fire Department required retaining and maintaining the dry standpipes during the building's upgrade to meet modern code requirements. It is understood that they were permitted to remain in place as an additional means of fire protection for the building.

Refer to Figure 10 below for an image of the dry standpipe connections at the [redacted] Building. Fire fighters can pump water and provide pressure through their fire apparatus vehicles to connections shown below through the dry standpipes. Typically, these independent dry standpipes are used as another means to supply additional water to fight fires in adjacent buildings.

Figure 10. Dry Standpipes

4.1.4 Water Supply

The [redacted] building's sprinkler system is supplied with municpal water through an 8" city water main that connects to the building through a 6" underground ductile iron pipe. Refer to Figure 11 for locations.

[redacted]

For the purposes of this report, the water supply information was provided by the San Francisco Fire Department through a request form. The department representatives conducted a waterflow test in December of 2017 taken from the nearest fire hydrant . The sprinkler contractors followed NFPA 13 and San Francisco Fire Department requirements to request water information before submitting sprinkler design/modidication plans. According to NFPA 13 Section 4.6.1.1 , “Where a waterflow test is used for the purposes of system design, the test shall be conducted no more than 12 months prior to working plan submittal unless otherwise approved by the authority having jurisdiction.” (NFPA 13 Section 4.6.1.1). It is understood that the San Francisco Fire Department local amendents do not require the derating of the water supply information.

Table 13 - Water Supply Information

	PSI	Flow (GPM)
Static	57	---
Residual	55	1085 GPM

4.2 Sprinkler Design Criteria

As per NFPA 13, section 4.3.2 & section A.4.3.2, the entire [redacted] building is classified as “Light Hazard” occupancy. The building is primarily used as office space and follows all the criteria as listed in NFPA 13. To ensure that that certain areas in the building do not fall under “Ordinary Hazard 1” or “Ordinary Hazard 2” classifications, building engineering staff are trained and required to perform daily site walks throughout the building to assure that stockpiles do not exceed 8' in height. The building does not contain any commodity classifications as it is not used as storage.

The sprinkler design criteria for the [redacted] building will be based NFPA 13, Figure 19.3.3.1.1 "Density/Area Curves". From reviewing this figure, for light hazard occupancies, the base design criteria will be 0.10gpm/ft^2 over 1500 ft$^{2.}$ Final design criteria will be determined after evaluating NFPA 13, Figure 19.3.3.2.3.1 "Design Area Reduction for Quick-Response Sprinklers" below. Refer to Figure 12 below.

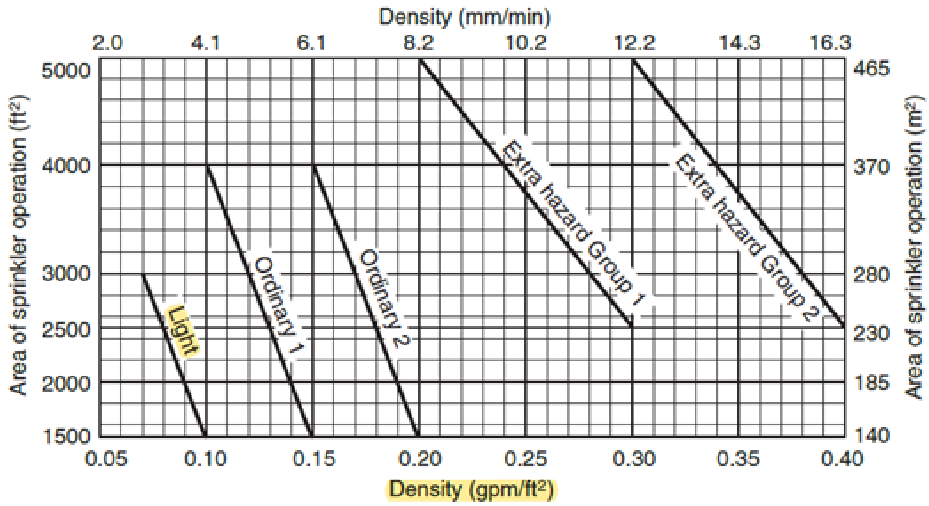

FIGURE 19.3.3.1.1 Density/Area Curves.

Figure 12. NFPA 13 Design/Area Curves

Per NFPA 13, Section 19.3.3.2.3, the building is equipped with listed quick response sprinklers since it complies with the following requirements:

- Wet pipe system
- Light hazard or ordinary hazard occupancy
- 20ft maximum ceiling height
- No unprotected ceiling pockets as allowed by 10.2.9 and 11.2.8 exceeding 32 ft^2.
- No unprotected areas above cloud ceilings as allowed by 9.2.7.

A design area reduction is allowed as per NFPA 13, Section 19.3.3.2.3.1. The design reduction is based off the ceiling height using the formula y=(-3x/2) + 55. X represents the ceiling height and y represents the percent ceiling reduction to the design area. Certain floors do have different ceiling heights, so the design area will vary throughout.

Hose stream allowances and water supply durations must also be taken into account when evaluating and hydraulically calculating a sprinkler system. From NFPA 13 Table 19.3.3.1.2, a light hazard occupancy will have a hose stream allowance of 100gpm. The sprinkler system must also operate for a minimum of 30 minutes.

Refer to Table 14 for the design criteria for all floors in the building.

Table 14 - Sprinkler Design Criteria

Occupancy Classification	Floors	Density (gpm/ft^2)	Base Design Area(ft^2)	Ceiling Height (ft)	Design Area Percent Reduction (%)	Final Design Area (ft^2)	Hose Stream Allowance (GPM)	Duration (Minutes)
Light Hazard	Basement, Ground Floor, 2nd Floor	0.10gpm/ft^2	1500ft^2	10'6"	39.25%	911.25ft^2	100 GPM	30 Minutes
Light Hazard	3rd Floor	0.10gpm/ft^2	1500ft^2	15'	32.50%	1012.5ft^2	100 GPM	30 Minutes
Light Hazard	4th Floor,5th Floor, 6th Floor	0.10gpm/ft^2	1500ft^2	13"	35.50%	967.50ft^2	100 GPM	30 Minutes

4.3 Sprinkler System Riser

In the middle of the [redacted] building, there is a single combination standpipe and sprinkler riser. The combination riser is a 6” Schedule 40 steel pipe that goes from the basement level up to the 6th floor. Refer to Figure 13 for more details.

[redacted]

4.4 Waterflow and Tamper Switches

CBC 903.3.9 requires that floor control valves (tamper switches) and waterflow detection devices are installed in the buildings with any of the following requirements:

- Buildings where the floor level of the highest story is located more than 30 feet above the lowest level of fire department vehicle access.
- Buildings that are four or more stories in height.
- Buildings that are two or more stories below the highest level of fire department vehicle access.

The [redacted] Building meets all the requirements listed above and therefore is required to provide tamper switches and waterflow on each floor of the building, which it does comply with. The tamper switch is supervised by the fire alarm system to detect if the control valves are closed which could compromise the functionality or reliability of the sprinkler system. The waterflow switch is also supervised by the fire alarm system and can detect if a sprinkler head is discharged. In the event, that a waterflow switch is activated, an alarm condition will be triggered at the fire alarm control panel.

4.5 Feed Mains

As per NFPA 13 Section 3.3.72 feed mains are, "The pipes supplying the cross mains, either directly or through risers." The feed mains for the [redacted] building typically are schedule 40 steel pipes, but there are a few floors where the feed main is 6" schedule 10 steel pipe. Refer to Table 15 for more details.

Table 15 - Feed Main Sizing

Feed Main Sizing (in.)
4
6

4.6 Cross Mains

As per NFPA 13 Section 3.3.53, cross mains are, "The pipes supplying the branch lines either directly or through riser nipples." There are certain pipes that could either be considered a branch line or cross main. For the purposes of this report, if a sprinkler is located on the pipe, it is considered a branch line. Refer to Table 16 for more details.

Table 16 - Cross Main Sizing

Cross Main Sizing (in.)
2
2-1/2
3
4
5
6

4.7 Branch Lines

As per NFPA 13 Section 3.3.19 branch lines are, "The pipes supplying the sprinklers, either directly or through sprigs, drops, return bends, or arm-overs." There are certain pipes that could either be considered a branch line or cross main. For the purposes of this report, if a sprinkler is located on the pipe, it is considered a branch line. Refer to Table 17 for more details.

Table 17 - Branch Line Sizing

Branch Line Sizing (in.)
1
1-1/4
1-1/2
2
2-1/2
3

4.8 Sprinklers

There are (3) types of Tyco sprinklers that are used at the [redacted] building. All sprinklers have a K-factor of 5.6 which is typical for light hazard occupancies. Refer to Table 18 for specifications.

Table 18 - Sprinkler Specifications

Sprinkler Description	SIN #	Response	Orifice	K-Factor	Temperature	Finish
Tyco TY-FRB Q.R. Upright	TY313	Quick-Response	1/2"	5.6	68°C	Brass
Tyco RF-II Q.R. Concealed Pendent	TY3531	Quick-Response	1/2"	5.6	68°C	Brass
Tyco TY-FRB Q.R. Pendent	TY323	Quick-Response	1/2"	5.6	68°C	Brass

4.9 Hydraulic Calculations

4.9.1 Hydraulically Most Remote Area

For the purposes of this report, hydraulic calculations were performed in the most remote area of the building. This area is basically the most difficult section of the building to get water to due to friction loss and flow. It was determined that the most remote area of the building is on the 6th floor northwest corner. Refer to Figure 14 for location.

[redacted]

4.9.2 Hydraulic Calculations

Refer to Section 14.2 for hydraulic hand calculations that were performed for the [redacted] Building from the hydraulically most remote area to the point of connection. These hydraulic calculations were difficult to perform by hand because of the non-uniform design of the sprinkler system. Almost every sprinkler head had different coverage areas and pressure balancing was required at every node point inside the design area. Refer to Section 14.3 for supplemental hydraulic calculations for the branch lines. According to NFPA 13, Table 10.2.4.2.1 (a), the maximum protection area for a light hazard noncombustible unobstructed hydraulically calculated system is 225 ft^2. The calculations started off at Node 701, which is the first sprinkler, which had a minimum starting pressure of 7 psi (NFPA 13 8.7.9.2). From the calculations, the sprinkler demand required will be 346.9 gpm and 49.1 psi at the POC. Refer to Table 19 for a summary of the hydraulic information.

Table 19 - Hydraulic Information - 6th Floor.

Hydraulic Information	
Occupancy Classification	Light Hazard
Density (gpm/ft^2)	0.10/1500 ft^2
Ceiling Height	13ft
Quick Response Sprinkler Area Reduction	967.50 ft^2 (35.5% reduction)
Hose Stream Allowance	100 gpm
Total Sprinkler Heads Flowing	13
K-Factor	5.6
Sprinkler System Flow Required	246.9 gpm
Total Flow Required	346.9 gpm
Total Pressure Required	49.1 psi
Safety Margin	7.3 psi (+14.9%)

4.9.3 Hydraulic Graph Sheet

From the hydraulic graph provided in Figure 15, it is evident that the city water supply is adequate in providing the sprinkler demand for the [redacted] building. Therefore, a fire pump will not be required. As noted in Section 4.1.4, it is understood that the San Francisco Fire Department local amendents do not require the derating of the water supply information.

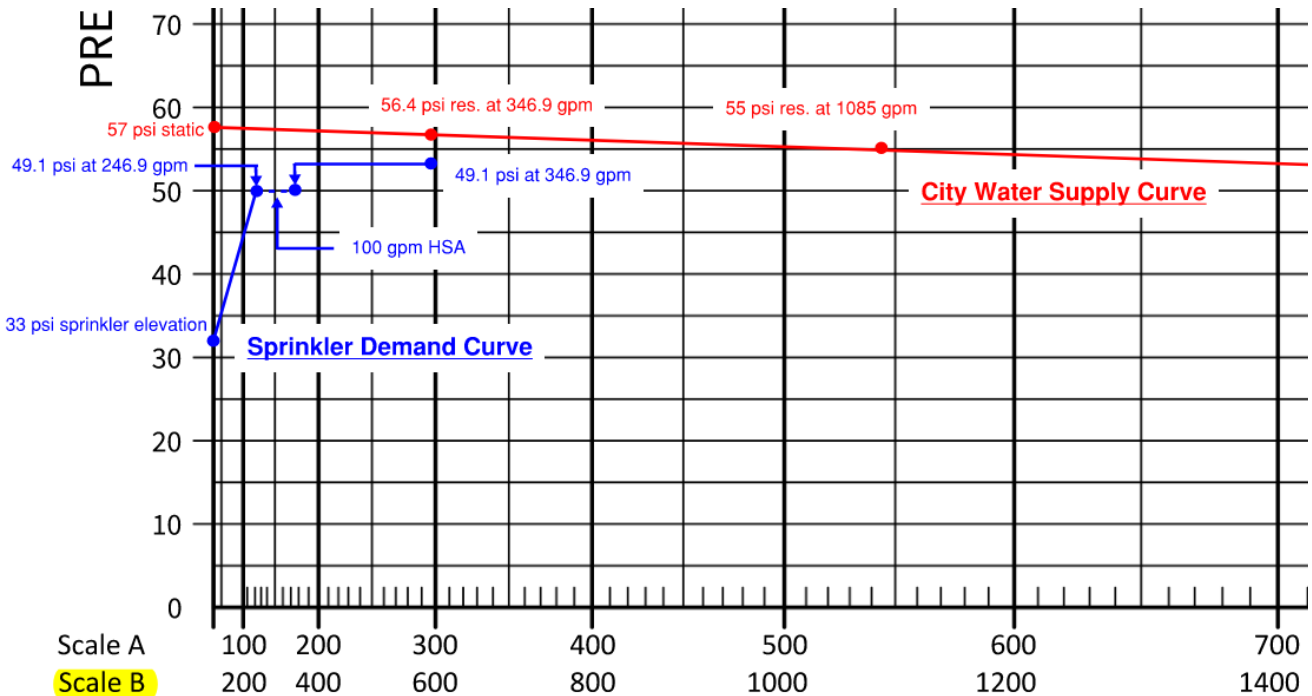

Figure 15. Hydraulic Graph Sheet

4.10 Inspection, Testing, and Maintenance (ITM)

Inspection, testing, & maintenace are vital to assure that the wet sprinkler system and associated components will function during an emergency. Unlike other technology in the building, such as lighting controls or HVAC systems, sprinkler systems are not used or tested on a daily basis. Therefore, there is a higher risk of sprinkler systems not functioning properly if left idle for long periods of time. Inspection, testing, & maintence requirements are detailed in NFPA 25. Refer to Section 14.4 of this report for more details.

4.11 Fire Sprinkler System Summary

Upon evaluation of the prescriptive requirements outlined in Chapter 903 and 905 of the California Building Code, it is evident that the [redacted] building's fire sprinkler system has been designed to meet the minimum requirements of NFPA 13 and 14. However, it is essential to recognize that compliance with prescriptive requirements does not necessarily equate to optimal safety for building occupants. To maintain the system's functionality and effectiveness, it is the responsibility of building owners and managers to perform periodic inspections, testing, and maintenance to ensure that the system will perform in an emergency.

5 FIRE ALARM SYSTEM

The [redacted] Building is equipped with a manual fire alarm per the prescriptive requirement of Section 907 of the California Building Code. The fire alarm system is designed according to NFPA 72. A fire alarm system is a network of interconnected devices whose primary function is to detect fires, alert the building's occupants, and notify the appropriate responding authorities. Fire alarm systems are considered a crucial part of life safety in many buildings and are usually connected to other important fire safety equipment including sprinkler systems. To detect fires, fire alarm systems are equipped with initiating devices, such as smoke detectors, heat detectors, manual pull stations, etc. If any of these devices are activated or senses the presence of a fire, a signal will be sent to the fire alarm control unit (FACU). The FACU activates the fire alarm notification appliances in the building which will emit an audible and visual cue to alert occupants to evacuate the building. The fire alarm system is also constantly monitored by a supervising station. In the event that a fire is detected in the building, the fire alarm control unit (FACU) will automatically send a signal to an appropriate authority to respond to the emergency. Section 5 of this report provides insight into the fire alarm system present within the [redacted] building. The section also provides a detailed summary of the applicable code requirements and evaluates the building's compliance with these regulations.

5.1 Overview of the Building's Fire Alarm System

5.1.1 Fire Alarm System Code Requirements

CBC Section 907.2.2 details the requirements for a manual fire alarm system in Group B Occupancies. Since the occupant load on all floors is greater than or equal to 500 and the occupant load is more than 100 persons above or below the lowest level of exit discharge, the [redacted] building is required to have a manual fire alarm system. There is an exception that allows one manual pull to be installed since the building is equipped with an automatic sprinkler system.

5.1.2 Fire Alarm Control Unit

The [redacted] building is equipped with a Notifier NFS-320 Intelligent Addressable Fire Alarm System. For more information. The operating features/characteristics of this fire alarm control unit include:

- Up to 159 detectors and 159 modules per SLC, 318 devices maximum
- Standard 80-character display
- 6.0 Ah power supply with four Class A/B built-in Notification Appliance Circuits (NAC)
- Multiple central station communication options:
- Standard UDACT
- Internet/GSM

Images of the fire alarm control unit are provided in Figure 16.

Figure 16. Fire Alarm Control Unit

5.1.3 Location of Fire Alarm Control Unit

The fire alarm control unit is in a dedicated fire control room in the southeast corner of the basement. Refer to Figure 17 for the location of the fire alarm control unit.

[redacted]

Figure 17. Location of Fire Alarm Control Unit

The location of the fire alarm control was approved during a pre-application meeting with an SFFD authority having jurisdiction. According to NFPA 72 10.4.1, “All systems shall be installed in accordance with plans, specifications, and standards approved by the authority having jurisdiction.”

The fire control room can be difficult for firefighters to locate in an emergency. In the 2019 SFFD administrative bulletins, Section H requires that signs or key maps are located at the main fire fighter response point of the building to indicate the location of the fire alarm control unit.

5.2 Fire Detection Devices

The [redacted] building is equipped with the following types of fire detection devices:

- Area Photoelectric Smoke Detectors
- Manual Pull Station
- Heat Detector

- Duct Detectors
- Waterflows

5.3 Location, Placing, and Spacing of Fire Detection Devices

The fire detection devices are shown on color-coated floor plans that are in Section 15.1 of this report. The location, placing, and spacing of all the fire detection devices installed in the building complied with the requirements of the applicable NFPA standards. Refer to the subsequent sections for location and spacing requirements.

5.3.1 Area Photoelectric Smoke Detectors

The [redacted] building is equipped with approximately seventy-eight (78) Notifier photoelectric area smoke detectors. The smoke detectors are typically located:

- Above fire alarm control unit as per NFPA 72 10.4.5
- Above fire alarm notification power supplies as per NFPA 72 10.4.5
- Elevator Lobbies as per NFPA 72 21.3.5.1
- Adjacent to non-ducted HVAC units

Note that the basement, 1st, and 2nd floors are equipped with full smoke detector coverage in the open areas due to the high volume of HVAC units as required during a pre-application meeting with the SFFD.

The [redacted] building has primarily smooth ceilings where the location and spacing of these area smoke detectors followed the requirements of NFPA 72 17.7.3.2.3. See excerpts below.

5.3.2 Manual Pull Station

The [redacted] building is equipped with one (1) Notifier NBG-12LX manual pull station that is located adjacent to the fire alarm control unit in the southeast corner of the basement. According to the CBC Section 907.2.2, since the building is equipped with an automatic sprinkler system throughout, manual pull stations are not required to be installed in the building. The SFFD Administrative Bulletin AB 2.01, in accordance with 2018 NFPA 101 9.6.2.6, requires that the one manual pull station required be located adjacent to the fire alarm control unit. See below for references.

CBC Section 907.2.2 Exception: "Manual fire alarm boxes are not required where the building is equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 and the occupant notification appliances will activate throughout the notification zones upon sprinkler water flow.

SFFD Administrative bulletin AB 2.01, Section HH: "If only one manual fire alarm box is provided in a fully sprinklered building or for a sprinkler waterflow and supervisory system, the fire alarm box shall be installed adjacent to FACU. This manual fire alarm box shall generate full building general alarm (total evacuation) where a building fire alarm system is installed. For a sprinkler waterflow and supervisory system, the manual fire alarm box shall generate an alarm signal at the FACU and transmit an alarm signal to the supervising station and shall not activate the exterior audible device. This single manual fire alarm box shall be required to be connected to a separate zone or circuit on the FACU that shall not be placed on TEST mode when the building FA system or the sprinkler waterflow and supervisory system are placed on TEST mode."

NFPA 72 17.15 details the installation requirements for the manual pull stations. that the [redacted] building is not required to have manual pull stations located at exits or exit access stairs. Therefore, NFPA 72 17.15.9.4 and 17.15.9.5 are not applicable.

5.3.3 Heat Detectors

The [redacted] building is equipped with one (1) Notifier FST-851 fixed temperature (135^{O}/57^{O}) thermal heat detector that is located on the roof level elevator lobby/landing. Unfortunately, roof floor plans could not be located that indicate the location of this heat detector. The purpose of this heat detector is to provide coverage for the elevator. In alarm condition this heat detector would activate the primary designated level elevator recall (Phase 1 Recall). Typically, smoke detectors are provided for the elevator recall function, but since the roof is exposed to the environmental conditions, the SFFD required a heat detector be installed per NFPA 79 21.3.10.

Although a heat detector was installed in place of a smoke detector, the SFFD required that the heat detector follow the installation requirements per NFPA 72 21.3.5.1. Typical heat detector location and spacing requirements are located in NFPA 72 17.6.3.

5.3.4 Duct Detectors

The [redacted] building is equipped with approximately twenty-nine (29) Notifier duct detectors. Note that duct detectors are made up of two components. The DNR is the duct detector housing and the FSP-851 is the photoelectric smoke detector. The duct detectors are used to detect smoke moving in the airstream of ductwork. For the [redacted] building duct detectors are located to provide coverage to ducted fire smoke dampers and ducted HVAC units.

NFPA 90A 6.4 and NFPA 72 A.17.7.4.1 detail the general requirements for duct detectors on HVAC equipment. See excerpts below.

5.3.5 Waterflow Switch

The waterflow switches throughout the [redacted] building were installed by the sprinkler contractor and are monitored by the fire alarm system. Both single fire alarm monitor modules and dual fire alarm monitor modules were used to interface the sprinkler system to the fire alarm system. If the switch detects waterflow through the sprinkler system an alarm condition will activate on the fire alarm control unit. The color-coated fire alarm plans in Section 15.1 do not show the fire alarms modules interfaced with the waterflow switches.

According to NFPA 72 17.13.2, activation of the waterflow switch shall occur within 90 seconds when flow occurs.

5.4 Disposition of Alarm, Supervisory, and Trouble Signal

5.4.1 Type of Fire Alarm System

The [redacted] building is equipped with a remote supervising station alarm system. NFPA 72 3.3.291.3 defines this type of alarm system as, “A protected premises fire alarm system (exclusive of any connected to a public emergency reporting system) in which alarm, supervisory, or trouble signals are transmitted automatically to, recorded in and supervised from a remote supervising station that has competent and experience servers and operations who, upon receipt of a signal, take such action as required by the Code.” In short summary, a supervising station will be monitoring the fire alarm system on a protected premise for all alarm, trouble, and supervisory signals. In all cases, the owner or an owner representative will be contacted by the remote supervising station in the event of a signal. The owner or owner representative will be responsible to respond in the event of a signal. In an alarm condition, the remote supervising station will alert the proper authorities. NFPA 72 26.5. details the requirements for a remote supervising station alarm system.

5.4.2 Fire Alarm Sequence of Operations

Refer to Figure 18 for the [redacted] Building's fire alarm sequence of operations.

The sequence of operations explains how the fire alarm system is supposed to operate. It is a map that details the response to the activation of a certain initiating device and the corresponding events that could impact the building. The sequence will also describe the different building systems that are interconnected to the fire alarm system as well.

[redacted]

Figure 18. Fire Alarm Sequence of Operations

5.4.3 Alarm Signal Disposition

In the [redacted] building alarms signals are initiated by the manual pull stations, area smoke detectors, waterflow, and heat detectors.

In the event of an alarm signal, the remote supervising station will retransmit the signal to a local communication center. This is typically to the local dispatching center that will alert the fire department. The remote supervising station will also alert the owner or owner representative. Refer to NFPA 72 Section 26.5.6.3.1 for more information.

5.4.4 Supervisory Signal Disposition

In the [redacted] building supervisory signals are initiated by the tamper switches, two-way communication monitoring, emergency responder radio communication system monitoring, cellular communicator, and duct detectors.

In the event of a supervisory signal, the remote supervising station will alert the owner or owner representative and the AHJ (if required by local code). Refer to NFPA 72 Section 26.5.6.3.2 for more information.

5.4.5 Trouble Signal Disposition

In the [redacted] building trouble signals are initiated faults to the fire alarm system, such as open circuits, low batteries, ground faults, etc. The [redacted] building's sequence of operation does not detail the specific conditions that cause trouble signals.

In the event of a trouble signal, the remote supervising station will alert the owner or owner representative and the AHJ (if required by local code). Refer to NFPA 72 Section 26.5.6.3.3. for more information

5.5 Fire Alarm Notification Appliances

5.5.1 Overview of Fire Alarm Notification Appliances

The [redacted] building is equipped throughout with Wheelock brand combination horn-strobe and strobe only fire alarm notification devices. Many of the notification devices are wall mounted, but in certain areas where installation was not feasible, ceiling mounted devices were installed. Weatherproof fire alarm notification devices were also installed to accommodate areas where moisture potentially could affect the operation of the device over time, such as in shower areas.

5.5.2 Overview of Fire Alarm Notification Appliances

The fire alarm notification devices in the [redacted] Building include the following:

- Wheelock Ceiling Strobe - STWC
- Wheelock Ceiling Horn/Strobe - HSWC
- Wheelock Wall Strobe - STW
- Wheelock Wall Horn/Strobe – HSW
- Wheelock Weatherproof Wall Strobe – RSSWP-2475W
- Wheelock Weatherproof Wall Horn/Strobe – ASWP-24WCWH

5.5.3 Location of Fire Alarm Notification Appliances

The fire alarm notification devices in the [redacted] building are shown on color-coated floor plans in Section 15.1 of this report.

5.5.4 Location, Spacing, and Placement

5.5.5 Visible Fire Alarm Notification Appliances

Per the CBC 907.5.2.3.1, visible fire alarm notification devices are required to be placed in public use areas. The local AHJ takes it one step further and specifies the different spaces/rooms that are required to have visible notification fire alarm devices as defined in the administrative bulletins of SFFD AB 2.01. Visible appliances were required to be placed in all public use areas, meeting rooms, huddle rooms, etc. The only areas not required to have visible appliances include private offices, MDF rooms, storage rooms, and services areas (electrical, mechanical, etc.).

All wall and ceiling mounted visible appliances were required to be designed and installed in accordance with NFPA 72 18.5. To determine the appropriate candelas to be placed in each space/room, refer to Figure 19 which references Tables 18.5.5.5.1 (a), Table 15.5.5.5.1 (b) from NFPA 72.

Δ Table 18.5.5.5.1(a) Room Spacing for Wall-Mounted Visual Notification Appliances

Maximum Room Size		Minimum Required Light Output [Effective Intensity (cd)]	
ft	m	One Visual Notification Appliance per Room	Four Visual Notification Appliances per Room (One per Wall)
20 × 20	6.10 × 6.10	15	NA
28 × 28	8.53 × 8.53	30	NA
30 × 30	9.14 × 9.14	34	NA
40 × 40	12.2 × 12.2	60	15
45 × 45	13.7 × 13.7	75	19
50 × 50	15.2 × 15.2	94	30
54 × 54	16.5 × 16.5	110	30
55 × 55	16.8 × 16.8	115	30
60 × 60	18.3 × 18.3	135	30
63 × 63	19.2 × 19.2	150	37
68 × 68	20.7 × 20.7	177	43
70 × 70	21.3 × 21.3	184	60
80 × 80	24.4 × 24.4	240	60
90 × 90	27.4 × 27.4	304	95
100 × 100	30.5 × 30.5	375	95
110 × 110	33.5 × 33.5	455	135
120 × 120	36.6 × 36.6	540	135
130 × 130	39.6 × 39.6	635	185

NA: Not allowable.

Δ Table 18.5.5.5.1(b) Room Spacing for Ceiling-Mounted Visual Notification Appliances

Maximum Room Size		Maximum Lens Height*		Minimum Required Light Output (Effective Intensity); One Visual Notification Appliance (cd)
ft	m	ft	m	
20 × 20	6.1 × 6.1	10	3.0	15
30 × 30	9.1 × 9.1	10	3.0	30
40 × 40	12.2 × 12.2	10	3.0	60
44 × 44	13.4 × 13.4	10	3.0	75
20 × 20	6.1 × 6.1	20	6.1	30
30 × 30	9.1 × 9.1	20	6.1	45
44 × 44	13.4 × 13.4	20	6.1	75
46 × 46	14.0 × 14.0	20	6.1	80
20 × 20	6.1 × 6.1	30	9.1	55
30 × 30	9.1 × 9.1	30	9.1	75
50 × 50	15.2 × 15.2	30	9.1	95
53 × 53	16.2 × 16.2	30	9.1	110
55 × 55	16.8 × 16.8	30	9.1	115
59 × 59	18.0 × 18.0	30	9.1	135
63 × 63	19.2 × 19.2	30	9.1	150
68 × 68	20.7 × 20.7	30	9.1	177
70 × 70	21.3 × 21.3	30	9.1	185

Figure 19. Spacing Requirements F.A. Visual Appliances

5.5.6 Audible Fire Alarm Notification Appliances

Audible fire alarm notification devices are required to meet the requirements stated in NFPA 72 18.4.4. In summary, the audible fire alarm notification devices must emit a sound pressure of at least 15 dB above the ambient sound pressure. The 5 dB above maximum sound level should not apply to this building as it is primarily used for office space.

The location, spacing, and placement of the fire alarm notification devices in the [redacted] building were designed and installed to assure that the code requirements stated above are met. The fire alarm plans were reviewed by the fire alarm contractor and the San Francisco Fire Department to assure compliancy with NFPA 72, the SFFD administrative bulletins, and the CBC.

5.6 Mass Notification System Requirements

The [redacted] Building is not equipped or required to be equipped with a mass notification system due to the size and occupancy use.

The [redacted] Building is classified as a Group B low-rise building. Typically for this occupancy classification, an EVAC system is not required unless the building is considered a high-rise (75 feet above the lowest level of fire department vehicle access). CBC Section 403.4.4 requires an EVAC system in high-rise buildings and Section 907.5.2.2 states the installation and design requirements.

5.7 Secondary Power Supply Requirements

Secondary power supply requirements for the [redacted] building are detailed in NFPA 72 Section 10.6.7.2.1. The [redacted] building will be required to have a secondary power supply capacity that can operate the fire alarm system for 24 hours in standby condition and for 5 minutes in alarm condition. Note that the 5 minutes in alarm condition must include activation/operation of the fire alarm notification devices. If the [redacted] building was equipped with an EVAC system, the requirements would be increased to 24 hours in standby condition and 15 minutes in alarm condition per NFPA 72 10.6.7.2.1.2.

Calculations for the secondary power supply requirements for the fire alarm panel are provided Figure 20. A 20% safety margin was included as required by NFPA 72 10.6.7.2.1.1. The fire alarm control unit is equipped with two (2) 12V 24Ah batteries to meet current requirements below.

QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
FIRE ALARM CONTROL UNIT BATTERY CALCULATION						
Fire Alarm Control Unit - NFS-320						
			EACH	TOTAL	EACH	TOTAL
1	NFS-320	Fire Alarm Control Unit	0.25	0.25	0.25	0.25
1	KDM-R2	CPU Backlight On	0.1	0.1	0.1	0.1
1		SLC-Activation	0.2	0.2	0.2	0.2
		TOTAL PANEL STANDBY CURRENT		0.55		
		TOTAL PANEL ALARM CURRENT				0.55
FIELD DEVICES						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
2	ACM-48A	Annunciator	0.016	0.032	0.07	0.14
78	FSP-851	Smoke Detector Head	0.0003	0.0234	0.0065	0.507
29	FSP-851	Duct Detector Smoke Heads	0.0003	0.0087	0.0065	0.1885
1	FST-851	Heat Detector Head	0.0003	0.0003	0.0065	0.0065
1	NBG12LX	Manual Pull Station	0.000375	0.000375	0.005	0.005
33	FRM-1	Control Relay Modules	0.000485	0.016005	0.0065	0.2145
15	FDM-1	Dual Monitor Module	0.00075	0.01125	0.0064	0.096
3	FMM-1	Monitor Module	0.0004	0.0012	0.0051	0.0153
TOTAL				0.09323		1.1728
TOTAL SYSTEM CURRENT						
	DESCRIPTION			STANDBY		ALARM
	Fire Alarm Notification Power Supply Currents			0.55		0.55
	Fire Alarm Field Devices Currents			0.09323		1.173
	Total Standby Current			0.64323		
	24-Hour Standby Current			15.43752		
	Total Alarm Current					1.7228
	5 MINUTES OF ALARM: HORN					0.144
	Subtotal Calculated Battery Requirement					15.581
	Total Batteries Required (20% Safety Factor)					18.697
	Batteries Supplies to Power Supply					2 x 24ah

Figure 20. Fire Alarm Control Unit Battery Calculations

Secondary power supply calculations for the [redacted] building's fire alarm notification power supplies are provided in Section 15.2 of this report. A 20% safety margin was included in these calculations as well. Calculations were performed for all the fire alarm notification power supplies throughout the building. All fire alarm notification power supplies were equipped with (2) 12V 7Ah batteries. It is quite evident that the batteries provided for the secondary power supply are sufficient to meet the requirements of NFPA 72 10.6.7.2.

5.8 Fire Alarm System Inspection, Testing, and Maintenance (ITM) Requirements

Inspection, testing, & maintenace are vital to assure that the fire alarm system and associated components will function during an emergency. Unlike other technology in the building, such as lighting controls or HVAC systems, fire alarm systems are not used or tested on a daily basis. Therefore, there is a higher risk of sprinkler systems not functioning properly if left idle for long periods of time. Inspection, testing, & maintence requirements are detailed in NFPA 72 Chapter 14. Table 14.3.1 details the periodic visual inspection frequency, while Table 14.4.3.2 details the periosid testing frequence for fire alarm components.

To clarify, there is a difference between inspection personnel and testing personnel. NFPA 72 3.3.200.1, defines inspection personnel as, "Individuals who conduct a visual examination of a system or portion thereof to verify that it appears to be in operating condition, in proper location, and is free of physical damage or conditions that impair operation." NFPA 72 Section 3.3.200.5, defines testing personnel as, " Individuals who perform procedures used to determine the status of a system as intended by conducting acceptance, reaceeptance, or periodic physical checks on the system."

NFPA 72 Chapter 7 details the requirements for documentation of the fire alarm system. Section 7.7.1.1 requires that all records of testing and operations be kept for approximately two years after the initial test.

5.9 Fire Alarm System Summary

Upon evaluation of the prescriptive requirements outlined in Chapter 907 of the California Building Code, it is evident that the [redacted] building's fire alarm system has been designed to meet the minimum requirements of NFPA 72. However, it is essential to recognize that compliance with prescriptive requirements does not necessarily equate to optimal safety for building occupants. To maintain the system's functionality and effectiveness, it is the responsibility of building owners and managers to perform periodic inspections, testing, and maintenance to ensure that the system will perform in an emergency.

6 SMOKE CONTROL

Section 6 of this report provides an overview of the smoke control approach for the [redacted] Building. Section 909 of the California Building Code provides prescriptive requirements and describes the different intents of the various types of smoke control systems. Smoke control refers to the strategies and mechanical systems utilized to manage the movement of smoke within a building in the event of a fire. The primary goal of smoke control is to limit the spread of smoke from one compartment to another and confine it to its original location. The [redacted] Building utilizes the passive approach for smoke control.

6.1 Passive Approach

The passive approach in smoke control involves the use of mechanical and construction features to limit the spread of smoke within a building. Generally, the genesis of the passive approach involves compartmentalization. If a building is divided into compartments or enclosed spaces separated by fire-rated construction, the spread of the smoke can be confined and contained to the area of origin. All openings into separate compartments must be protected by opening protectives, such as fire doors, fire smoke dampers, and smoke barriers that also limit the spread of smoke between compartments.

The [redacted] building passive approach is primarily controlled by the building's fire alarm system. In the event of a fire alarm condition, the fire/smoke doors and fire/smoke dampers will automatically close to contain the fire and products of combustion to the area of origin. The mechanical HVAC systems will also shut down to limit the spread of smoke. Each floor or zone is separated by fire rated constructed and therefore the likelihood of the spread of the smoke is reduced. Refer to Section 5.4.2 for an overview of the [redacted] Building's fire alarm sequence of operations.

6.2 Atrium

The [redacted] building has a 3-story atrium between the basement level to the second floor. There is an open interior stairway that connects all three floors. The second floor is open to the ground floor and similarly, the basement and ground floor has horizontal openings between floors as well.

Per CBC Section 404.5, smoke control systems are required for atriums that connect more than two stories. However, the architect and building owner decided to install fire-rated shutter between the openings of the basement level and ground floor. In a fire alarm condition, these horizontal and vertical fire-rated shutters will automatically deploy and should efficiently compartmentalize the fire to the floor of origin. This would create a two-story opening, which per CBC Section 712.1.9 does not require a mechanical smoke control system. CBC Section 712.1.13 allows fire rated doors, shutters, opening protectives to close openings and separate floors that are otherwise atmospherically connected.

6.3 Smoke Control Summary

Upon evaluation of the smoke control approaches outlined in Section 909 of the California Building Code, it is evident that the [redacted] building meets the design intent of a passive smoke control approach. It is essential to recognize that utilizing a passive approach requires multiple life safety systems working in conjunction optimally, which can be challenging to maintain. It is the responsibility of building owners and managers to perform periodic inspections, testing, and maintenance to ensure that the system will perform in an emergency.

7 STRUCTURAL

Section 7 of this report provides an overview of the structural requirements for the [redacted] Building and evaluates its compliance. These prescriptive requirements of the structural requirements are outlined in Chapters 5, 6, and 7 of the California Building Code. Chapter 5 addresses allowable building areas, heights, and stories, whereas Chapter 6 provides guidance into the fire resistance ratings of various construction types. Chapter 7 takes a more detailed approach and on fire and smoke protection requirements within the building.

7.1 Construction Type, Allowable Height, Number of Stories, & Allowable Areas:

7.1.1 Type of Construction

The [redacted] building is classified as Type II-A construction. Type II-A buildings are required to be constructed from noncombustible material and will typically have structural elements including exterior walls, structural frame, and floor/ceiling/roof protection with a fire resistive rating of at least one hour. Section 7.3 of this report provided the CBC prescriptive fire-resistive requirements for a Type II-A building.

7.1.2 Allowable Building Height

Per the CBC Table 504.3, a building with a Type II-A construction that has an occupancy classification of Business Group B can have a maximum height of 85 feet measured above grade plan. The [redacted] building complies with this requirement as the building is 73 feet above grade plane. Refer to Table 20 for a summary.

Table 20 -Allowable Building Height

Occupancy Classification (Type II-A; Sprinklered Building)	Actual Building Height Above Grade Plane (ft)	Allowable Building Height Above Grade Plane (ft)
B	73	85

7.1.3 Allowable Building Story

Per the CBC Table 504.4, a building with a Type II-A construction that has an occupancy classification of Business Group B can have a maximum of 6 stories above grade plan. The [redacted] building complies with this requirement as the building is six stories above grade plane. Refer to Table 21 for a summary.

Table 21-Allowable Building Story

Occupancy Classification (Type II-A; Sprinklered Building)	Actual Building Stories	Allowable Building Stories
B	6	6

7.1.4 Allowable Floor Area:

The [redacted] building complies with the allowable floor area per story and total allowable building area. Section 13 of this report details the procedure followed to carry out the allowable area calculations, in accordance with CBC Section 503. Refer to Table 22 for a summary.

Table 22-Allowable Areas

Floor	Floor Area [ft^2]	Allowable Floor Area [ft^2]
Basement	13,670	112,500
1st Floor	13,650	112,500
2nd Floor	11,250	112,500
3rd Floor	13,650	112,500
4th Floor	13,650	112,500
5th Floor	13,650	112,500
6th Floor	13,650	112,500
Total Building Area [ft^2]		Allowable Building Area
93,170		337,500

7.2 Structural Components:

A full set of structural engineering plans is not available for the [redacted] building. The structural information provided in this section is compiled from multiple tenant improvement projects from 2015-2020. The construction plans from the tenant improvement project provide details of certain structural aspects of the building.

7.2.1 Concrete Construction

The concrete construction of the [redacted] building is specified to conform to ACI 301 "Specifications for Structural Concrete for Buildings". All concrete exterior exposed slabs on grade, concrete interior slabs on grade, concrete walls/footings, and concrete on metal deck are specified to a minimum compressive strength of 4,000 psi at the end of the 28-day test age. The reinforced beams and slabs have a minimum compressive strength of 5,000 psi at the end of 26-day test age.

7.2.2 Floor and Roof Assemblies

The floor assemblies are on a steel deck and covered with a concrete slab. The specifications are 3 inches of concrete on 3 inches of composite steel deck. The floor assembly is reinforced with welded wire fabric listed as 6x6 W1.4xW1.4. The steel deck type is Verco Type W ASC Type W. The maximum dead load deflection is ¾ inches or L/180. The steel deck conforms to ASTM A653, and a metal protective coating of zinc will conform to ASTM A653-G60.

The roof assembly is on a steel deck and covered with a concrete slab. The specification of the steel deck for the roof assembly is 3-inch-deep x 18 gauge. The roof deck shear is 934lbs/ft. The composite slab is 3 inches of concrete on 3-inches of the composite steel deck. The roof assembly is reinforced with welded wire fabric 6x6 W1.4xW1.4. The steel deck type is Verco Type N ASC Type N-24. The steel deck conforms to ASTM A653, and a metal protective coating of zinc will conform to ASTM A653-G60.

7.2.3 Columns

Detailed information about the columns for the [redacted] building is not available. The circular columns are assumed to be made of concrete reinforced with steel. The columns are considered load bearing and have one-hour fire resistive protection. It is interesting to note that the basement to the second floor has a different column configuration than the third to the sixth floor. The basement to second floor has a circular concrete column that is approximately 8'-6" in height and 2'-7" in width from floor to the underside of the slab. These floors have concrete beams located throughout the floor to assist with the structural load. The third to the sixth floor has columns that are approximately 14'-6" in height and 2'-6" in width from floor to the underside of the slab. These floors do not have structural beams to assist with the structural load. Instead, the columns are designed with "drop caps", which are small, thickened areas on the concrete beam that can take on increased loads. Refer to Figure 21 for column dimensions.

[redacted]

Figure 21-Column Dimensions #1

The columns throughout the [redacted] building are spaced 18 feet apart from the center. The diameter of the beam is also measured to be 2 feet. Refer to Figure 22 for additional measurements.

[redacted]

Figure 22-Column Dimensions #2

7.2.4 Girders and Beams

Like the [redacted] building's columns, detailed information on the girders and beams is not available. It is assumed that most of the building's girders and beams are made of concrete with reinforced steel. Assumptions about the location of that reinforced steel within the concrete beam will be made in future sections. As noted above, the girders and beams are located only from basement level to the second floor. Measurements from building section plans show that the concrete beams are approximately 1'-7" in width and 1-7" in height. Available construction plans from recent tenant improvement projects and building section plans indicate that certain areas in the basement and ground floor are supported with steel beams as well. It is assumed that the steel beams are W21x44. Refer to Figure 23 for dimensions of the beam.

[redacted]

Figure 23-Beam Dimensions

7.2.5 Walls and Partitions

Information on the exterior walls could not be located for the [redacted] building. It is assumed that the exterior walls have a steel frame with composite slabs of concrete similar to the flooring assemblies.

The [redacted] building has multiple types of details for interior wall partitions including 2-hour shaft walls, one hour rated partitions, 1-hour rated partitions, and 2-hour rated partitions.

The specifications for the 2-hour rated interior partitions for a shaft wall includes a 1" shaft liner Type "X" gypsum panel and another 2 layers of 5/8" type X Gypsum board on the exposed side to the underside of the slab above. The design complies with UL 437 and the overall thickness is 5-1/4". The head-of-wall connection complies with UL-2079 (UL standard for safety tests for fire resistance of building joint systems). 4"x 20 GA C-H MTL Studs at 24" OC (on center) is used to support the wall.

The specifications for the 1-hour rated interior partition include a layer of 5/8" Type "X" gypsum board on each side to the underside of the slab above. The design complies with UL U419, and the overall thickness is 4-7/8" The head-of-wall connection complies with UL-2079. 3-5/8"x 20 GA C-H MTL Studs at 24" OC (on center) is used to support the wall. Min 5/8" depth Hilti CP 606 Flexible fire stop sealant is used in gaps between the gypsum board and existing slab.

The specifications for the 2-hour rated interior partition include two layers of 5/8" Type "X" gypsum board on each side to the underside of the slab above. The design complies with UL U419, and the overall thickness is 6-1/8" The head-of-wall connection complies with UL-2079. 3-5/8"x 20 GA C-H MTL Studs at 24" OC (on center) is used to support the wall. Min 5/8" depth Hilti CP 606 Flexible fire stop sealant is used in gaps between the gypsum board and existing slab.

The specifications for the non-rated interior partition include a layer of 5/8" Type "X" gypsum board on each side to the underside of the slab above. 3-1/2" MTL Studs at 16" OC (on center) is used to support the wall. Corner beads are used on the exposed edges. Acoustical sealants are used at the perimeter of the partition.

7.2.6 Penetrations

Detailed information on the penetrations is not available for the [redacted] building. Penetrations are common in buildings to accommodate electrical conduit, duct work, fire smoke dampers, etc. It is assumed that fire proofing material is used to maintain the integrity of the any penetrations through fire-rated walls and floors. The local jurisdiction requires that penetration fire stop systems are installed according to ASTM E814 (Standard Test Method for Fire Test of Through-Penetration ire Stops) or UL 1479 (Standard for Safety for Fire Tests of Through-Penetration Fire Stops).

7.3 Fire Resistance Rating Requirements:

7.3.1 General Fire Resistance Rating

The prescriptive fire resistance rating requirements for the [redacted] building (Type II-A construction) are found in the CBC Table 601 and 602. The building is required to have a minimum fire resistance rating of one- hour for most structural elements including load bearing walls, exterior walls, floor construction, and roof construction. The non-load bearing interior walls and partitions are not required to have any fire resistive protection. Refer to Table 23 for a summary.

Table 23-Fire Resistance Requires (Type II-A Building)

Building Element	Fire Resistance Ratings
	Type II-A
Primary Structural Frame	1 hour
Load Bearing Exterior Walls	1 hour
Load Bearing Interior Walls & Partitions	1 hour
Non-bearing Exterior Walls and Partitions (Dependent on Fire Separation Distance)	1 hour
Non-bearing Interior Walls and Partitions	0 hour
Floor Construction and Associated Secondary Members	1 hour
Roof Construction and Associated Secondary Members	1 hour

7.3.2 Fire Separation Distance

The fire separation distance (FSD) is used to determine the non-bearing exterior wall fire-resistance rating requirements. The FSD is the distance measured from the building face to one of the following: closest interior lot line, centerline of a street, alley, or public way, or to an imaginary line between two buildings on a lot. The distance is required to be measured at right angles from the face of the wall and separately for each story. The fire separation distance for the [redacted] building is approximately nine feet from the closest interior lot line. Therefore, per the CBC Table 602, the non-bearing exterior walls of the [redacted] building are required to have a minimum fire-resistive rating of one hour. Refer to Table 24 for a summary.

Table 24-Fire Separation Distances

Fire Separation Distance	Fire Resistance Rating
5 ≤ X < 10 feet	1 hour

7.3.3 Shafts Enclosures and Interior Stairways

Per the CBC Section 713.4 and 1023.2, shaft enclosures and interior exit stairways are required to have a fire resistance rating of not less than 2 hours if the building is connected by four stories or more. Therefore, since the [redacted] building is six stories, all shaft enclosures are required to have a minimum fire resistance of 2 hours. The elements of the [redacted] building that have a fire resistance of 2 hours are shown in the table below. Refer to Table 25 for a summary.

Table 25-Shaft Enclosure & Interior Stairway Fire Resistance Requirements

Building Element	Fire Resistance Ratings
Shaft Enclosures	2 hours
Elevator Shafts	2 hours
Interior Exit Stairways	2 hours

7.3.4 Incidental Use

Incidental Uses are considered ancillary areas within a building that poses a greater level of risk. Per CBC Table 509, incidental uses are required to be separated from the remainder of the building typically by horizontal assemblies or fire barriers. Certain incidental uses can have no separation if the building is provided by an automatic sprinkler system. For the [redacted] building, each floor has a tenant equipment room that contains stationary storage batteries. The room is separated from the building by a one-hour fire barrier. Refer to Table 26 for a summary.

Table 26-Incidental Use Fire Resistance Requirements

Room or Area	Separation and/or Protection
Stationary Storage Battery Systems	1 hour

7.3.5 Opening Protectives

Most of the doors that are located throughout the [redacted] building are non-rated. Fire door assemblies are required with fire resistance construction and provide a specific degree of fire protection in an opening. The CBC Table 706.1(2) specifies the minimum required assembly rating for fire doors and fire shutters based on the type of assembly (Fire wall, fire barriers, shafts, etc.) and the required wall assembly rating (1-hr, 2-hr, etc.). Table 5 details the fire door and fire shutter ratings that are applicable to the [redacted] building. Refer to Table 27 for a summary.

Table 27-Fire Door Assembly Rating Requirements

Rated Separation	Minimum Fire Door and Shutter Assembly Rating	Size Limitation
Other 1-hour fire barriers	45 minutes	25% of length of wall
2-hour enclosures for shafts and interior exit stairways	90 minutes	25% of length of wall

7.4 Interior Finish Requirements

7.4.1 Interior Wall and Ceiling Finish Requirements

CBC 803.1.2 states the classifications of interior wall and ceiling finishes in accordance with the flame index spread. These classifications are in accordance with ASTM E84 or UL 723. These materials are grouped in class A, B, and C. Class A has the lowest flame spread, while Class C has the highest flame spread. To meet the requirements of the classifications, the flame index spread cannot exceed 450.

CBC Table 803.13 states the requirements for interior wall and ceiling finishes by occupancy classification. Refer to Table 28 for a summary ceiling finish requirements based on the different occupancies within the building.

When any special wall hangings/coverings, awnings/ceilings, or other decorative interior features/structures are proposed, they should be closely reviewed for code compliance, potential fire hazard and for fire sprinkler discharge obstructions.

Table 28 - Interior wall and ceiling finish requirements

Occupancy	Interior Exit Stairways and Exit Passageways	Corridors and enclosure for exit access stairways	Rooms and Enclosed Spaces
Group A-3	B	B	C
Group B	B	C	C
Group F	C	C	C
Group S	C	C	C

7.4.1 Interior Wall and Ceiling Finish Requirements

CBC 804.2 states the classifications and requirements of interior floor finishes and floor covering material. These classifications are based on the critical radiant flux measurements in accordance with ASTM E648 or NFPA 253. These materials are groups in either Class I (0.45 watts/cm^2) or Class II (0.22 watts/cm^2). Class I is more flame resistant than Class II.

CBC 804.4.2 states the minimum requirements of interior floor finishes and floor covering material. Based on the occupancy classifications of the [redacted] building, the minimum critical radiant flux will not be less than Class II.

7.5 Structural Summary

Upon evaluation of the prescriptive requirements outlined in Chapter 5, 6, and 7 of the California Building Code, it is evident that the [redacted] building has been designed to meet the minimum requirements.

8 PERFORMANCE BASED DESIGN

Performance-based design refers to an alternative approach to traditional building design that focuses on achieving specific performance objectives rather than following prescriptive design requirements. This approach can involve evaluating the building's anticipated performance under various scenarios and assessing its capacity to fulfill performance criteria. Performance based design is typically utilized when buildings cannot adhere to the prescriptive codes. However, it does allow for more flexibility in design while also maintaining the safety for occupants within the building.

Section 8 of this report evaluates two critical scenarios: fires in the IT room and Atrium. The assessment of the IT room fire includes an analysis of flashover occurrence, secondary ignition, sprinkler activation, and smoke detector activation. The evaluation of the Atrium fire involves conducting an ASET (available safe egress time) vs. RSET (required safe egress time) analysis to determine if tenable conditions can be maintained for all occupants to safely evacuate the building.

8.1 [redacted] Building Fuel Sources & Hazards

Section 8.1 of this report summarizes potential fuel sources and hazards located within the [redacted] building.

8.1.1 Office Furniture & Appliances

The primary fuel sources for the [redacted] building include the typical items found in an office including furniture, office supplies, electronics, and workstations. These items can be comprised of combustible materials such as wood, fabric, polyurethane foam insulation, plastics, and rubbers that can start or sustain a fire. In the case of the [redacted] building, the open offices contain an abundance of potential fuel packages.

8.1.2 Basement IT Equipment Room

The main IT equipment room is located in the basement level of the [redacted] building. The room contains the server and associated electronic equipment to support the entire west coast business operation. The servers are stored in large racks that reach approximately eight feet above floor level. Dedicated HVAC equipment is provided specifically for this room to effectively lower the temperature and reduce the likelihood of overheating. The IT equipment room should be considered as a hazard since it is equipped with an abundance of closely spaced electronics. As the IT equipment is constantly operating, the room is completely reliant on the air conditioning equipment to reduce the likelihood of electronic malfunction. If a fire were to start in this room, it would spread and grow quickly with the available fuel sources.

8.1.3 Gas Meter Rooms

The [redacted] building contains a gas meter room in the basement level. The room houses the metering equipment and pipeline connection for natural gas to enter the premises. Natural gas when mixed with air and exposed to an ignition source is combustible. The room is separated from the remainder of the building by two-hour fire barriers. A factor that could create a safety hazard for the building is if there is a leak in the gas lines and the door to the meter room is propped open.

8.1.4 Atrium

The [redacted] building has a 3-story atrium between the basement level to the second floor. There is an open interior stairway that connects all three floors. The second floor is open to the ground floor and similarly, the basement and ground floor has horizontal openings between floors as well. Atriums are considered a safety hazard for occupants in the building as they can allow smoke and other products of combustion to spread throughout the building. To reduce the likelihood of smoke spread, the architect and building owner decided to install fire-rated shutter between the openings of the basement level and ground floor. In a fire alarm condition, these horizontal shutters will automatically close and should efficiently compartmentalize the fire to floor of origin. It should be noted that the compartmentalization in the atrium is completely reliant on the fire alarm system and fire-rated shutter functioning properly. Figure 24 below provides a floor plan view of the openings between the ground floor and basement level. Refer to Section 6.2 for an overview of the prescriptive requ[redacted]

Figure 24 - Ground Floor Openings to Basement Level

8.1.5 Open Offices (Travelling Fire)

Each level of the [redacted] building contains an open floor layout with workstations and furniture located throughout. This open plan should be considered a hazard as it provides an environment for traveling fires to occur. If a fire were to start in the office open, secondary ignition is likely to occur due to closely spaced fuel packages. Since the open office extends the entire length of the building, a fire could progressively spread from one end of the building to the other end.

8.2 Design Fire 1: IT Equipment Room

The basement level contains a tenant IT room that houses the servers and associated electronic equipment to support the entire west coast business operation. The room contains three large server racks that reach approximately eight feet above the floor level and are spaced approximately 0.6m apart. The ignition source for this design fire is an electrical short that eventually leads to the middle server rack catching on fire. This IT room was chosen as a basis for the design fire due to the significant equipment housed within the space. Loss or damage to the servers would have a major and adverse impact on the owner and the operations of the business. It is currently unclear which type of fire protection equipment is currently located in the IT room. However, since property protection is vital, it is assumed that the IT equipment room is protected by a dual interlock pre-action system. Essentially, this is a dedicated fire protection system where both the smoke detection and sprinkler activation must occur before water is discharged within the protected area. The IT equipment room dimensions and openings are provided in Table 29. Refer to Figure 25 for a depiction of the IT room.

Table 29 - I.T. Equipment Room Dimensions

I.T. Room Dimensions	
Room Length [m]	6.5

I.T. Room Dimensions	
Room Width [m]	4.8
Room Height [m]	3.35
Total Room Surface Area [m^2]	138.11
Opening Height [m]	2.03
Opening Width [m]	0.91
Area of Opening [m^2]	1.85

[redacted]

Figure 25 - Depiction of IT Equipment

8.2.1 Design Fire 1: HRR Experimental Data

To determine the HRR for the design fire, experimental data involving computer racks from the 2016 SFPE Handbook was referenced. Specifically, this data came from Figure 26.35 where three separate tests were conducted involving stainless steel mesh-type racks containing computer and electronic equipment. Considering that it is unclear the contents of the computer racks in the [redacted] Building, the HRR experimental data from Test 3 was utilized as it is considered the worst-case scenario. Test 3 had the top shelves filled with cardboard sheets which were located above the electronic equipment. In the experimental data, introducing the cardboard sheets raised the peak HRR from 155 kW to approximately 600kW. Refer to Figure 26 below for the experimental HRR data from Figure 26.35 of the SFPE Handbook.

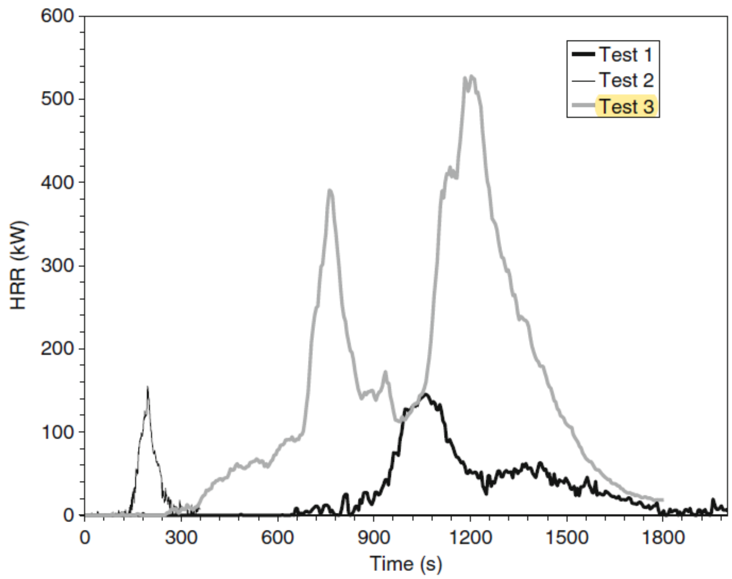

Figure 26 - 2016 SFPE Handbook Figure 26.35 (HRR of Computer Equipment Racks)

8.2.2 Design Fire 1: Heat Release Rate Curve

As previously mentioned, one of the three computer racks is ignited due to an electrical short and eventually catches on fire. For this design fire, the computer rack positioned at the center of the others is the initial ignition source. The objective was to determine if secondary ignition would occur for the remaining two computer racks. Therefore, a critical heat flux required for ignition needed to be determined for the computer racks. Given that the computer racks for Test 3 are ignited by cardboard sheets, Table A.35 from the SFPE handbook is referenced. Among all the listed materials, corrugated paper proved to be the most representative of cardboard paper. Therefore, a critical heat flux of 10 kW/m^2 is utilized. Refer to Figure 27 for the critical heat flux data from Table A.35.

Table A.35 Critical heat flux and thermal response parameter of materials [10–14]

	CHF (kW/m^2)		TRP (kW·s$^{1/2}$/m^2)	
Material	ASTM E2058 FPA	ASTM E1354 Cone	ASTM E2058 FPA	ASTM E1354 Cone
Natural				
Flour	10	–	218	–
Sugar	10	–	255	–
Tissue paper	10	–	95	–
Newspaper	10	–	108	–
Wood (red oak)	10	–	134	–
Wood (douglas fir)	10	–	138	–
Wood (douglas fir)/fire retarded (FR)	10	–	251	–
Wood (hemlock)	–	–	–	175
Corrugated paper (light)	10	–	152	–

Figure 27 - 2016 SFPE Handbook Table A.35 (Critical Heat Flux)

To assess the possibility of secondary ignition, the radiative component of the heat release rate (Qr) of a fire must be calculated. Based on a critical heat flux of 10 kW/m^2 and an aisle width of 0.6 meters, the following formula is utilized:

$$Q_R = 4\pi q_r"R^2$$

$$Q_R = 4\pi \times 10\frac{kW}{m^2} \times (0.6m)^2$$

$$Q_R = 45.24\ kW$$

Assuming a radiative fraction of 0.3, the total HRR required for the computer rack ignition can be calculated.

$$Q = \frac{q_r}{\xi}$$

$$Q = 45.22\ kW/0.3$$

$$Q = 150.8\ kW$$

Therefore, once the center computer rack reaches 150.8 kW, secondary ignition will occur for the two adjacent racks since they are both spaced 0.6m apart. From the calculations performed, secondary ignition does occur for the remaining two IT racks. Both adjacent computer racks ignite at approximately 692 Seconds.

The cumulative HRR reaches approximately 1050 kW and has a burning duration of approximately 40 minutes. Based on the experimental data used as the basis for the HRR curve of this design fire, the computer rack has a very slow growth phase. The initial 400 seconds of the HRR can be regarded as the incipient stages of the fire, during which the HRR at this phase may be considered negligible. Refer to Figure 28 for a graph of the IT room HRR.

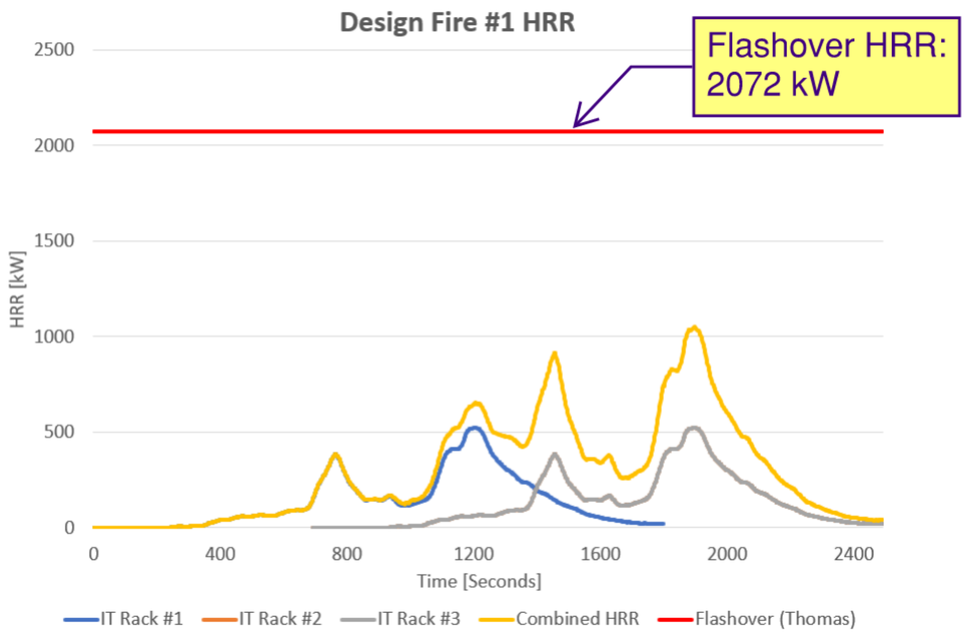

Figure 28 - IT Room HRR Curve

8.2.3 Design Fire 1: Flashover Correlations

The Thomas correlation is used in this report to determine flashover conditions for the IT room compartment. Refer to the formula below. The dimensions of the openings within the compartment and the dimensions of the compartment are used to calculate a HRR value in which flashover is anticipated to occur. Refer to Table 29 for the room dimensions and opening dimensions inputs.

$$Q_{FO} = 7.8A_T + 378A_O\sqrt{H_O}$$

$$Q_{FO} = 7.8 \times 138.11 + 378 \times 1.85\sqrt{0.91}$$

$$Q_{FO} = 2072 \text{ kW}$$

Using Thomas's approach, based on the dimensions of the space and openings, a heat release rate (HRR) of 2072 kW was determined as the criteria for the compartment to reach flashover. From Figure 28, it is evident that the cumulative HRR of the IT server racks do not reach a HRR that would achieve flashover. This is likely due to the IT server racks having a slow growth rate and lacking sufficient combustible fuel sources to reach a substantial HRR for flashover to occur.

8.2.4 Design Fire 1: Pre-Action Smoke Detector Activation

As previously mentioned, it is unclear the type of existing fire protection equipment located within the IT Room. Therefore, it is assumed that the IT equipment room is protected by a dual interlock pre-action system. Essentially, this is a dedicated fire protection system where both the smoke detection and sprinkler activation must occur before water is discharged within the protected area. This section will be focused on determining the activation time of the smoke detector by utilizing Alpert's Ceiling Jet Correlation. Refer to Figure 29 for Alpert Ceiling Jet Correlation formulas which were inputted into a excel spreadsheet to determine the temperature of the ceiling jet and time to smoke detection activation. The cumulative heat release rate (HRR) from Figure 28 was used in the formula and inputted into the excel spreadsheet.

Small Plume Turning Region:

$$T_{cj} - T_{\infty} = 16.9\frac{\dot{Q}^{2/3}}{H^{5/3}} \qquad \frac{r}{H} \leq 0.18$$

$$u_{cj} = 0.96\left(\frac{\dot{Q}}{H}\right)^{1/3} \qquad \frac{r}{H} \leq 0.15$$

Large Plume Turning Region:

$$T_{cj} - T_{\infty} = \frac{5.38}{H}\left(\frac{\dot{Q}}{r}\right)^{2/3} \qquad \frac{r}{H} > 0.18$$

$$u_{cj} = 0.195\left(\frac{\dot{Q}^{1/3}H^{1/2}}{r^{5/6}}\right) \qquad \frac{r}{H} > 0.15$$

Temperature of the Detector:

$$T_d^{i+1} = \frac{\sqrt{u_j}}{RTI}\left(T_j - T_d^i\right) + T_d^i$$

Figure 29 - Alpert Ceiling Jet Correlation Formulas

Input data is provided in Table 30 below. The criteria for smoke detector activation are from NFPA 72 Table B.4.7.5.3 that states, based on experimental data, that an average ceiling temperature change of 21.1°C will cause a smoke detector to activate. In this design fire scenario, an ambient room temperature of 295K was assumed, and therefore, the smoke detector will activate when the ceiling temperature reaches approximately 316.1°C.

It is important to acknowledge that smoke detector RTIs can vary across different publications, often presenting values that range from 0 to 5. Due to this variation, an RTI value of 3 $[m\text{-}s]^{1/2}$ is utilized which can be considered as a moderate midpoint within the range.

Based on the HRR curve from Figure 30, the smoke detector will activate approximately at 674 seconds or approximately 11.2 minutes. While 11.2 minutes may be considered relatively long for smoke detector activation in a room of this size, it is important to note that the model accounts for the incipient stage of the fire, during which the fire is gradually and slowly developing. If the incipient stage is excluded from the calculation, the smoke detector would activate within a more reasonable timeframe of approximately 5.4 minutes.

Note that at 11.2 minutes, the pre-action system has not yet discharged water since the sprinkler system has not yet been activated.

Table 30 - I.T. Equipment Room Smoke Detection Activation Input

I.T. Room Pre-action Smoke Detector Activation	
Ambient Room Temperature [K]	295

I.T. Room Pre-action Smoke Detector Activation	
RTI $[m\text{-}s]^{1/2}$	3
Ceiling Height [m]	3.35
Distance from Fire [m]	2
Activation Temperature [K]	316.1
Time of Smoke Detector Activation [s]	674
HRR at time of Smoke Detector Activation [kW]	101.11

8.2.5 Design Fire 1: Pre-Action Sprinkler Activation

The IT equipment room is assumed to be equipped with sprinkler protection which complies with all of the applicable requirements of the codes and standards. Per NFPA 13, this compartment is likely classified as a light hazard occupancy, and the sprinklers are assumed to be ordinary temperature, quick response, and pendant mounted. Based on the ordinary hazard classification, the spacing between sprinkler heads is 4.6m with a maximum protection area of $20m^2$. Since the room is relatively small, two sprinkler heads are provided. sprinkler heads are assumed to have a standard activation temperature of 330K and a RTI of 50 $[m\text{-}s]^{1/2}$. By using Alpert's plume correlation (Refer to Figure 29), it was determined that the first sprinkler inside the space would activate at approximately 744 seconds or 12.4 minutes. See Table 31 for input data. The cumulative heat release rate (HRR) from Figure 28 was used in the formula and inputted into the excel spreadsheet.

Table 31 - I.T. Equipment Room Sprinkler Activation Input

I.T. Room Pre-Action Sprinkler Activation	
Ambient Room Temperature [K]	295
Ceiling Height [m]	3.35
Distance from Fire [m]	1.2
RTI $[m\text{-}s]^{1/2}$	50
Activation Temperature [K]	330
Time of Sprinkler Activation [s]	744
HRR at time of Sprinkler Activation [kW]	329.1

While 12.4 minutes may be considered relatively long for sprinkler activation in a room of this size, it is important to note that the model accounts for the incipient stage of a fire, during which the fire is gradually and gradually developing. If the incipient stage is excluded from the calculation, the sprinkler would activate within a more reasonable timeframe of approximately 6.5 minutes.

When both the smoke detector and sprinklers are activated, the pre-action system will discharge water into the compartment which is assumed to control the fire. The discharge of water will affect the HRR of the space by not allowing the HRR to reach its peak values.

The maximum HRR will reach approximately 330 kW compared to 1050kW without activation. Figure 30 depicts the IT room HRR curve with pre-action system activation. It should be concluded that sprinkler activation will assist at controlling the fire and not allowing the HRR to reach its maximum peak potential.

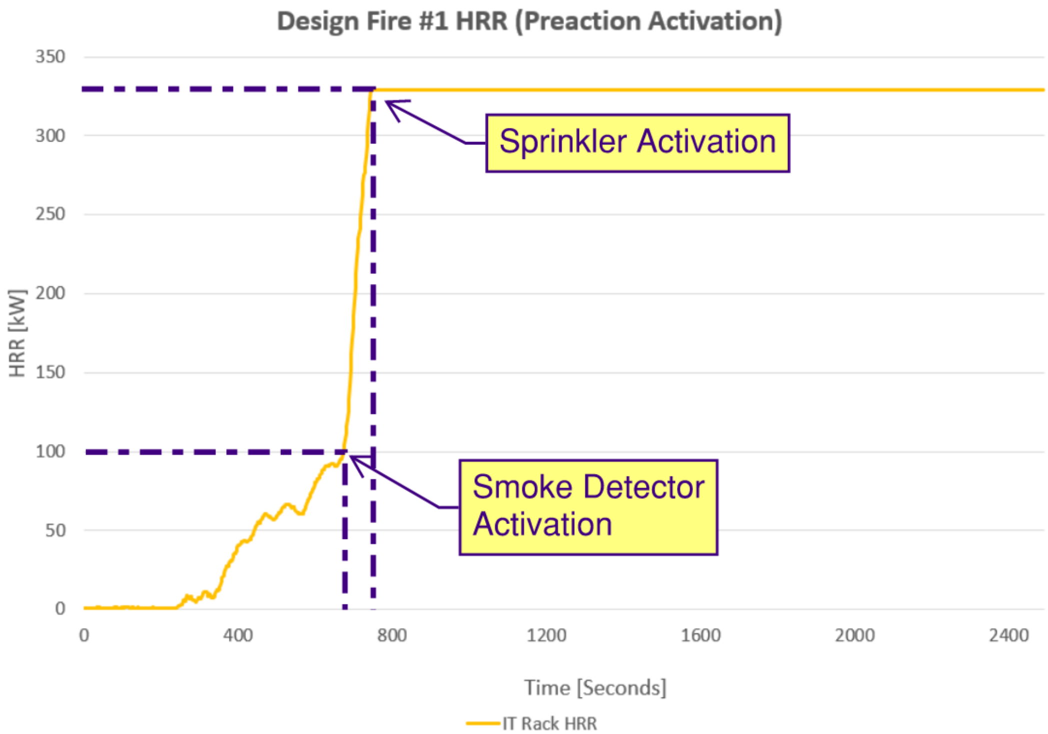

Figure 30 - IT Room HRR Curve Pre-Action System Activation

8.2.6 Design Fire 1: Limitations and Uncertainties

For this design fire, there are multiple factors that come into play when discussing limitations and uncertainties. The HRR data of computer racks from the 2016 SFPE handbook is used to determine the HRR curve for this design fire. However, it should be noted that the computer racks from the experimental data are likely not an exact match as the ones present at the [redacted] building. The experimental data used computer racks that were approximately 6 feet tall, had six shelves that contained personal computers/CRT monitors/ data acquisition units, and had cardboard and computer paper located throughout the racks. In a realistic scenario, it is highly unlikely that modern IT racks will contain these types of materials and equipment. Therefore, the HRR curve determined for this design fire is likely not indicative of a realistic scenario. There are also likely other items stored within the I.T. room that potentially could affect the HRR curve.

A limitation of this design fire is that it did not account for a computer room air conditioning (CRAC) unit affecting the formation of a smoke layer at the ceiling. Most modern I.T. rooms are equipped with a CRAC unit to effectively lower the temperature and reduce the likelihood of overheating. Based on the placement of the CRAC unit, one could assume that air releasing from the unit could potentially affect the smoke layer from forming on the ceiling. Alternatively, based on placement, one could argue that the CRAC unit could potentially cause the smoke layer to spread at a quicker rate.

The last uncertainty of this design fire is the activation criteria for the dual interlock pre-action system. The activation criteria used for the design fire in Section 8.2.4 and 8.2.5 is based on research and may not be representative of the actual equipment located within the space.

8.3 Design Fire 2: Atrium Fire

The [redacted] building contains a 3-story atrium between the basement level to the second floor with an interior staircase connecting the spaces. The atrium is considered a fire and life safety hazard for occupants in the building as it can allow smoke and other products of combustion to spread throughout the building. The design fire occurs at the base of the atrium in the basement level. This atrium is not equipped with a mechanical smoke control system. In the event of a fire alarm condition, horizontal and vertical fire rated shutters automatically release and compartmentalize and separate the basement from the 1st and 2nd floor.

This section of the report will focus on an ASET vs RSET analysis. This analysis will specifically focus on the deployment of the fire-rated shutters to assess whether the conditions on the levels above the fire, as well as the areas remote from the fire, will remain safe and suitable for the evacuation of building occupants.

8.3.1 Life Safety Analysis (ASET vs RSET)

The objective of the building and its associated systems are to maintain tenable conditions such that occupants remote from the fire are able to safely evacuate the building. To evaluate the performance-based design, a computer smoke modeling software will be used to determine if tenable conditions are maintained at the required egress pathways.

The means of egress system of the building is compliant with the code, however as part of the performance-based analysis, an evacuation assessment (egress analysis) will be used to determine if all occupants can safely egress prior to any degradation in the tenability criteria. The intent of this timed egress analysis is to show that the available safe egress time (ASET) is greater than the required safe egress time (RSET). Although a smoke control system is not required prescriptively, this analysis will use the safety factors from Section 909. Therefore, per CBC Section 909.4.6 tenable conditions should be maintained for 1.5x the time needed for evacuation. This is to account for the uncertainty related to human behavior during evacuation, such as the occupant walking speed and pre-movement time. The RSET is determined by the timed egress analysis, while the ASET is determined by computer smoke modeling. Figure 31 conceptually shows a "pass" condition and a "fail" condition for this analysis.

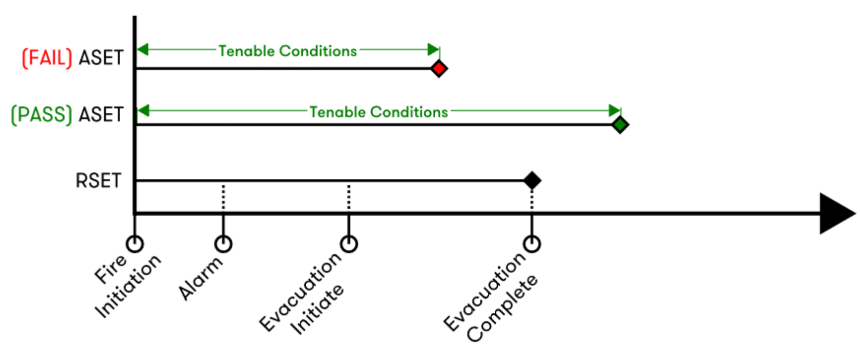

Figure 31. Conceptual ASET/RSET timeline indicating pass/fail conditions.

8.3.2 Required Safe Egress Time

8.3.2.1 Methodology

The estimation of the time taken for occupants to clear the level or enter an interior exit stairway (place of safety) is outlined in the subsequent sections of this report. The evacuation time was assessed using a computer evacuation modelling software, Pathfinder version 2022 by Thunderhead Engineering. The software allows the user to create 3-dimensional building geometry including rooms, doors, stairs, and obstructions. Refer to Figure 32 for a depiction of the [redacted] Building Pathfinder simulation. The model incorporates SFPE movement calculations for walking speeds, boundary layers and egress flow. The RSET (Required Safe Egress Time) is the total time required for an occupant to safely enter an exit after a fire initiates. Refer to Section 8.3.2.2 for further details on the egress scenarios, occupant loads, egress widths and other aspects associated with the egress analysis.

Figure 32. [redacted] Building Pathfinder Simulation

8.3.2.2 Pathfinder Inputs and Results

8.3.2.2.1 Evacuation Assessment

The estimation of the time taken for occupants to evacuate was determined based on the hydraulic calculations listed in The SFPE Handbook of Fire Protection Engineering (Gwynne & Rosenbaum, 2016). This methodology provides a simplified set of equations to determine the RSET, where occupants move as a group from egress component to egress component:

$$RSET = (t_d + t_n + t_{pre}) + 1.5 \times (t_{trav} + t_{flow}) \quad (1)$$

where:

RSET	=	Required safe evacuation time to an exit, (s)
t_d	=	Time from ignition to detection by an automatic system, (s)
t_n	=	Time from detection to occupant notification, (s)
t_{pre}	=	Total pre-movement time, (s)
t_{trav}	=	Travel time to an exit or exit stair, (s)
t_{flow}	=	Time spent in congestion waiting to enter an exit or exit stair, (s)

8.3.2.2.2 Evacuation Model

The evacuation time was assessed using a computer evacuation modelling software, Pathfinder version 2022 by Thunderhead Engineering. The software allows the user to create 3-dimensional building geometry including rooms, doors, stairs, and obstructions. The model incorporates SFPE movement calculations for walking speeds, boundary layers and egress flow.

Simulations were performed using the SFPE mode which employs the hydraulic model defined in the SFPE handbook 5th Edition. The SFPE model hydraulic model has been extensively validated against the examples in the SFPE Handbook and typically provides less optimized results, and hence the most conservative results (Thunderhead Engineering, 2022).

The evacuation model was developed based on the egress and occupancy drawings provided. Refer to Section 11 for the egress floor plans.

8.3.2.2.3 Egress Model Inputs

Egress model inputs and assumptions are provided below:

Detection time (t_d) = 34 seconds,

- Detection time/sprinkler activation time as was determined by the FDS Model. Refer to Section 8.3.4.1 for detection activation times. 34 seconds is the time in which the first detector activates in the basement level.

Notification time (t_n) = 10s,

Considering that the design fire has smoke detectors activating before the sprinklers, notification time is based on NFPA 72 Section 10.12.1.

- Section 10.12.1: "Actuation of alarm notification appliances or emergency voice communications, emergency control functions, and annunciation at the protected premises shall occur within 10 seconds after the activation of an initiating device."

Therefore 10 seconds considers the maximum allowed duration before actuation of alarm notification.

Pre-movement time (t_{pre}) = 55 s

Pre-movement encompasses the time taken for occupants to respond to the building alarm and begin movement. Since the [redacted] building is equipped with a full fire alarm system with notification appliances located throughout, the pre-movement time is expected to be low. Based on data available from the SFPE handbook, a wide range of premovement times were provided for office spaces (Gwynne & Boyce, 2016). Table 64.5 from the SFPE Handbook included premovement time for a 6-story office building (Sharma), which is similar to the [redacted] Building. Premovement time from this recorded data ranged from 10 seconds to 55 seconds. Therefore, a conversative pre-movement value of 55 seconds is used to be representative of a diverse population. Refer to Figure 33 for a depiction of the data from Table 64.5.

Table 64.5 Pre-evacuation data—business occupancy

			Procedure			Sample		Results (sec)
Occupancy	Source	Observational conditions (L: location, N: nature, SC: spatial configuration, P: participants, E: environment, V: variable)	Strategy	Staff (designated)	Technology	Collection method	Size	Mean S.D., range
Business	Gwynne et al. [47]	L: USA N: UE1–2 SC: 14 floors P: 825 evacuees: 44 % F, 56 % M, 1 % impaired V: impact of procedure (UE1–2)	Phased UE1: local alarm UE2: general alarm	2–4/floor	AL, PV (duration 15–20s) to 3 floors followed by general alarm Tone alert	Video, observer	UE1: 132 UE2: 150	[74.0 –, 23–152][a] [–, 5–173][a]
	Sharma et al. [48]	L: UK N:UE, pre-2009 SC:6 floors P:- E:- V: performance	Full	–	–	Video, survey	19	28 [11, 10–55]

Figure 33. SFPE Table 64.5 Pre-Evacuation Data Mid-Rise Building

The building occupants are expected to be awake and are expected to move quickly to the nearest exit without significant delay.

Travel time (t_{trav}):

The Pathfinder egress model utilizes "SFPE Mode" which automatically implements the flow model referenced in the SFPE Handbook 5th Edition (Gwynne & Rosenbaum, 2016), where walking speeds are automatically determined by occupant density within each room and flow through doors is controlled by door width. Travel speeds are understood to be approximately 3.9 ft/s (1.19 m/s), The SFPE Handbook typically recommends a maximum unimpeded walking speed of 1.19 m/s or 235 ft/min for this type of occupant density (Gwynne & Rosenbaum, 2016).

Flow time (t_{flow}):

- Flow rate through stair doors = 24.0 person/min/ft (1.3 persons/s/m)
- Flow rate downstairs = 18.5 persons/min/ft (0.94 persons/s/m)
- The SFPE Handbook typically recommends these maximum flow rates for doors and stairs having a riser and tread of 7 and 11 inches, respectively (Gwynne & Rosenbaum, 2016).

8.3.2.2.4 Egress Model Assumptions

The following inputs and assumptions are included in the model:

- The exact number of occupants is randomly distributed in their respective spaces in the model.

- Occupants within the model travel to their closest exit, unless queuing occurs where the occupants then are able to change their egress path to another egress path within the room to distribute the exit flow.
- Stair riser height and tread depth are 7 inches and 11 inches, respectively, based on CBC Section 1009.7.2. This relates to the slowest stair/tread configuration, based on the maximum permitted riser height and minimum permitted tread depth as permitted by the CBC (Gwynne & Rosenbaum, 2016).
- Paths of travel to exits, exit path width, visibility of exits and availability of exits are assumed to be maintained as required per Chapter 10. Section 1015.2 of CBC states that exits shall be unobstructed and their availability obvious. Section 1011.1 states that exits signs shall be readily visible from any direction of travel. Exit signage and means of egress illumination are assumed to comply with Chapter 10 of the CBC.

8.3.2.2.5 Occupant Loads

Refer to Table 5 for the occupant loads assigned to each floor within the model, which have been calculated according to CBC Table 1004.1.2. Additionally, Section 11 contains the egress floor plans and the corresponding calculations.

8.3.2.2.6 Means of Egress Strategy

A summary of the egress strategy from each analyzed level is provided below based on the latest available floor plans provided by the architectural team. Refer to Section 11 for the egress floor plans.

<u>Basement, 2nd, 3rd, 4th, 5th, and 6th Floor:</u>

Interior exit stairs: There are two 2-hr fire rated interior exits stairways located on the eastern and western corners of the building that serve each floor of the building (excluding the ground floor). These stairs discharge on the ground floor.

<u>Ground Floor:</u>

Exit Discharge: There are two exit discharge doors located on the eastern and western corners of the building that occupants on the ground floor utilize to egress from the building.

8.3.2.2.7 Egress Components and Inputs

The clear egress widths of the following egress components are:

- Basement to 6th Floor interior “Exit Stair 1” = 45 in clear width
- Basement to 6th Floor interior “Exit Stair 1” = = 34 in clear width
- Basement to 6th Floor interior “Exit Stair 2” = 48 in clear width
- Basement to 6th Floor interior “Exit Stair 2” = = 34 in clear width
- Ground Floor Egress/Exit Discharge Doors (stair to the exterior) = 34 in clear width

8.3.2.2.8 Evacuation Time

This section presents the results of the evacuation modeling. Results for the scenario are summarized in Table 32. These values represent only the modeled travel time, i.e., walking time as well as queuing time. The total RSET value is determined when all occupants on all floors reach an exit stairway including the detection time, pre-movement time evacuation time and safety factor, which is evaluated in Table 33.

The occupants on the 5th floor required the most amount of time to reach an interior exit stair. Therefore, 629 seconds will be considered the evacuation time excluding a safety factor. It is also understood that the 5th floor has a longer evacuation time despite having fewer occupants (when compared to the 6th floor) due to congestion in the stairway.

Table 32. Egress Modelling Results – Evacuation Time: Travel Time (t_{travel}) + Flow Time (t_{flow})

Space	Clearance Time
6th Floor	9.4 min (566 s) *
5th Floor	10.5 min (629 s) *
4th Floor	9.7 min (583 s) *
3rd Floor	6.6 min (442 s) *
2nd Floor	7.4 min (265 s) *
Ground Floor	3.9 min (233 s) *
Basement	1.8 min (110 s) *

* Based on last person on each floor entering an exit stairway Refer to Section 16

Refer to Section 16 for images displaying the results of Pathfinder modeling for each floor. These images depict the pre-evacuation conditions (zero seconds) and the time required for all occupants on each floor to reach an exit.

8.3.2.2.9 RSET Calculations

As summarized in Section 8.3.2.2.1, the RSET for the building is based on the detection, notification, pre-movement and travel time. The total RSET value for the design scenario, including the detection time and pre-movement time are included in Table 33. As previously mentioned, the travel is based on the time when all occupants on these six floors enter an exit stairway, which is 629 seconds.

Egress model inputs and assumptions are provided below:

Detection time (t_d): is based on smoke detector activation time for the modeled design fire scenario described in Section 8.3.2.2.3 of this report.
Notification time (t_n) = 10 s,
Pre-movement time (t_{pre}) = 60 s
Evacuation time (t_{evac})**: travel time** (t_{trav}) + **flow time** (t_{flow}): is based on the results of the egress model simulations reported in Table 32.
RSET: is the sum of the detection time, notification time, pre-movement time, travel time, and flow time per Equation 1 in Section 8.3.2.2.1 A 1.5x safety factor is included in the evacuation/movement time (travel and flow time) per 2018 IBC Code Commentary Section 909.8.1.

$$RSET = (t_d + t_n + t_{pre}) + 1.5 \times (t_{pre} + t_{evac})$$

Table 33. Required Safe Evacuation Time (RSET)

Component	RSET Calculation
t_d	34 Seconds

Component	RSET Calculation
t_n	10 Seconds
t_{pre}	55 Seconds
$\boldsymbol{t_{evac}}$	629 seconds x 1.5 S.F. = 944 Seconds
Calculated RSET	1043 Seconds (~18 minutes)

After applying the safety factor, the RSET (Required Safe Egress Time) for the [redacted] Building is determined to be 18 minutes.

8.3.3 Available Safe Egress Time

8.3.3.1 Design Fire Scenario

This analysis intends to utilize a design fire based on the maximum potential combustible fuel load present within the office space. However, based on available experimental data from the 2016 SFPE Handbook and other online resources including the NIST Fire Calorimetry Database, there are wide range of experimental data offering heat release rate measurements for potential fuel loads within an office space. For instance, in the SFPE handbook, Figure 26.69 presents data on the HRR of two office chairs. According to the more conservative test results, the peak HRR for these chairs is approximately 500 kW, and it takes around 700 seconds for the HRR to reach that level. Figure 26.70 in the SFPE handbook, on the other hand, presents the HRR data for workstations. In one test from this experiment, it takes approximately 700 seconds for the HRR to reach a level of 2,500 kW. Given the diverse range of available data and the uncertainty surrounding the specific fuel loads within the [redacted] Building, it is proposed that a fire growth rate is used as the basis for the HRR of the design fire scenario.

The design fire is assumed to be accidental in nature and not contain any accelerants. The fire growth rate for these design fires will vary depending on the configuration and material of the combustible items. Therefore, a worst credible design fire size must be considered.

Fire growth rates are often designated as slow, medium, fast or ultra-fast, based upon on how quickly an item burns, in relation to other items. Figure 34 compares various standard fire growth rates. The design fire is assumed to follow a fast t^2 growth rate where the heat release rate (HRR) is proportional to a coefficient multiplied by time squared. Test data detailing fire growth rates and peak heat release rates for various materials and fuel packages are detailed in NFPA 72.

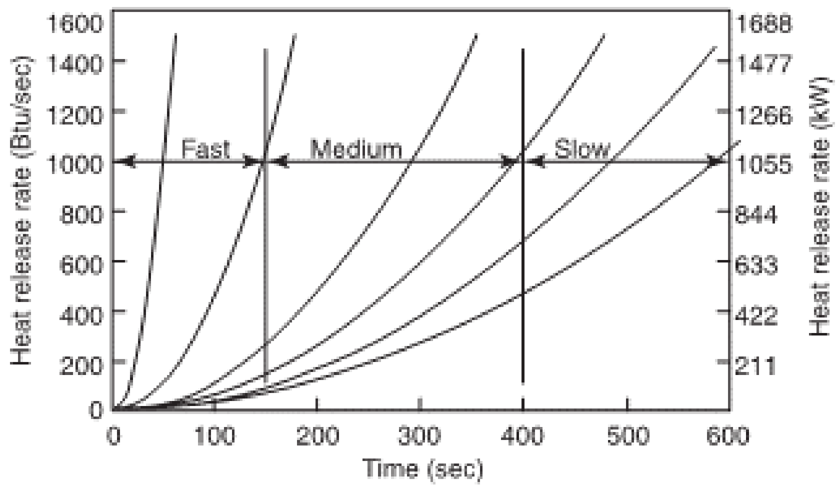

Figure 34. Heat Release Rate for Fire Growth - NFPA 72 Figure B.2.3.2.6.2

The fire growth is defined as:

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

Where:

$\dot{Q}$: Heat Release Rate (HRR) [kW]

α: fire growth rate coefficient [kW s^{-2}]

t: time [s]

In the context of this design fire, a fast fire growth rate should be deemed appropriate. This conservative approach considers the immediate ramp-up time which assumes that the fire intensifies rapidly. Most available experimental data on HRR involving office fuel loads often includes an initial incipient stage where the fire grows slowly, typically taking anywhere around 5 to 10 minutes for significant growth to occur. It should be noted that from previous experience, the San Francisco Fire Department has accepted a fast fire growth rate for design fires involving office spaces.

In addition, the design fire is also sprinkler controlled, which means that if any sprinkler head within the model is activated during the simulation, the HRR will remain constant at its current level. For instance, let's consider a 20-minute simulation where, at the 10-minute mark, the HRR of the design fire is 1000 kW, and a sprinkler is activated. In this case, the design fire will maintain the same HRR of 1000 kW for the remaining 10 minutes of the simulation. Refer to Table 34 for a summary of the design fire and Figure 35 for the location of this design fire.

Table 34. Summary of Proposed Design Fires

Scenario	Location	Fire Size
A	Basement Atrium	**Fast Growth Fire, sprinkler controlled** - The fire is a fast-growth fire. Sprinkler activation is anticipated to occur where the HRR will be maintained at that level until the end of the simulation. HRR decay is not modelled, but rather conservatively assumed to maintain the HRR at sprinkler activation.

[redacted]

Figure 35 - Basement Atrium Fire Location

For other inputs, including yield of fire products and chemicals, a Douglas Fir Christmas Tree was chosen as the basis for the fuel package. In atrium scenarios, Christmas trees are frequently employed to simulate a high fuel load that is not typically present under normal circumstances. Refer to Figure 36 for this data from the SFPE Handbook.

Table A.39 (continued)

Material	ΔH_T (kJ/g)	y_{CO_2} (g/g)	y_{CO} (g/g)	y_{ch} (g/g)	y_S (g/g)	ΔH_{ch} (kJ/g)	ΔH_{con} (kJ/g)	ΔH_{rad} (kJ/g)
2,6-dichlorobenzonitrile (dichlobenil) ($C_7H_3NCl_2$)	17.8	0.39	0.068	–	–	4.3	–	–
Diuron ($C_9H_{10}ON_2Cl_2$)	20.3	0.76	0.080	–	0.159	10.2	7.7	2.5
Trifluoromethylbenzene ($C_6H_5CF_3$)	18.7	1.19	0.069	–	0.185	10.8	5.1	5.7
Metatrifluoromethylphenylacetonitrile ($C_9H_6NF_3$)	16.0	0.89	0.058	–	0.168	7.3	4.0	3.3
Tetramethylthiurammonosulfide ($C_6H_{12}N_2S_3$)	22.6	1.06	0.041	–	–	19.6	–	–
Methylthiopropionylaldehyde (C_4H_8OS)	25.0	1.62	0.001	–	0.005	23.8	18.8	5.0
Pesticides								
2,4-D acid (herbicide, $C_8H_6O_3Cl_2$)	11.5	0.50	0.074	–	0.163	4.5	3.0	1.5
Mancozeb ($(C_4H_6N_2S_4Mn)_iZn_{0.4}$)	14.0	0.50	–	–	–	9.5	–	–
Folpel ($C_9H_4O_2NSCl_3$)	9.1	0.37	0.072	–	0.205	3.6	–	–
Chlorfenvinphos ($C_{12}H_{24}O_4Cl_3P$)	18.0	0.43	0.011	–	0.288	7.7	–	–
Chlormephos ($C_5H_{12}O_2S_2ClP$)	19.1	0.51	0.075	–	0.055	13.9	–	–
Natural materials								
Tissue paper	–	–	–	–	–	11.4	6.7	4.7
Newspaper	–	–	–	–	–	14.4	–	–
Wood (red oak)	17.1	1.27	0.004	0.001	0.015	12.4	7.8	4.6
Wood (Douglas fir)	16.4	1.31	0.004	0.001	–	13.0	8.1	4.9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 36. SFPE Handbook Douglas-Fire Yield Data

8.3.3.2 Methodology

As discussed in Section 8.3, fire and smoke modeling were performed using Fire Dynamics Simulator (FDS) to evaluate the performance of the smoke control system. FDS has been designed specifically for fire safety applications by the National Institute of Standards and Technology (NIST)[1]. FDS enables the designer to build a three-dimensional (3-D) model of the building and simulate the various design fire scenarios in order to evaluate the performance of the building from a fire safety perspective and measure the hazardous products of combustion that could impact building occupants.

The objective of this modeling was to determine the Available Safe Egress Time (ASET) for occupants evacuating the building. ASET is determined when the acceptance criteria listed in Table 37 is reached.

An evacuation assessment was also performed and summarized in Section 8.3.2 to determine the Required Safe Egress Time (RSET) for occupants exiting the building. The overall objective of the atrium analysis is to determine if buildings occupants have enough time to evacuate the building (RSET) prior to the condition becoming untenable (ASET). Specifically, the focus is on the deployment of the fire-rated shutters to assess whether the conditions on the levels above the fire, as well as the areas remote from the fire, will remain safe and suitable for the evacuation of building occupants.

8.3.3.2.1 Model Inputs

Inputs and values into the FDS model are provided in Table 35.

Table 35. FDS Model Input Parameters

Parameter	Quality/Value	Discussion
Soot yield	0.015 g/g	A soot yield value of 0.015 g/g is used for Douglas Fir. The value is from the SFPE Handbook Table A.39
CO Yield	0.004 g/g	A CO value of 0.004 g/g is used for Douglas Fir. The value is from the SFPE Handbook Table A.39.
CO_2 Yield	1.31 g/g	A CO_2 value of 1.31 g/g is used for Douglas Fir. The value is from the SFPE Handbook Table A.39.
Chemical Composition (Douglas Fir)	$CH_{1.7}O_{0.074}N_{0.002}$	The chemical composition of Douglas Fir is from the SFPE Handbook Table A.38
Location of fire above floor	0.5 m	In FDS, the base of the fire will be located a height of 0.5m above the ground in the basement to maximize entrainment of air into the plume.
Size of Burner	1m x 1m x 0.5m	In FDS, the burner is 1 m in length, 1 m in the width, and 0.5 m in height
Fire growth rate	$Q = 0.0469*t^2$	A fast-growth fire is utilized to conservatively account for a wide range of fuels.

[1] The documentation including validation and verification documentation can be found here: https://pages.nist.gov/fds-smv/manuals.html

Parameter	Quality/Value	Discussion
Fire cell size	0.25 m	The entire model's grid cells have a size of 0.25m. Fire model grid cell size was verified in Section 8.3.3.2.3.
Visibility factor	8	The building will be provided with light-emitting exit signs throughout which enables the visibility factor to be increased from 3 for light-reflective signs to 8 for light-emitting signs (McGratthan, 2017)
Ambient Temperature	20°C	The ambient temperature of the model is assumed to be 20°C.

8.3.3.2.2 FDS Model Assumptions

The following inputs and assumptions are also included in the model:

- The FDS model is based on the floor plans from Section 2.3.
- Floor to ceiling heights: Basement, Level 1, and Level 2 will be modeled with consistent floor to ceiling height of 3m (10 ft) on each level. These correspond to the most prevalent floor to ceiling heights within the areas open to the atrium and they also enable an exact match to the fire cell grid.
- Only major architectural features that affect smoke movement and filling are incorporated into the model.
- Rooms separated from the atrium are modeled as solid obstructions (i.e., smoke is not able to disperse into rooms), resulting in reduced smoke reservoir volume as smoke is contained to the egress circulation areas (exit access) and hence increased impact on occupant evacuation.
- The building is modeled as airtight.
- Inert material and surface thermal properties are applied to obstructions in the FDS model.
- Simulation time: 20 minutes based on the RSET simulation.

8.3.3.2.3 Field Cell Verification

FDS is a Computational Fluid Dynamics (CFD) model. The program uses a three-dimensional grid to split the building up into thousands of grid cells. The program then performs fluid flow and thermodynamic equations on each cell. The fidelity of the model is therefore dependent on the size of the grid cells used. The grid size is modelled with 0.25 m grid cells throughout.

For fire applications, the accuracy of the model has been found to be a function of the characteristic fire diameter, D*, divided by the mesh cell size, x, across the fire. It is important to have a fine enough mesh in the near field, so as to capture the relevant fire phenomena.

The calculation of D* is shown below (McGrattan et al., 2017):

$$D^* = \left(\frac{\dot{Q}}{\rho_\infty c_p T_\infty \sqrt{g}} \right)^{\frac{2}{5}}$$

, and where $D^*/x > 4$

Table 36. D* parameters

Parameter	Symbol	Value	Units
Ambient Temperature	T_∞	293	K
Density of Air	ρ_∞	1.2	kg/m^3

Parameter	Symbol	Value	Units
Specific Heat of Air	C_p	1	kJ/ (kg K)
Acceleration Due to Gravity	g	9.8	m/s^2
Cell Dimension in X Direction	x	0.25	m

8.3.3.3 Tenability Criteria

The acceptance criteria, detailed below, were established for the modeling tenability analyses to limit occupant exposure to potentially untenable or hazardous conditions due to fire. The metrics for assessing tenable conditions are listed below and measured 2m (approximately 6ft) above the finished floor level along egress pathways (CBC 909.8.1).

8.3.3.3.1 Smoke Layer

Per CBC 909.8.1, "The height of the lowest horizontal surface of the smoke layer interface shall be maintained not less than 6 ft above a walking surface that forms a portion of a required egress system within the smoke zone. According to the prescriptive requirements of the Code, in order to meet the tenability criteria, the smoke layer must be kept at a minimum height of 6 feet.

8.3.3.3.2 Visibility

The building is primarily a business occupancy with some assembly spaces and thus, it may at any time contain a mix of occupants familiar and unfamiliar with the building. However, it is expected that a majority of the people, especially on the office floors, work in the building and have a working knowledge of the means of egress.

The issue of visibility and wayfinding is of critical importance because occupants need a clear and obvious path to an exit. During a fire, smoke can obscure a person's vision and impede their ability to safely navigate to an exit. During the course of a fire event the building environment may become more difficult to navigate due to reduced visibility in the egress paths. Thus, maintaining acceptable visibility while occupants are traveling to an exit is essential. Once occupants arrive at the exit, it becomes even more critical to ensure that occupants are not exposed to untenable heat and toxic gases.

Research has shown that occupants unfamiliar with their surroundings can egress safely in an environment where visibility is as low as 30 feet (10 meters) (Purser, 2016). Visibility is evaluated on the basis of 30 feet, with the exception where occupants are queued at an exit. Once occupants have found an exit and are waiting to enter the exit, 16 feet (5 meters) visibility is acceptable (Noren & Rosberg, 2014). In order to enhance visibility during an emergency event, light-emitting exit signs are provided throughout the building rather than light-reflecting exit signs. Therefore, the calculations are based on light emitting signs.

8.3.3.3.3 Heat Exposure

Thermal exposure can manifest itself in multiple ways, causing injury or death, by heat stroke, surface burns, or respiratory burns. For the purposes of the smoke analysis system the most restrictive injury is by means of a respiratory burn. Burning to the respiratory tract may occur on inhalation of air above 140°F (60°C) when that air is saturated with water (Purser & McAllister, 2016). The value of 140°F is used to evaluate whether the occupied portions of the floor remain tenable for the duration of the evacuation time.

8.3.3.3.4 Carbon Monoxide Dosing

Carbon monoxide (CO) is always produced in a real fire and the amount to which occupants are exposed to carbon monoxide is determined by both the concentration of the gas as well as the amount of time over which the occupant is exposed, referred to as the dose (Purser, 2008). The limit applied to the analysis is the Immediately Dangerous to Life or Health (IDLH) concentration established by NIOSH of 1,200 ppm (NIOSH, 2012). NIOSH adopted this concentration as the IDLH number based on studies by (Patty, 1963) and (Henderson, 1921) who found that a one-hour exposure to a concentration of 1,200 ppm of CO would cause unpleasant, but no dangerous symptoms.

Based upon the above fire engineering assessment, Table 37 summarizes the applicable considerations and associated acceptance criteria for the smoke control analysis. For the design fire scenarios, tenability criteria will be measured and maintained in all areas remote from the area of fire origin. This includes levels above and below the floor of fire origin, as well as remote areas on the level of fire origin. Occupants beyond the area of fire origin may be unaware of the gravity of the emergency and the fire location. It is imperative that occupants are provided enough time to safely evacuate. In the area of fire origin where a heavy amount of smoke is being produced, it is impossible to maintain tenable conditions throughout the entire time that that building is evacuating. Once a fire initiates, occupants in the area of fire origin will be the first people to either see the fire, smell the smoke or hear that there is an emergency, and they are expected to quickly evacuate to an exit or areas beyond the fire origin because of the immediate danger.

Table 37. Acceptance Criteria for the ASET Analysis

Design Goal	Tenability Criteria	Acceptance Criteria Limit	References
Occupant Tenability (ASET > RSET)	Measuring height	Tenability is measured 6 feet (2m) above floor level	
	Smoke Layer	6 feet (approximately 2m) above walking surface.	CBC Section 909.8.1
	Visibility	32 feet (10 m) for floor; 16 feet (5 meters) at an exit.	SFPE Handbook (Purser & McAllister, 2016, Table 63.5); (Noren & Rosberg, 2014)
	Heat exposure	140°F (60°C)	SFPE Handbook (Purser & McAllister, 2016, SFPE Chapter 63, page 2381)
	Toxicity	Carbon monoxide (CO) 1,200ppm	NIOSH (National Institute of Occupant Safety and Health)

8.3.4 Results

8.3.4.1 Smoke Detector Activation

To ensure timely detection and early warning of a fire to building occupants, smoke detection is essential. In this model, photoelectric smoke detectors have been placed around the atrium on all levels based on the fire alarm plans provided in Section 15.1. A total of four smoke detectors around the atrium in the basement have inputted into the model, which will activate once the obscuration level reaches 3.24 %/m. Refer to Table 38 for smoke detector activation times.

Table 38. Smoke Detector Activation Times

Floor	Smoke Detector Location	Activation Time
Basement	North	44 Seconds
Basement	South	82 Seconds
Basement	East	34 Seconds
Basement	West	94 Seconds

The first smoke detector that activates at 34 seconds is located on the east side of the atrium. The last detector to activate at 94 seconds is located at the west side of the atrium. For the purposes of determining a time of detection (t_d) for the RSET analysis, 34 seconds will be used, which corresponds to the time taken for the first smoke detector to activate.

8.3.4.2 Fire-Rated Shutter Activation

As previously discussed, the deployment of the fire-rated shutters is vital to assess whether the conditions on the levels above the fire, as well as the areas remote from the fire, will remain safe and suitable for the evacuation of building occupants. In the [redacted] building, the fire-rated shutters are designed to activate in response to a fire alarm condition. Therefore, when a smoke detector or sprinkler head is triggered, the fire-rated shutters will activate. However, it is important to recognize that the fire-rated shutters require a certain amount of time to fully deploy and Per NFPA 80, "the average closing speed must not exceed 24 inches per second and must be at least 6 inches per second." Therefore, to account for the time needed for the fire-rated shutters to activate, a conservative delay of 30 seconds has been included in the control function within the model. Considering that the first initiating device to activate within the model is a smoke detector at 34 seconds, the fire-rated shutters will not fully deploy until 64 seconds. Refer to Figure 37 for an image of the fire shutter deployment (in purple) at 64 seconds.

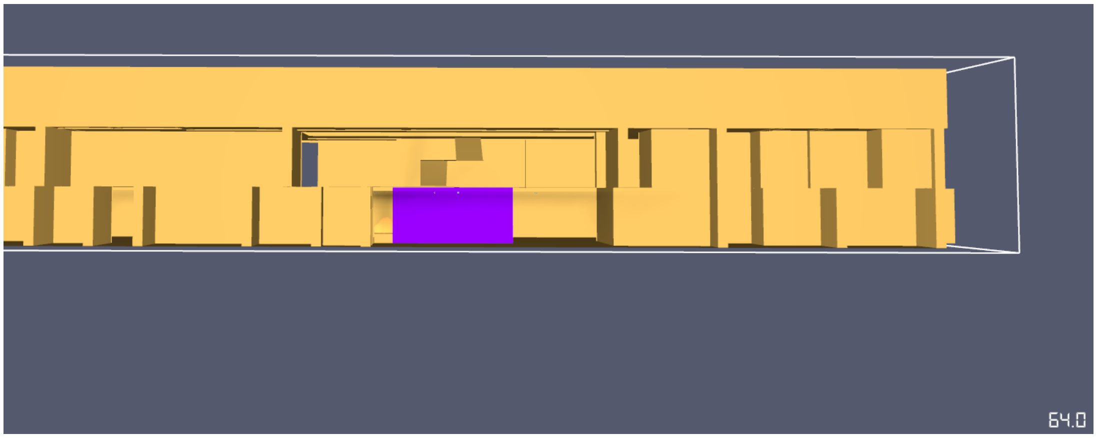

Figure 37. Fire-Rated Shutter Deployment

8.3.4.3 Sprinkler Activation

Sprinklers are vital for controlling fires. In this model, light-hazard sprinklers have been placed around the atrium on all levels based on the contractor sprinkler plans provided in Section 14.1 of this report. The sprinklers have an activation temperature of 68°C and a conservative RTI of 50. A total of 6 sprinklers have been inputted into the model and will activate once temperature reaches 68°C. Refer to Table 39 for sprinkler activation times.

Table 39. Sprinkler Activation Times

Floor	Tag	Activation Time
Basement	N01	220 s
Basement	N02	124 s
Basement	N03	186 s
Basement	S01	110 s
Basement	S02	172 s
Basement	S03	156 s

The first sprinkler to activate, at 110 seconds. All sprinklers included into the model in the eventually activated, which is attributed to the formation of a ceiling jet plume in the open office area.

In should be noted that the design fire is also sprinkler controlled, which means that if any sprinkler head within the model is activated during the simulation, the HRR will remain constant at its current level. Therefore, at 100 seconds, the HRR of the fire at that time (~550 kW) is maintained until the end of the simulation. Refer to Figure 38 for more details.

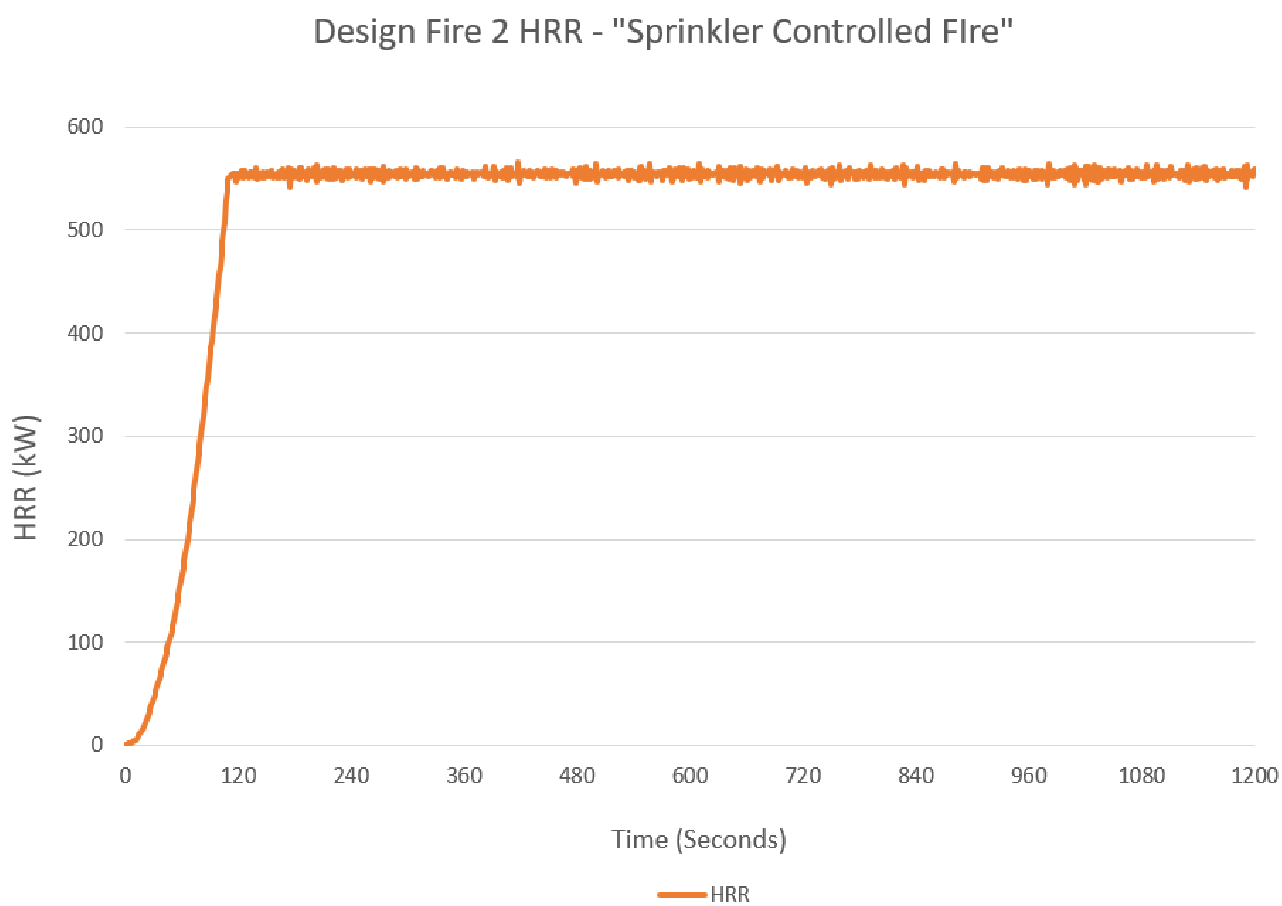

Figure 38 – Design Fire HRR – 'Sprinkler Controlled.'

8.3.4.4 ASET vs. RSET Results

Based on the analysis performed, in the event of a major fire at the base of the atrium, due to the fire-rated shutter deployment, the floors above and areas remote from the fire will be able to maintain tenable conditions for occupants to evacuate. The results from the fire and smoke modelling simulations of the design fire scenarios are summarized in Table 40. All smoke spread simulations were ran for 20 minutes (1,200s), which is approximately the calculated RSET with the 1.5 safety factory included.

Table 40. Fire & Smoke Modelling Results Summary – ASET Values

RSET	Basement	Level 1	Level 2
	ASET		
1043s	< 1043s	> 1043s	> 1043s

Due to the deployment of the fire-rated shutters, the 1st and 2nd floors of the building were able to maintain tenable conditions during the design fire. However, due to the proximity to the fire source, it was not possible to maintain tenable conditions in the basement.

Table 41 provides a summary of the tenability criteria results. The 1st and 2nd floors were able to maintain tenable conditions based on the criteria specified in Section 8.3.3.3. In the basement, tenable conditions were not maintained due to the fire's proximity, except for carbon monoxide (CO) concentrations. The low CO yield of Douglas Fir allowed levels to remain acceptable despite other factors compromising overall tenability.

Table 41. Tenability Results Summary

Smoke Layer			Visibility			Temperature			CO Concentration		
B	L1	L2	B	L1	L2	B	L1	L2	B	L1	L2
X	✓	✓	X	✓	✓	X	✓	✓	✓	✓	✓

8.3.4.5 FDS Modeling-Figures

The following graphs are presented for the atrium fire:

- Figure 39– shows an image of the smoke layer from the basement level to the second floor. This image demonstrates that the basement level does not maintain tenable conditions, while the 1st floor and 2nd floor do maintain acceptable conditions.
- Figure 40 – shows an image of the visibility from the basement level to the second floor. This image demonstrates that the basement level does not maintain tenable conditions, while the 1st floor and 2nd floor do maintain acceptable conditions.
- Figure 41– shows an image of the temperature from the basement level to the second floor. This image demonstrates that the basement level does not maintain tenable conditions, while the 1st floor and 2nd floor do maintain acceptable conditions.
- Figure 42– shows an image of the CO toxicity from the basement level to the second floor. This image demonstrates that all floors maintain tenable conditions due to the low CO yield of Douglas Fir.

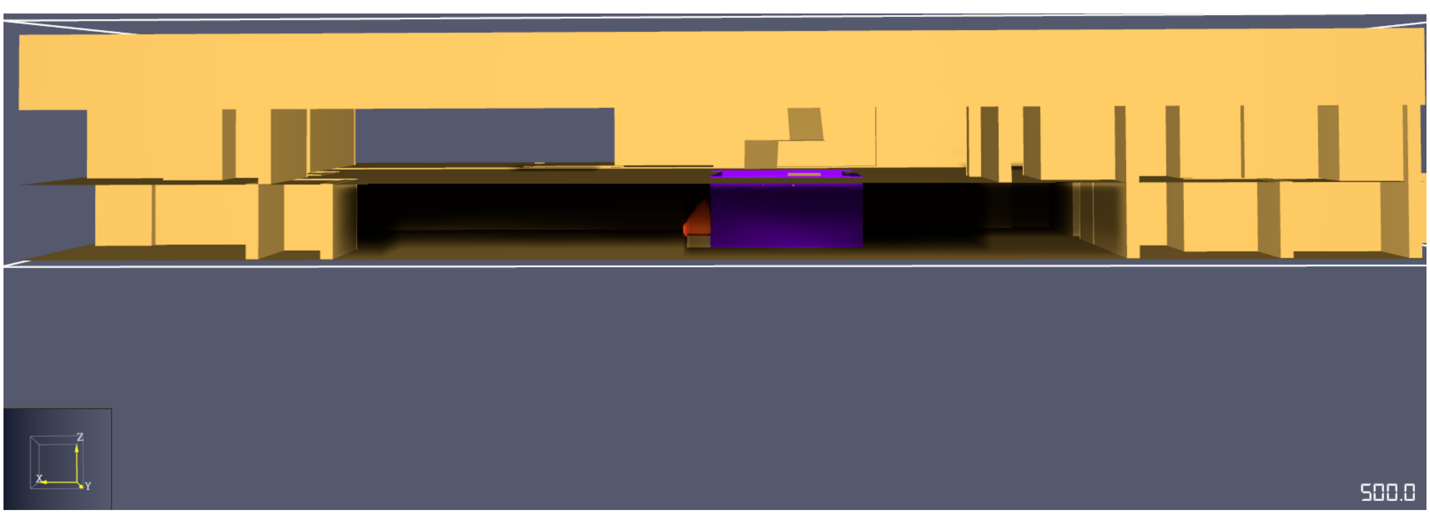

Figure 39. Section view of the smoke layer in the basement level. Image taken at 500 Seconds.

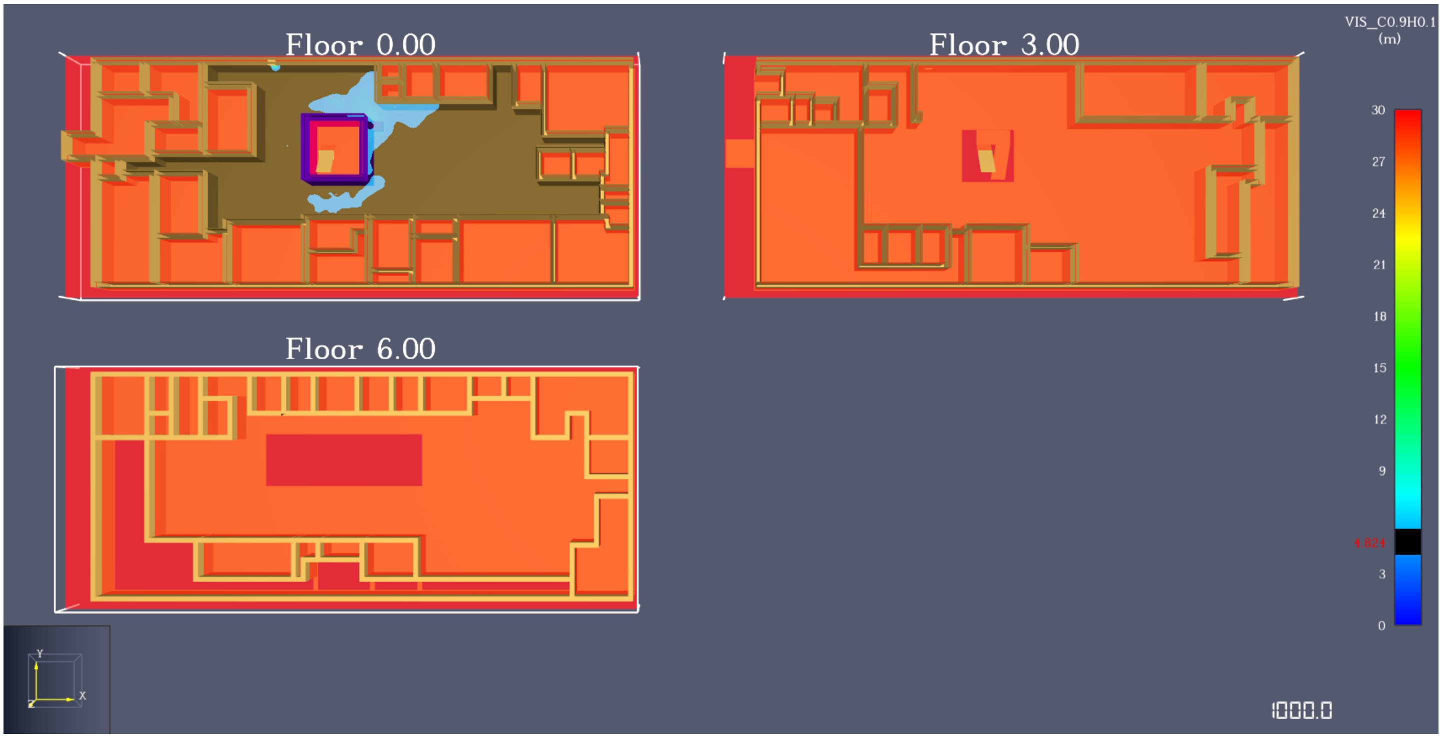

Figure 40. Section view of the visibility throughout the building. Image taken at 1000 Seconds.

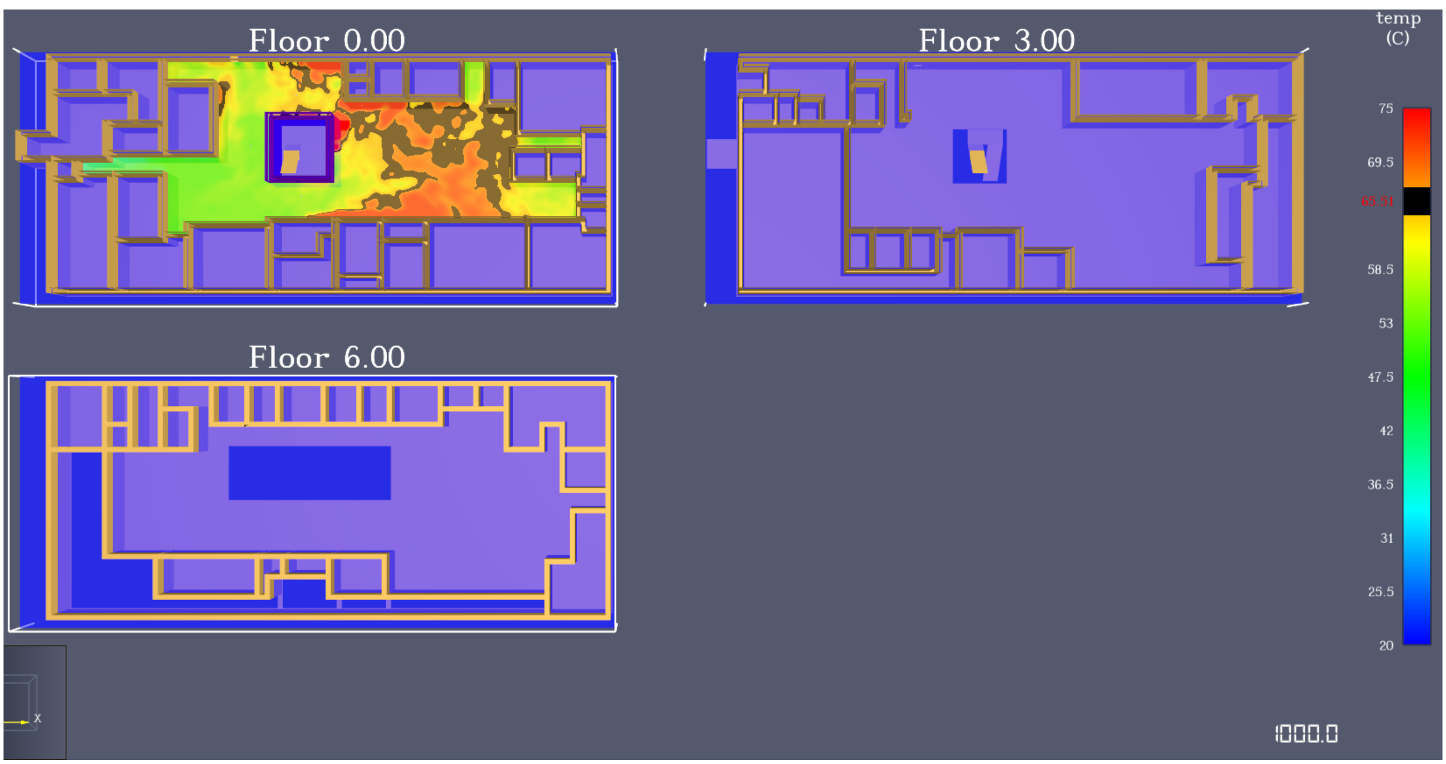

Figure 41. Section view of the Temperature throughout the building. Image taken at 1000 Seconds.

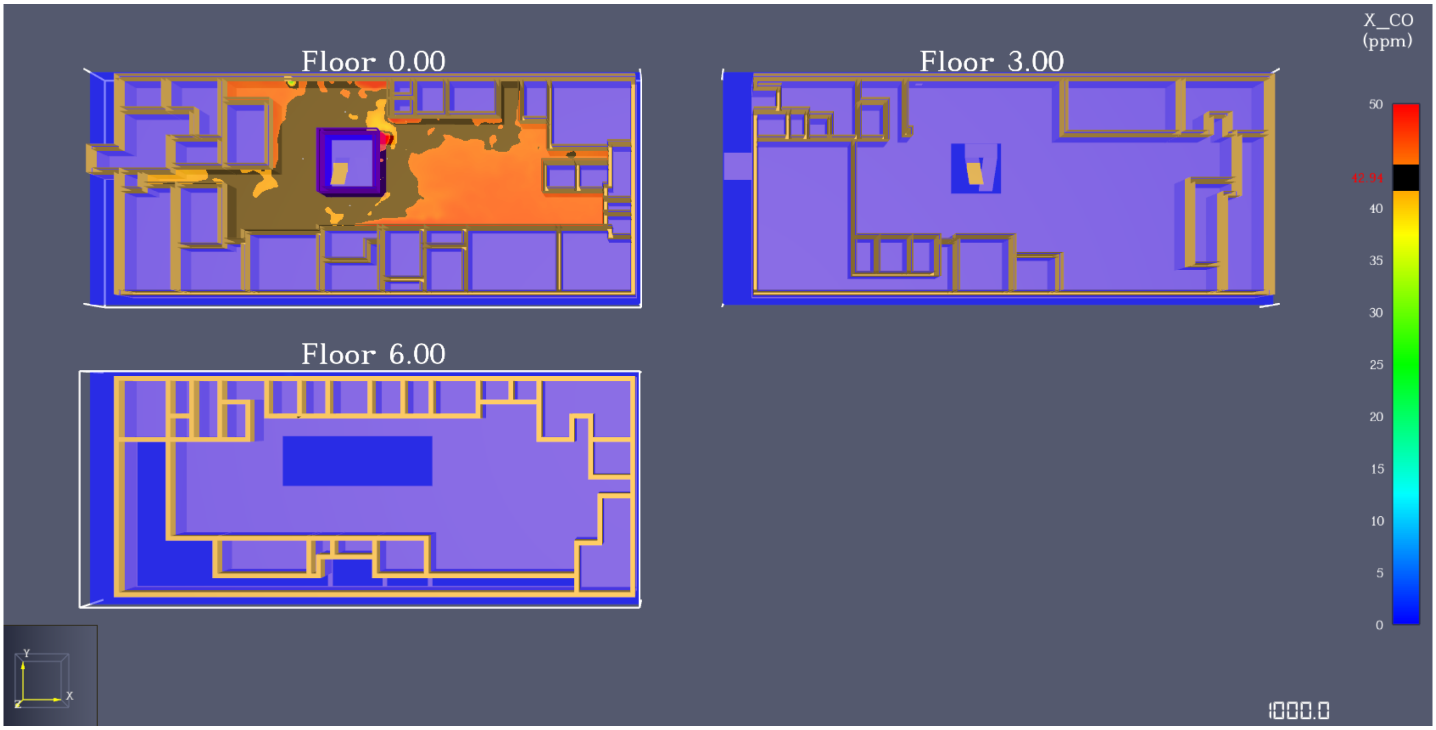

Figure 42. Section view of CO Toxicity throughout the building. Image taken at 1000 Seconds.

9 SUMMARY AND RECOMMENDATIONS

When the [redacted] building was renovated in 2015, it became a modern office building with unique architectural features and design which sets it apart from other structures with similar occupancies. The building was designed to comply with the prescriptive code as originally mandated. However, due to its location in San Francisco, additional safety measures were implemented in accordance with local amendments to ensure the building has a higher level of safety for its occupants. The building's design incorporates a range of safety features that go beyond the minimum requirements of the prescriptive codes. For example, it includes two-way communication systems, stringent fire alarm system requirements, and overengineered fire protection systems, among other measures.

From the analysis performed in this report regarding egress design, fire alarm system, communication systems, fire suppression system, structural and construction design, smoke control, and flammability requirements, the [redacted] building complies with the prescriptive requirements of the Code.

The first performance-based assessment regarding the I.T. room determined that flashover is unlikely to occur, the smoke detector would activate at approximately 674 seconds, and the sprinkler would activate at approximately 744 seconds after the onset of the fire. The results also indicated that secondary ignition does occur. These results suggest that the room is vulnerable to a fire scenario that could significantly impact the operations of the business and safety of occupants. To mitigate this risk, it is recommended that a fire protection system, such as a clean agent halon system or CO2 system, be installed to suppress fires and minimize equipment damage. Additionally, regular equipment maintenance performed by qualified professionals should be conducted to minimize the risk of ignition. The room should also be regularly inspected to ensure that the space does not contain large amounts of combustible materials to reduce potential fuel sources.

The second fire scenario involves the atrium, which connects the basement level to the second floor. The scenario was assessed using Fire Dynamic Simulator (FDS) and Pathfinder to determine the Available Safe Egress Time (ASET) and Required Safe Egress Time (RSET). The ASET analysis specifically focused on the deployment of the fire-rated shutters to assess whether the conditions on the levels above the fire, as well as the areas remote from the fire, will remain safe and suitable for the evacuation of building occupants.

Pathfinder was utilized to determine the RSET, and the results indicated a time of 1034 seconds (~18 minutes) which takes into account a 1.5x safety factor. ASET was calculated by FDS, which simulated and assessed various tenability criteria, including smoke layer descent, heat exposure, visibility, and carbon monoxide dosing. The results indicated that the ASET could be maintained for 18 minutes for floors and areas remote from the fire. This is primarily due to the activation of fire-rated shutters, which compartmentalized the basement from the floors above.

After conducting design fire evaluations for this building, several recommendations are made to enhance the safety of the occupants. Firstly, it is recommended that the building's ownership or management group avoid placing any items around the atrium to reduce the risk of potential fuel sources and hazards spreading to other floors. It is also crucial for the building maintenance team and any outside contractual maintenance companies to conduct regular inspection, testing, and maintenance on all fire protection systems to ensure that all life safety features are in normal working condition. Finally, an impractical solution would be the installation of a smoke exhaust system for the atrium to prevent the accumulation of smoke and limit its spread to other parts of the building in the event that the fire-rated shutters failed. While this option may not be feasible in an existing building, a smoke exhaust system can still help maintain a safe environment, particularly away from the fire origin.

10 REFERENCES

1) "Cornertest1." Edited by Bundy, *NIST*, 14 May 2021, https://www.nist.gov/el/fcd/cross-laminated-timber-compartments/cornertest1.
2) Bundy. "Fire Barriers in Full-Scale Chair Mock-Ups." *NIST*, 14 July 2021, https://www.nist.gov/el/fcd/fire-barriers-full-scale-chair-mock-ups.
3) Society of Fire Protection Engineers (2016). *SFPE Handbook of Fire Protection Engineering, 5th Edition.*

4) Gwynne, Steven, M. V. & Rosenbaum, Eric R. (2016). Employing the Hydraulic Model in Assessing Emergency Movement, SFPE Handbook of Fire Protection Engineering 5th Edition, Chapter 59. New York, NY: Springer.

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6) McGrattan, K., et al. (2017). *Fire Dynamics Simulator User's Guide NIST Special Publication 1019 6th Edition.* Gaithersburg, MD: NIST.

7) Noren, J., Rosberg, D. (2014). Developing a Swedish Best Practice Guideline for Proper Use of CFD-Models when Performing ASET-Analysis, Fire and Evacuation Modeling Technical Conference (FEMTC), Gaithersburg, MD.

8) Thunderhead Engineering (2015). Verification and Validation, Release 0504 x64, Manhattan, KS.

11 APPENDIX A (EGRESS FLOOR PLANS)

11.1 Basement

[redacted]

11.2 Ground Floor

[redacted]

11.3 Second Floor

[redacted]

11.4 Third Floor

[redacted]

11.5 Fourth Floor

[redacted]

11.6 Fifth Floor

[redacted]

11.7 Sixth Floor

[redacted]

12 APPENDIX B (OCCUPANT LOAD CALCULATIONS)

12.1 Basement Occupant Load Calculations

[redacted]

12.2 1st Floor Occupant Load Calculations

[redacted]

12.3 2nd Floor Occupant Load Calculations

[redacted]

12.4 3rd Floor Occupant Load Calculations

[redacted]

12.5 4th Floor Occupant Load Calculations

[redacted]

[redacted]

12.6 5th Floor Occupant Load Calculations

[redacted]

[redacted]

12.7 6th Floor Occupant Load Calculations

[redacted]

[redacted]

13 APPENDIX C (ALLOWABLE FLOOR AREA CALCULATIONS)

General Notes:

- The building does not qualify for an area factor increased based on frontage. The building does not have 25 percent of its permieter on a public way or an open space. The building also does not have a minimum distance of 20 feet from the public way or open space.
- In the CBC, the S_a factor cannot exceed 3. The 2018 International Building Code (IBC) does allow the factor to be increased to 4, but the CBC does not adopt this requirement.
- The building is equipped with an automatic sprinkler system.

Calculations:

The [redacted] building is considered a single-occupancy, multistory building. The building is classified as Business Group B. Per the CBC Section 506.2.3, the allowable area is determined using the Equation : $A_a = [A_T + (NS \times I_F)] \times S_a$. The allowable area factors are located in the CBC Table 506.2 as described in Table 11.

Table 11 -Allowable Floor Area (Type-IIA)

Occupancy Classification (Type II-A)	Tabular Allowable Floor Area [ft²]
B (Non-Sprinklered)	37,500
B (Multi-Story Sprinklered)	112,500

Maximum Allowable Floor Area per Story:

$A_a = [A_T + (NS \times I_F)] \times S_a$

$A_a = [112{,}500 + (37{,}500 \times 0)] \times 1$

$A_a = 112{,}500\ ft^2$

The total allowable area per floor is 112,500 ft^2. The building complies with these requirements.

Maximum Allowable for the Building:

The total aggregate sum of all of the floor areas cannot exceed 337,500 ft^2. The building complies with these requirements.

$A_a = [A_T + (NS \times I_F)] \times S_a$

$A_a = [112{,}500 + (37{,}500 \times 0)] \times 3$

$A_a = 337{,}500\ ft^2$

The total aggregate sum of all of the floor areas cannot exceed 337,500 ft^2

14 APPENDIX D (FIRE SUPPRESSION SYSTEMS)

14.1 Sprinkler Floor Plans

14.1.1 Basement Level

[redacted]

14.1.2 Ground Floor

[redacted]

14.1.3 2nd Floor

[redacted]

14.1.4 3rd Floor

[redacted]

14.1.5 4th Floor

[redacted]

14.1.6 5th Floor

[redacted]

14.1.7 6th Floor

[redacted]

14.2 Hydraulic Calculations (6FL To POC)

HYDRAULIC CALCULATIONS															
Step No.	Nozzle Ident and Location	Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
1	Node 701 to Node 8	q	14.8	1	E-2	L	13.5	C=	120	Pt	7.0	Pt		k=	5.6
						F	2			Pe		Pv			
		Q	14.8			T	15.5	pf	0.075	Pf	1.2	Pn		Pt=	7.0
2	Node 8 to Node 9	q	15.3	1		L	8.25	C=	120	Pt	8.2	Pt		k=	5.34 from Node 706
						F				Pe		Pv			to Node 8
		Q	30.1			T	8.25	pf	0.277	Pf	2.3	Pn			
3	Node 9 to Node 10	q	17.3	1 1/4		L	11.5	C=	120	Pt	10.5	Pt		k=	5.34 from Node 709
						F				Pe		Pv			to Node 9
		Q	47.4			T	11.5	pf	0.169	Pf	1.9	Pn			
4	Node 10 to Node 11	q	18.7	1 1/2	T-8	L	5.34	C=	12	Pt	12.4	Pt		k=	5.36 from Node 710
						F	8			Pe		Pv			to Node 10
		Q	66.1			T	13.34	pf	0.147	Pf	2.0	Pn			
5	Node 11 to Node 12	q	21.2	2 1/2	E-6	L	1	C=	120	Pt	14.4	Pt		k=	5.59 from Node 713
						F	6			Pe	0.4	Pv			to Node 11
		Q	87.3			T	7	pf	0.031	Pf	0.2	Pn			
6	Node 12 to Node 13	q		6		L	1.25	C=	120	Pt	15.0	Pt		k=	
						F				Pe		Pv			
		Q	87.3			T	1.25	pf	0.004	Pf	0.0	Pn			
7	Node 13 to Node 14	q	77.0	6		L	6.92	C=	120	Pt	15.0	Pt		k=	19.88 from Node 706
						F				Pe		Pv			to Node 13
		Q	164.3			T	6.92	pf	0.001	Pf	0.0	Pn			
8	Node 14 to Node 15	q	21.1	6		L	10.34	C=	120	Pt	15.0	Pt		k=	5.45 from Node 712
						F				Pe		Pv			to Node 14
		Q	185.4			T	10.34	pf	0.002	Pf	0.0	Pn			
9	Node 15 to Node 16	q	41.4	6		L	4.59	C=	120	Pt	15.0	Pt		k=	10.69 from Node 707
						F				Pe		Pv			to Node 15
		Q	226.8			T	4.59	pf	0.002	Pf	0.0	Pn			
10	Node 16 to Node 17	q	20.1	6		L	5.34	C=	120	Pt	15.0	Pt		k=	5.18 from Node 711
						F				Pe		Pv			to Node 16
		Q	246.9			T	5.34	pf	0.003	Pf	0.0	Pn			
11	Node 17 to Node 25	q		6		L	76.52	C=	120	Pt	15.0	Pt			
						F				Pe		Pv			
		Q	246.9			T	76.52	pf	0.003	Pf	0.2	Pn			
12	Node 25 to Node 26	q		6	T-30	L	22.25	C=	120	Pt	15.2	Pt			
					E-14	F	53			Pe		Pv			
		Q	246.9		LtE-9	T	75.25	pf	0.003	Pf	0.2	Pn			
12	Node 26 to Node 27	q		6	CV-40.25	L	6	C=	120	Pt	15.4	Pt			
					BV-12.59	F	64.18			Pe	3.4	Pv			Schedule 10 Pipe
		Q	246.9		LtE-11.34	T	70.18	pf	0.003	Pf	0.2	Pn			
13	Node 27 to Node 41	q		6	PO-30	L	32.5	C=	120	Pt	19.0	Pt			
					E-14	F	44			Pe	29.2	Pv			BOR Requirements
		Q	246.9			T	76.5	pf	0.003	Pf	0.2	Pn			246.9 Gpm; 48.4 Psi
14	Node 42 to Node 43	q		6	8.00E-142	L	123	C=	120	Pt	48.4	Pt			
					2EE-18	F	166			Pe		Pv			Feed Main for Building
		Q	246.9		BFP-6	T	289	pf	0.002	Pf	0.6	Pn			Scheudle 10 Pipe
15	Node 42 to Node 43	q		6	E-22.09	L	15.67	C=	140	Pt	49.0	Pt			Ductile Iron Pipe
					GV-4.75	F	26.84			Pe		Pv			6.280 I.D.
		Q	246.9			T	42.51	pf	0.002	Pf	0.1	Pn			UG to POC
16		q				L		C=		Pt	49.1	Pt			
						F				Pe		Pv			POC Requirements
		Q	246.9			T		pf		Pf		Pn			246.9 Gpm; 49.1 Psi

14.3 Supplemental Hydraulic Calculations – Branch Lines

SUPPLEMENTAL HYDRAULIC CALCULATIONS

Step No.	Nozzle Ident and Location	Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
1	Node 706 to Node 8	q	15.3	1	T-5	L	4	C=	120	Pt	7.5	Pt		Pt=	7.45
						F	5			Pe		Pv			Pressure at Node 706 is determined from
		Q	15.3			T	9	pf	0.079	Pf	0.7	Pn			balancing the pressure at Node 8
2		q				L		C=		Pt	8.2	Pt			$K = Q_T / \sqrt{P_B}$
						F				Pe		Pv			K = 15.3/√8.2
		Q	15.3			T		pf		Pf		Pn			K = 5.34
1	Node 709 to Node 9	q	17.3	1	T-5	L	4	C=	120	Pt	9.6	Pt		Pt=	9.552
						F	5			Pe		Pv			Pressure at Node 709 is determined from
		Q	17.3			T	9	pf	0.100	Pf	0.9	Pn			balancing the pressure at Node 9
2		q				L		C=		Pt	10.5	Pt			$K = Q_T / \sqrt{P_B}$
						F				Pe		Pv			K = 17.3/√10.5
		Q	17.3			T		pf		Pf		Pn			K = 5.34
1	Node 710 to Node 10	q	18.8	1	T-5	L	4	C=	120	Pt	11.3	Pt		Pt=	11.332
						F	5			Pe		Pv			Pressure at Node 710 is determined from
		Q	18.8			T	9	pf	0.116	Pf	1.0	Pn			balancing the pressure at Node 10
2		q				L		C=		Pt	12.3	Pt			$K = Q_T / \sqrt{P_B}$
						F				Pe		Pv			K = 18.8/√12.3
		Q	18.8			T		pf		Pf		Pn			K = 5.36
1	Node 713 to Node 11	q	21.2	2	T-10	L	4.34	C=	120	Pt	14.3	Pt		Pt=	14.275
						F	10			Pe		Pv			Pressure at Node 713 is determined from
		Q	21.2			T	14.34	pf	0.005	Pf	0.1	Pn			balancing the pressure at Node 11
2		q				L		C=		Pt	14.4	Pt			$K = Q_T / \sqrt{P_B}$
						F				Pe		Pv			K = 21.2/√14.4
		Q	21.2			T		pf		Pf		Pn			K = 5.59
1	Node 702 to Node 703	q	18.2	1		L	6	C=	120	Pt	10.5	Pt		Pt=	10.54
						F				Pe		Pv			Pressure at Node 702 is determined from
		Q	18.2			T	6	pf	0.109	Pf	0.7	Pn			balancing the pressure at Node 13
2	Node 703 to Node 704	q	18.7	1 1/4		L	12.09	C=	120	Pt	11.2	Pt			
						F				Pe		Pv		k=	5.6
		Q	36.9			T	12.09	pf	0.106	Pf	1.3	Pn		q=	5.6(√11.2) = 18.74
3	Node 704 to Node 705	q	19.8	1 1/2		L	6	C=	120	Pt	12.5	Pt			
						F				Pe		Pv		k=	5.6
		Q	56.7			T	6	pf	0.111	Pf	0.7	Pn		q=	5.6(√12.5) = 19.79
4	Node 705 to Node 13	q	20.3	2	2E-10 T-10	L	11	C=	120.000	Pt	13.2	Pt			
						F	20			Pe		Pv		k=	5.6
		Q	77.0			T	31	pf	0.058	Pf	1.8	Pn		q=	5.6(√13.2) = 20.34
5		q				L		C=		Pt	15.0	Pt			$K = Q_T / \sqrt{P_B}$
						F				Pe		Pv			K = 77/√15
		Q	77.0			T		pf		Pf		Pn			K = 19.88
1	Node 712 to Node 34	q	21.1	1 1/2	T-8	L	4.34	C=	120	Pt	14.2	Pt		Pt=	14.196
						F	8			Pe		Pv			Pressure at Node 712 is determined from
		Q	21.1			T	12.34	pf	0.018	Pf	0.2	Pn			balancing the pressure at Node 14
2	Node 34 to Node 14	q		1 1/2	T-8	L	1	C=	120	Pt	14.4	Pt			
						F	8			Pe	0.4	Pv			
		Q	21.1			T	9	pf	0.018	Pf	0.2	Pn			
3		q				L		C=		Pt	15.0	Pt			$K = Q_T / \sqrt{P_B}$
						F				Pe		Pv			K = 21.1/√15
		Q	21.1			T		pf		Pf		Pn			K = 5.45
1	Node 707 to Node 708	q	20.7	1 1/2		L	7.67	C=	120	Pt	13.6	Pt		Pt=	13.571
						F				Pe		Pv			Pressure at Node 707 is determined from
		Q	20.7			T	7.67	pf	0.017	Pf	0.1	Pn			balancing the pressure at Node 15
2	Node 708 to Node 31	q	20.7	1 1/2	T-8	L	3.17	C=	120	Pt	13.7	Pt			
						F	8			Pe		Pv		k=	5.6
		Q	41.4			T	11.17	pf	0.062	Pf	0.7	Pn		q=	5.6(√13.7) = 20.727
3	Node 31 to Node 15	q		2	T-10	L	1	C=	120	Pt	14.4	Pt			
						F	10			Pe	0.4	Pv			
		Q	41.4			T	11	pf	0.018	Pf	0.2	Pn			
4		q				L		C=		Pt	15.0	Pt			$K = Q_T / \sqrt{P_B}$
						F				Pe		Pv			K = 41.4/√15
		Q	41.4			T		pf		Pf		Pn			K = 10.69
1	Node 711 to Node 32	q	20.0	1	C-5	L	5.67	C=	120	Pt	12.7	Pt		Pt=	12.743
						F	5			Pe		Pv			Pressure at Node 711 is determined from
		Q	20.0			T	10.67	pf	0.130	Pf	1.4	Pn			balancing the pressure at Node 16
2	Node 32 to Node 33	q		1 1/2	E-4	L	16.54	C=	120	Pt	14.1	Pt			
						F	4			Pe		Pv		k=	5.6
		Q	20.0			T	20.54	pf	0.016	Pf	0.3	Pn		q=	5.6(√14.1) = 21.027
3	Node 33 to Node 16	q		1 1/2	T-8	L	1	C=	120	Pt	14.4	Pt			
						F	8			Pe	0.4	Pv			
		Q	20.0			T	9	pf	0.016	Pf	0.1	Pn			
4		q				L		C=		Pt	14.9	Pt			$K = Q_T / \sqrt{P_B}$
						F				Pe		Pv			K = 20/√14.9
		Q	20.0			T		pf		Pf		Pn			K = 5.181

14.4 Inspection, Testing, and Maintenance Requirements – NFPA 25

Table 5.1.1.2 Summary of Sprinkler System Inspection, Testing, and Maintenance

Item	Frequency	Reference
Inspection		
Assessment of the internal piping condition		Chapter 14
Control valves		Chapter 13
Fire department connections		Chapter 13
Gauges (wet and deluge systems)		Chapter 13
Gauges (dry and preaction systems)		Chapter 13
Hanger/braces/supports	Annually	5.2.3
Heat tracing	Per manufacturer's requirements	5.2.6
Hydraulic design information sign	Annually	5.2.5
Information signs	Annually	5.2.7, 5.2.8, 5.2.9
Pipe and fittings	Annually	5.2.2
Sprinklers	Annually	5.2.1
Sprinklers (spare)	Annually	5.2.1.4
Supervisory signal devices (except valve supervisory switches)		5.2.4, Chapter 13
System valves		Chapter 13
Valve supervisory signal devices		5.2.4, Chapter 13
Waterflow alarm devices	Quarterly	5.2.4
Test		
Antifreeze solution	Annually	5.3.4
Control valves		Chapter 13
Gauges		Chapter 13
Main drain		Chapter 13
Sprinklers	At 50 years and every 10 years thereafter	5.3.1.1.1, 5.3.1.1.1.1, 5.3.1.1.1.2
Sprinklers	At 75 years and every 5 years thereafter	5.3.1.1.1.5
Sprinklers (dry)	15 years and every 10 years thereafter	5.3.1.1.1.6
Sprinklers (extra-high or greater temperature solder type)	5 years	5.3.1.1.1.4
Sprinklers (fast-response)	At 20 years and every 10 years thereafter	5.3.1.1.1.3
Sprinklers (harsh environments)	5 years	5.3.1.1.2
Supervisory signal devices (except valve supervisory switches)		Chapter 13
System valves		Chapter 13
Valve supervisory signal devices		Chapter 13
Waterflow alarm devices (mechanical)	Quarterly	5.3.3.1
Waterflow alarm devices (vane and pressure switch type)	Semiannually	5.3.3.2

13.1.1.2

Table 13.1.1.2 shall be used to determine the minimum required frequencies for inspection, testing, and maintenance.

Table 13.1.1.2 Summary of Valves, Valve Components, and Trim Inspection, Testing, and Maintenance

Item	Frequency	Reference
Inspection		
Alarm Valves		
Exterior	Quarterly	13.4.1.1
Interior	5 years	13.4.1.2
Strainers, filters, orifices	5 years	13.4.1.2
Backflow Prevention Assemblies		
Reduced pressure	Weekly	13.7.1
Reduced-pressure detectors	Weekly	13.7.1
Interior	5 years	13.7.1.3
Check Valves		
Interior	5 years	13.4.2.1
Control Valves		
All valves except locked or supervised	Weekly	13.3.2.1
Locked or supervised	Monthly	13.3.2.1.1
Electrically supervised	Quarterly	13.3.2.1.2
Dry Pipe Valves/ Quick-Opening Devices		
Enclosure (during cold weather)		Chapter 4
Exterior	Monthly	13.4.5.1.2
Interior	Annually	13.4.5.1.3
Strainers, filters, orifices	5 years	13.4.5.1.4
Low temperature alarm	Annually	Chapter 4
Deluge Valves		
Enclosure (during cold weather)	Daily/weekly	Chapter 4
Exterior	Monthly	13.4.4.1.1
Interior	Annually/5 years	13.4.4.1.2
Strainers, filters, orifices	5 years	13.4.4.1.3
Fire Department Connections	Quarterly	13.8.1
Gauges	Monthly/quarterly	13.2.5
Hose Valves	Quarterly	13.6.1
Preaction Valves		
Enclosure (during cold weather)		Chapter 4
Exterior	Monthly	13.4.3.1.1
Interior	Annually/5 years	13.4.3.1.2
Strainers, filters, orifices	5 years	13.4.3.1.3
Pressure-Regulating and Relief Valves		
Master pressure-regulating	Weekly	13.5.4.1
Sprinkler system pressure-reducing	Quarterly	13.5.1.1
Hose connection pressure-regulating	Annually	13.5.2.1
Hose rack pressure-regulating	Annually	13.5.3.1
Fire pump circulation relief	With no flow test	13.5.6.1
Fire pump main pressure-relief	With fire pump test	13.5.6.2.1
Valve Supervisory Signal Initiating Device	Quarterly	13.3.2.1.3
Supervisory Signal Devices (except valve supervisory switches)	Quarterly	13.2.6.1

Testing		
Backflow Prevention Assemblies	Annually	13.7.2
Control Valves		
Operation and position	Annually	13.3.3.1
Valve status test	After the control valve closed and reopened	13.3.3.4
Supervisory	Semiannually	13.3.3.5
Deluge Valves		
Trip test	Annually/3 years	13.4.4.2.3
Dry Pipe Valves/ Quick-Opening Devices		
Air leakage	3 years	13.4.5.2.9
Priming water	Quarterly	13.4.5.2.1
Low air pressure alarm	Annually	13.4.5.2.6
Quick-opening devices	Quarterly	13.4.5.2.4
Trip test	Annually	13.4.5.2.2
Full-flow trip test	3 years	13.4.5.2.2.2
Gauges	5 years	13.2.5.2
Main Drains	Annually/quarterly	13.2.3
Preaction Valves		
Priming water	Quarterly	13.4.3.2.1
Low air pressure alarms	Quarterly	13.4.3.2.11
Trip test	Annually/3 years	13.4.3.2.2 and 13.4.3.2.3
Air leakage	3 years	13.4.3.2.6
Low temperature alarm	Annually	13.4.3.2.12
Pressure-Regulating and Relief Valves		
Master pressure-regulating	Quarterly/annually	13.5.4.2 and 13.5.4.3
Sprinkler systems pressure-reducing	Annually/5 years	13.5.1.3 and 13.5.1.2
Hose connection pressure-regulating	Annually/5 years	13.5.2.3 and 13.5.2.2
Hose rack pressure-regulating	Annually/5 years	13.5.3.3 and 13.5.3.2
Fire pump circulation relief	With churn test	13.5.6.1.2
Fire pump pressure relief valves	With fire pump test	13.5.6.2.2
Hose Valves	Annually/3 years	13.6.2
Waterflow Alarms	Quarterly/semiannually	13.2.4
Supervisory Signal Devices (except valve supervisory switches)	Annually	13.2.6.2
Maintenance		
Alarm Valves	Per manufacturer	13.4.1.3
Backflow Prevention Assemblies	Per manufacturer	13.7.3
Check Valves	Per manufacturer	13.4.2.2
Control Valves (outside screw and yoke)	Annually	13.3.4
Deluge Valves	Annually/5 years	13.4.4.3
Dry Pipe Valves/ Quick-Opening Devices	Annually	13.4.5.3
Hose Valves	As needed	13.6.3
Preaction Valves	Annually/5 years	13.4.3.3

Table 6.1.1.2 Summary of Standpipe and Hose Systems Inspection, Testing, and Maintenance

Item	Frequency	Reference
Inspection		
Cabinet	Annually	6.2.8
Control valves		Chapter 13
Gauges		Chapter 13
Hose	Annually	6.2.5
Hose connection	Annually	6.2.3
Hose nozzle	Annually and after each use	6.2.6
Hose storage device	Annually	6.2.7
Hydraulic design information sign	Annually	6.2.2
Hose valves		Chapter 13
Piping	Annually	6.2.4
Pressure-regulating devices		Chapter 13
Supervisory devices (except valve supervisory devices)		Chapter 13
Valve supervisory devices		Chapter 13
Test		
Control valves		Chapter 13
System valves		Chapter 13
Flow test	5 years	6.3.1
Hose		NFPA 1962
Hose connection pressure regulating devices		Chapter 13
Hose valves		Chapter 13
Hydrostatic test	5 years	6.3.2
Main drain test		Chapter 13
Pressure control valve		Chapter 13
Pressure-reducing valve		Chapter 13
Supervisory signal devices (except valve supervisory switches)		Chapter 13
Valve status test		Chapter 13
Valve supervisory devices		Chapter 13
Waterflow alarm devices		Chapter 13
Maintenance		
Hose valves		Chapter 13
Pressure gauges		Chapter 13
Valves (all types)	Annually/as needed	Chapter 13

15 APPENDIX E (FIRE ALARM SYSTEM)

15.1 Fire Alarm Floor Plans

15.1.1 Basement

[redacted]

15.1.2 Ground Floor

[redacted]

15.1.3 2nd Floor

[redacted]

15.1.4 3rd Floor

[redacted]

15.1.5 4th Floor

[redacted]

15.1.6 5th Floor

[redacted]

15.1.7 6th Floor

[redacted]

15.2 Fire Alarm Notification Secondary Power Supply Calculations

15.2.1 Basement Notification Power Supply Battery Calculations

BASEMENT NOTIFICATION POWER SUPPLY BATTERY CALCULATION						
Basement Fire Alarm Notification Power Supply (Booster Panel) - FIRELITE (FCPS-24FS6)						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
1	FCPS-24FS6	Fire Alarm Notification Power Supply	0.065	0.065	0.145	0.145
		TOTAL PANEL STANDBY CURRENT		0.065		
		TOTAL PANEL ALARM CURRENT				0.145
FIELD DEVICES						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
4	STW	Wheelock Wall Strobe 15cd	0	0	0.057	0.228
1	STW	Wheelock Wall Strobe 30cd	0	0	0.085	0.085
3	STWC	Wheelock Ceiling Strobe 15cd	0	0	0.061	0.183
5	HSW	Wheelock Wall Horn/Strobe 15cd	0	0	0.082	0.41
2	HSW	Wheelock Wall Horn/Strobe 30cd	0	0	0.102	0.204
5	HSW	Wheelock Wall Horn/Strobe 75cd	0	0	0.148	0.74
1	HSW	Wheelock Wall Horn/Strobe 110cd	0	0	0.197	0.197
2	HSWC	Wheelock Ceiling Horn/Strobe 15cd	0	0	0.082	0.164
2	HSWC	Wheelock Ceiling Horn/Strobe 95cd	0	0	0.176	0.352
1	ASWP-2475W	Wheelock Weatherproof Wall Horn/Strobe 15cd	0	0	0.168	0.168
TOTAL						2.731
TOTAL SYSTEM CURRENT						
	DESCRIPTION			STANDBY		ALARM
	Fire Alarm Notification Power Supply Currents			0.065		0.145
	Fire Alarm Field Notification Devices Currents			0		2.731
	Total Standby Current			0.065		
	24-Hour Standby Current			1.56		
	Total Alarm Current					2.876
	5 MINUTES OF ALARM: HORN					0.240
	Subtotal Calculated Battery Requirement					1.800
	Total Batteries Required (20% Safety Factor)					2.160
	Batteries Supplies to Power Supply					2 x 7ah

15.2.2 Ground Floor Power Supply Battery Calculations

FIRE ALARM NOTIFICATION POWER SUPPLY BATTERY CALCULATION						
Ground Floor Fire Alarm Notification Power Supply (Booster Panel) - FIRELITE (FCPS-24FS6)						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
1	FCPS-24FS6	Fire Alarm Notification Power Supply	0.065	0.065	0.145	0.145
		TOTAL PANEL STANDBY CURRENT		0.065		
		TOTAL PANEL ALARM CURRENT				0.145
FIELD DEVICES						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
1	STW	Wheelock Wall Strobe 15cd	0	0	0.057	0.057
2	STW	Wheelock Wall Strobe 30cd	0	0	0.085	0.17
2	STWC	Wheelock Ceiling Strobe 15cd	0	0	0.061	0.122
2	HSW	Wheelock Wall Horn/Strobe 15cd	0	0	0.082	0.164
9	HSW	Wheelock Wall Horn/Strobe 30cd	0	0	0.102	0.918
2	HSW	Wheelock Wall Horn/Strobe 75cd	0	0	0.148	0.296
1	HSW	Wheelock Wall Horn/Strobe 110cd	0	0	0.197	0.197
2	HSWC	Wheelock Ceiling Horn/Strobe 15cd	0	0	0.082	0.164
2	HSWC	Wheelock Ceiling Horn/Strobe 95cd	0	0	0.176	0.352
TOTAL						2.440
TOTAL SYSTEM CURRENT						
	DESCRIPTION			STANDBY		ALARM
	Fire Alarm Notification Power Supply Currents			0.065		0.145
	Fire Alarm Field Notification Devices Currents			0		2.440
	Total Standby Current			0.065		
	24-Hour Standby Current			1.56		
	Total Alarm Current					2.585
	5 MINUTES OF ALARM: HORN					0.215
	Subtotal Calculated Battery Requirement					1.775
	Total Batteries Required (20% Safety Factor)					2.131
	Batteries Supplies to Power Supply					2 x 7ah

15.2.3 2nd Floor Power Supply Battery Calculations

FIRE ALARM NOTIFICATION POWER SUPPLY BATTERY CALCULATION						
2nd Floor Fire Alarm Notification Power Supply (Booster Panel) - FIRELITE (FCPS-24FS6)						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
1	FCPS-24FS6	Fire Alarm Notification Power Supply	0.065	0.065	0.145	0.145
		TOTAL PANEL STANDBY CURRENT		0.065		
		TOTAL PANEL ALARM CURRENT				0.145
FIELD DEVICES						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
2	STW	Wheelock Wall Strobe 15cd	0	0	0.057	0.114
1	STW	Wheelock Wall Strobe 75cd	0	0	0.135	0.135
5	STWC	Wheelock Ceiling Strobe 15cd	0	0	0.061	0.305
2	HSW	Wheelock Wall Horn/Strobe 15cd	0	0	0.082	0.164
6	HSW	Wheelock Wall Horn/Strobe 75cd	0	0	0.148	0.888
3	HSWC	Wheelock Ceiling Horn/Strobe 15cd	0	0	0.082	0.246
2	HSWC	Wheelock Ceiling Horn/Strobe 95cd	0	0	0.176	0.352
TOTAL						2.204
TOTAL SYSTEM CURRENT						
	DESCRIPTION			STANDBY		ALARM
	Fire Alarm Notification Power Supply Currents			0.065		0.145
	Fire Alarm Field Notification Devices Currents			0		2.204
	Total Standby Current			0.065		
	24-Hour Standby Current			1.56		
	Total Alarm Current					2.349
	5 MINUTES OF ALARM: HORN					0.196
	Subtotal Calculated Battery Requirement					1.756
	Total Batteries Required (20% Safety Factor)					2.107
	Batteries Supplies to Power Supply					2 x 7ah

15.2.4 3rd Floor Power Supply Battery Calculations

FIRE ALARM NOTIFICATION POWER SUPPLY BATTERY CALCULATION						
3rd Floor Fire Alarm Notification Power Supply (Booster Panel) - FIRELITE (FCPS-24FS6)						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
1	FCPS-24FS6	Fire Alarm Notification Power Supply	0.065	0.065	0.145	0.145
		TOTAL PANEL STANDBY CURRENT		0.065		
		TOTAL PANEL ALARM CURRENT				0.145
FIELD DEVICES						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
5	STW	Wheelock Wall Strobe 15cd	0	0	0.057	0.285
2	STW	Wheelock Wall Strobe 75cd	0	0	0.135	0.27
7	STWC	Wheelock Ceiling Strobe 15cd	0	0	0.061	0.427
2	HSW	Wheelock Wall Horn/Strobe 15cd	0	0	0.082	0.164
4	HSW	Wheelock Wall Horn/Strobe 30cd	0	0	0.102	0.408
1	HSW	Wheelock Wall Horn/Strobe 75cd	0	0	0.148	0.148
3	HSW	Wheelock Wall Horn/Strobe 110cd	0	0	0.197	0.591
4	HSWC	Wheelock Ceiling Horn/Strobe 15cd	0	0	0.082	0.328
2	HSWC	Wheelock Ceiling Horn/Strobe 30cd	0	0	0.102	0.204
2	HSWC	Wheelock Ceiling Horn/Strobe 95cd	0	0	0.176	0.352
TOTAL						3.177
TOTAL SYSTEM CURRENT						
	DESCRIPTION			STANDBY		ALARM
	Fire Alarm Notification Power Supply Currents			0.065		0.145
	Fire Alarm Field Notification Devices Currents			0		3.177
	Total Standby Current			0.065		
	24-Hour Standby Current			1.56		
	Total Alarm Current					3.322
	5 MINUTES OF ALARM: HORN					0.277
	Subtotal Calculated Battery Requirement					1.837
	Total Batteries Required (20% Safety Factor)					2.204
	Batteries Supplies to Power Supply					2 x 7ah

15.2.5 4th Floor Power Supply Battery Calculations

FIRE ALARM NOTIFICATION POWER SUPPLY BATTERY CALCULATION						
4th Floor Fire Alarm Notification Power Supply (Booster Panel) - FIRELITE (FCPS-24FS6)						
QTY.	**MODEL**	**DESCRIPTION**	**STANDBY**		**ALARM**	
			EACH	TOTAL	EACH	TOTAL
1	FCPS-24FS6	Fire Alarm Notification Power Supply	0.065	0.065	0.145	0.145
		TOTAL PANEL STANDBY CURRENT		0.065		
		TOTAL PANEL ALARM CURRENT				0.145
FIELD DEVICES						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
5	STW	Wheelock Wall Strobe 15cd	0	0	0.057	0.285
	STW	Wheelock Wall Strobe 30cd	0	0	0.085	0
1	STW	Wheelock Wall Strobe 75cd	0	0	0.135	0.135
	STW	Wheelock Wall Strobe 110cd	0	0	0.182	0
11	STWC	Wheelock Ceiling Strobe 15cd	0	0	0.061	0.671
	STWC	Wheelock Ceiling Strobe 30cd	0	0	0.085	0
	STWC	Wheelock Ceiling Strobe 75cd	0	0	0.135	0
	STWC	Wheelock Ceiling Strobe 95cd	0	0	0.163	0
2	HSW	Wheelock Wall Horn/Strobe 15cd	0	0	0.082	0.164
4	HSW	Wheelock Wall Horn/Strobe 30cd	0	0	0.102	0.408
1	HSW	Wheelock Wall Horn/Strobe 75cd	0	0	0.148	0.148
3	HSW	Wheelock Wall Horn/Strobe 110cd	0	0	0.197	0.591
2	HSWC	Wheelock Ceiling Horn/Strobe 15cd	0	0	0.082	0.164
5	HSWC	Wheelock Ceiling Horn/Strobe 30cd	0	0	0.102	0.51
	HSWC	Wheelock Ceiling Horn/Strobe 75cd	0	0	0.148	0
2	HSWC	Wheelock Ceiling Horn/Strobe 95cd	0	0	0.176	0.352
TOTAL						3.428
TOTAL SYSTEM CURRENT						
	DESCRIPTION			**STANDBY**		**ALARM**
	Fire Alarm Notification Power Supply Currents			0.065		0.145
	Fire Alarm Field Notification Devices Currents			0		3.428
	Total Standby Current			0.065		
	24-Hour Standby Current			1.56		
	Total Alarm Current					3.573
	5 MINUTES OF ALARM: HORN					0.298
	Subtotal Calculated Battery Requirement					1.858
	Total Batteries Required (20% Safety Factor)					2.229
	Batteries Supplies to Power Supply					2 x 7ah

15.2.6 5th Floor Power Supply Battery Calculations

FIRE ALARM NOTIFICATION POWER SUPPLY BATTERY CALCULATION						
5th Floor Fire Alarm Notification Power Supply (Booster Panel) - FIRELITE (FCPS-24FS6)						
QTY.	**MODEL**	**DESCRIPTION**	**STANDBY**		**ALARM**	
			EACH	TOTAL	EACH	TOTAL
1	FCPS-24FS6	Fire Alarm Notification Power Supply	0.065	0.065	0.145	0.145
		TOTAL PANEL STANDBY CURRENT		0.065		
		TOTAL PANEL ALARM CURRENT				0.145
FIELD DEVICES						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
5	STW	Wheelock Wall Strobe 15cd	0	0	0.057	0.285
1	STW	Wheelock Wall Strobe 30cd	0	0	0.085	0.085
	STW	Wheelock Wall Strobe 75cd	0	0	0.135	0
	STW	Wheelock Wall Strobe 110cd	0	0	0.182	0
11	STWC	Wheelock Ceiling Strobe 15cd	0	0	0.061	0.671
	STWC	Wheelock Ceiling Strobe 30cd	0	0	0.085	0
	STWC	Wheelock Ceiling Strobe 75cd	0	0	0.135	0
	STWC	Wheelock Ceiling Strobe 95cd	0	0	0.163	0
3	HSW	Wheelock Wall Horn/Strobe 15cd	0	0	0.082	0.246
3	HSW	Wheelock Wall Horn/Strobe 30cd	0	0	0.102	0.306
2	HSW	Wheelock Wall Horn/Strobe 75cd	0	0	0.148	0.296
3	HSW	Wheelock Wall Horn/Strobe 110cd	0	0	0.197	0.591
3	HSWC	Wheelock Ceiling Horn/Strobe 15cd	0	0	0.082	0.246
2	HSWC	Wheelock Ceiling Horn/Strobe 30cd	0	0	0.102	0.204
	HSWC	Wheelock Ceiling Horn/Strobe 75cd	0	0	0.148	0
2	HSWC	Wheelock Ceiling Horn/Strobe 95cd	0	0	0.176	0.352
TOTAL						3.282
TOTAL SYSTEM CURRENT						
	DESCRIPTION			**STANDBY**		**ALARM**
	Fire Alarm Notification Power Supply Currents			0.065		0.145
	Fire Alarm Field Notification Devices Currents			0		3.282
	Total Standby Current			0.065		
	24-Hour Standby Current			1.56		
	Total Alarm Current					3.427
	5 MINUTES OF ALARM: HORN					0.286
	Subtotal Calculated Battery Requirement					1.846
	Total Batteries Required (20% Safety Factor)					2.215
	Batteries Supplies to Power Supply					2 x 7ah

15.2.7 6th Floor Power Supply Battery Calculations

FIRE ALARM NOTIFICATION POWER SUPPLY BATTERY CALCULATION						
6th Floor Fire Alarm Notification Power Supply (Booster Panel) - FIRELITE (FCPS-24FS6)						
QTY.	**MODEL**	**DESCRIPTION**	**STANDBY**		**ALARM**	
			EACH	TOTAL	EACH	TOTAL
1	FCPS-24FS6	Fire Alarm Notification Power Supply	0.065	0.065	0.145	0.145
		TOTAL PANEL STANDBY CURRENT		0.065		
		TOTAL PANEL ALARM CURRENT				0.145
FIELD DEVICES						
QTY.	MODEL	DESCRIPTION	STANDBY		ALARM	
			EACH	TOTAL	EACH	TOTAL
5	STW	Wheelock Wall Strobe 15cd	0	0	0.057	0.285
10	STWC	Wheelock Ceiling Strobe 15cd	0	0	0.061	0.61
2	HSW	Wheelock Wall Horn/Strobe 15cd	0	0	0.082	0.164
6	HSW	Wheelock Wall Horn/Strobe 30cd	0	0	0.102	0.612
3	HSW	Wheelock Wall Horn/Strobe 75cd	0	0	0.148	0.444
2	HSW	Wheelock Wall Horn/Strobe 110cd	0	0	0.197	0.394
6	HSWC	Wheelock Ceiling Horn/Strobe 15cd	0	0	0.082	0.492
1	HSWC	Wheelock Ceiling Horn/Strobe 30cd	0	0	0.102	0.102
2	HSWC	Wheelock Ceiling Horn/Strobe 95cd	0	0	0.176	0.352
1	RSSWP-2475	Wheelock Weatherproof Strobe 15cd	0	0	0.138	0.138
2	ASWP-24WCWH	Wheelock Weatherproof Wall Horn/Strobe 110cd	0	0	0.355	0.71
TOTAL						4.303
TOTAL SYSTEM CURRENT						
	DESCRIPTION			**STANDBY**		**ALARM**
	Fire Alarm Notification Power Supply Currents			0.065		0.145
	Fire Alarm Field Notification Devices Currents			0		4.303
	Total Standby Current			0.065		
	24-Hour Standby Current			1.56		
	Total Alarm Current					4.448
	5 MINUTES OF ALARM: HORN					0.371
	Subtotal Calculated Battery Requirement					1.931
	Total Batteries Required (20% Safety Factor)					2.317
	Batteries Supplies to Power Supply					2 x 7ah

16 APPENDIX F (PATHFINDER EGRESS MODELING-FIGURES)

16.1 Basement Level

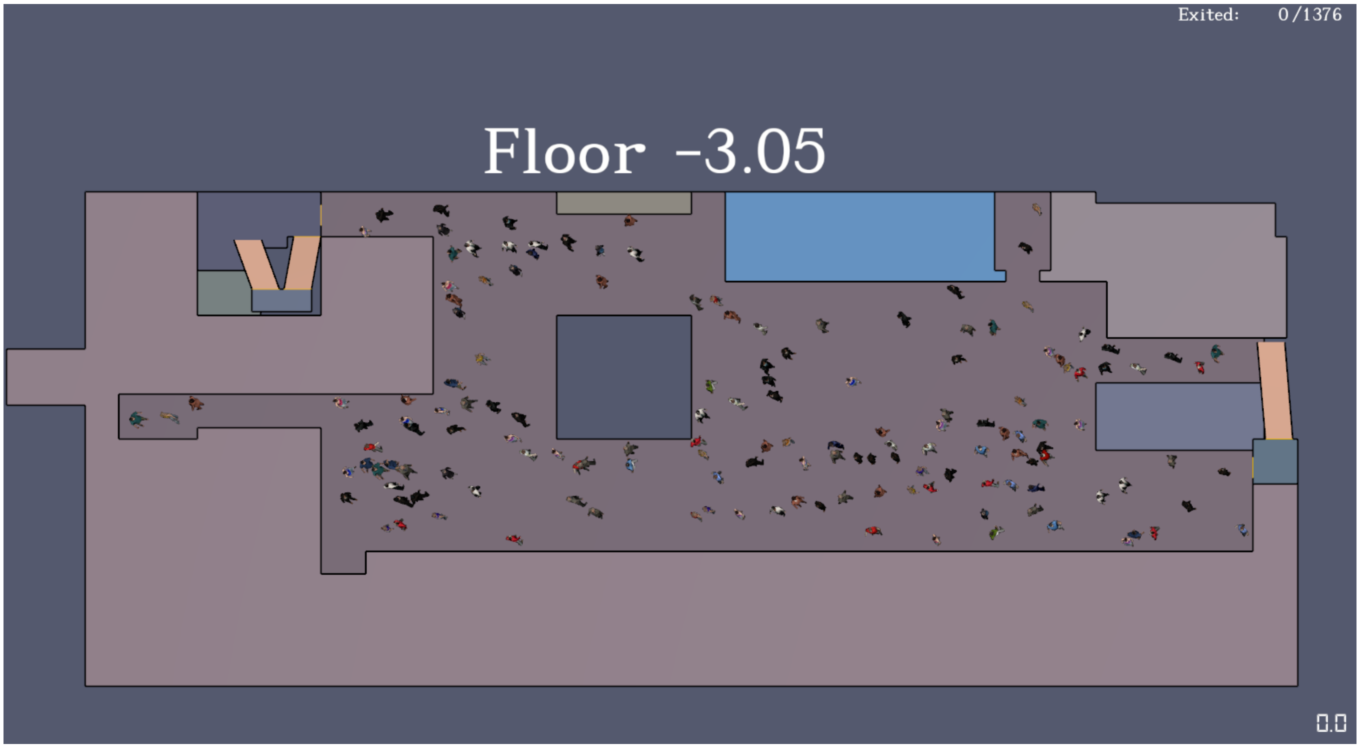

Figure 43. Occupant Density: Basement - Time = 0 s

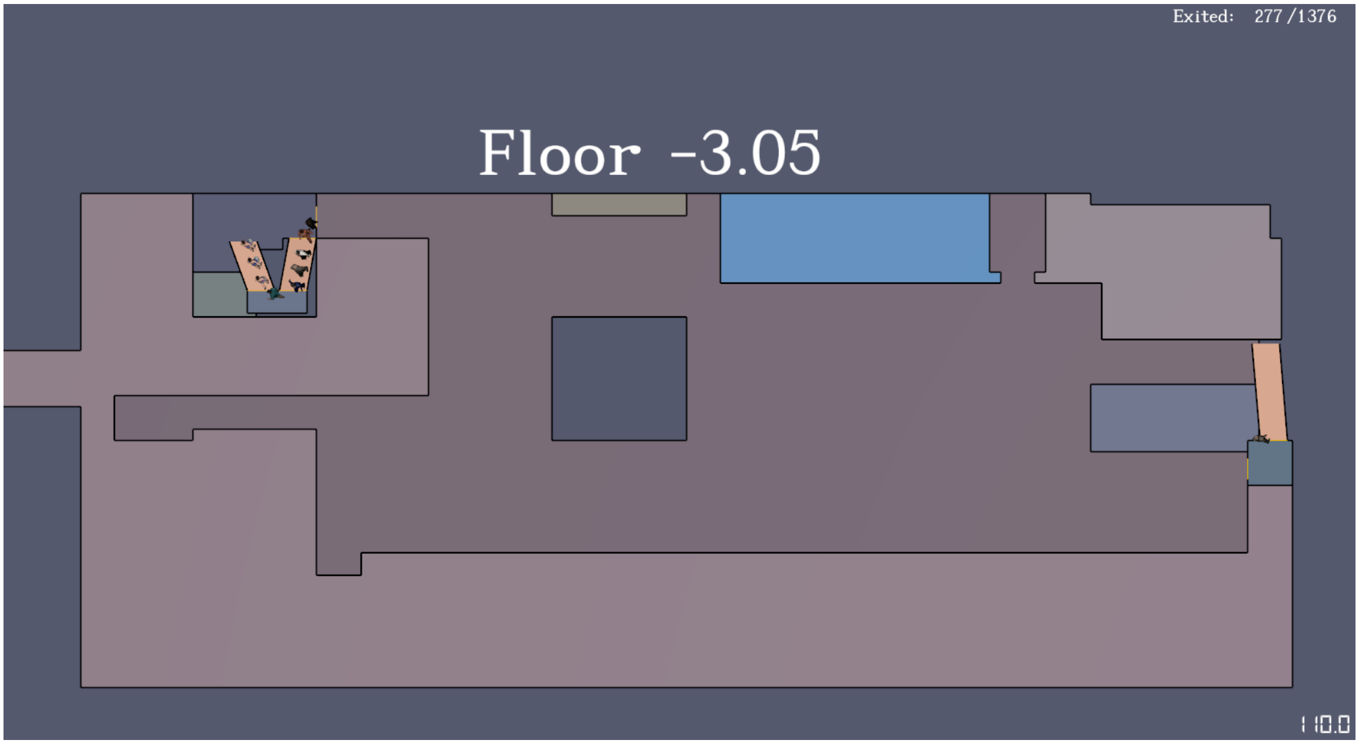

Figure 44. Occupant Density: Basement -Time when all occupants have cleared the level = 110 s

16.2 Ground Floor

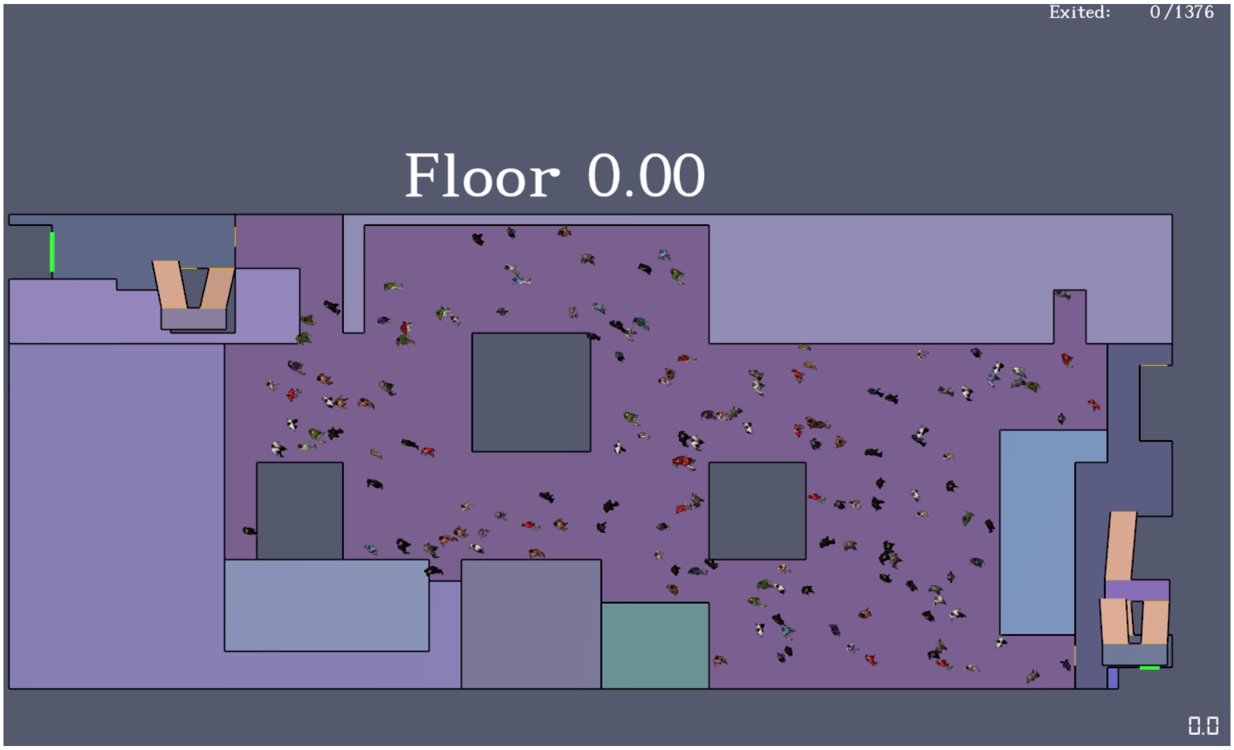

Figure 45. Occupant Density: Ground Floor - Time = 0 s

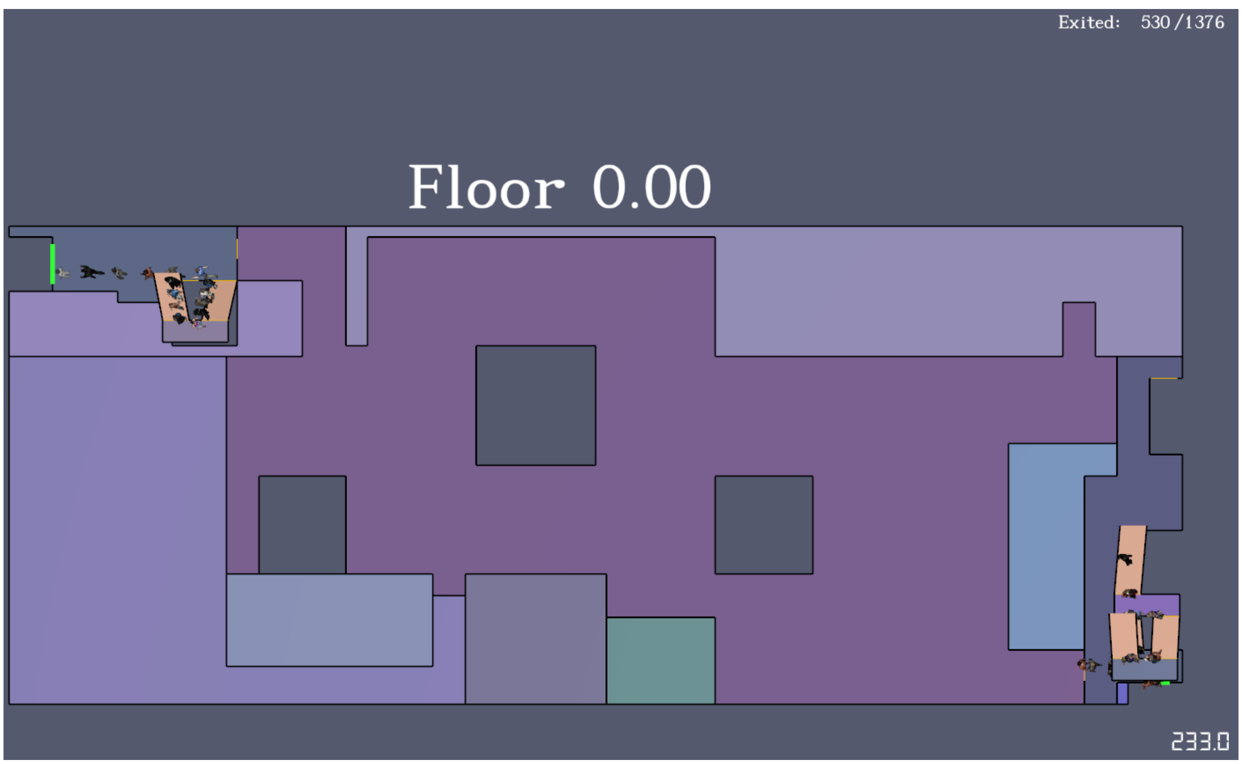

Figure 46. Occupant Density: Grd Fl -Time when all occupants have cleared the level = 233 s

16.3 2nd Floor

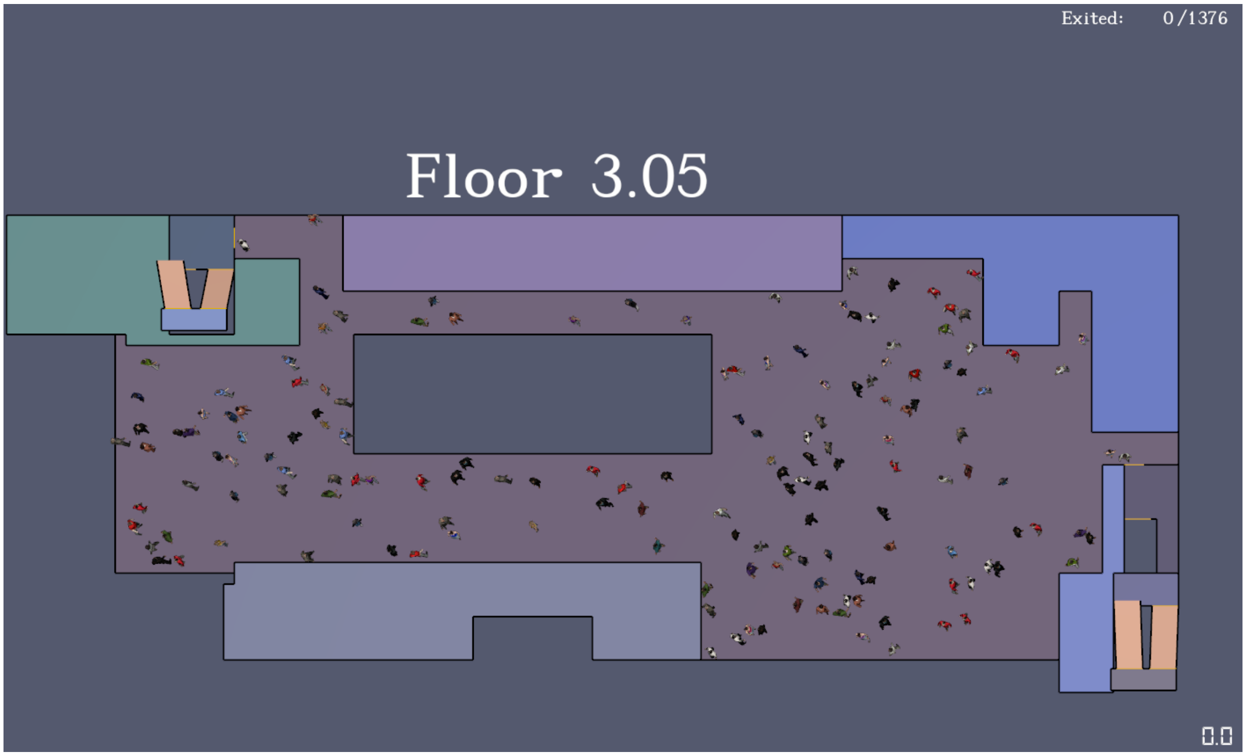

Figure 47. Occupant Density: 2nd Floor - Time = 0 s

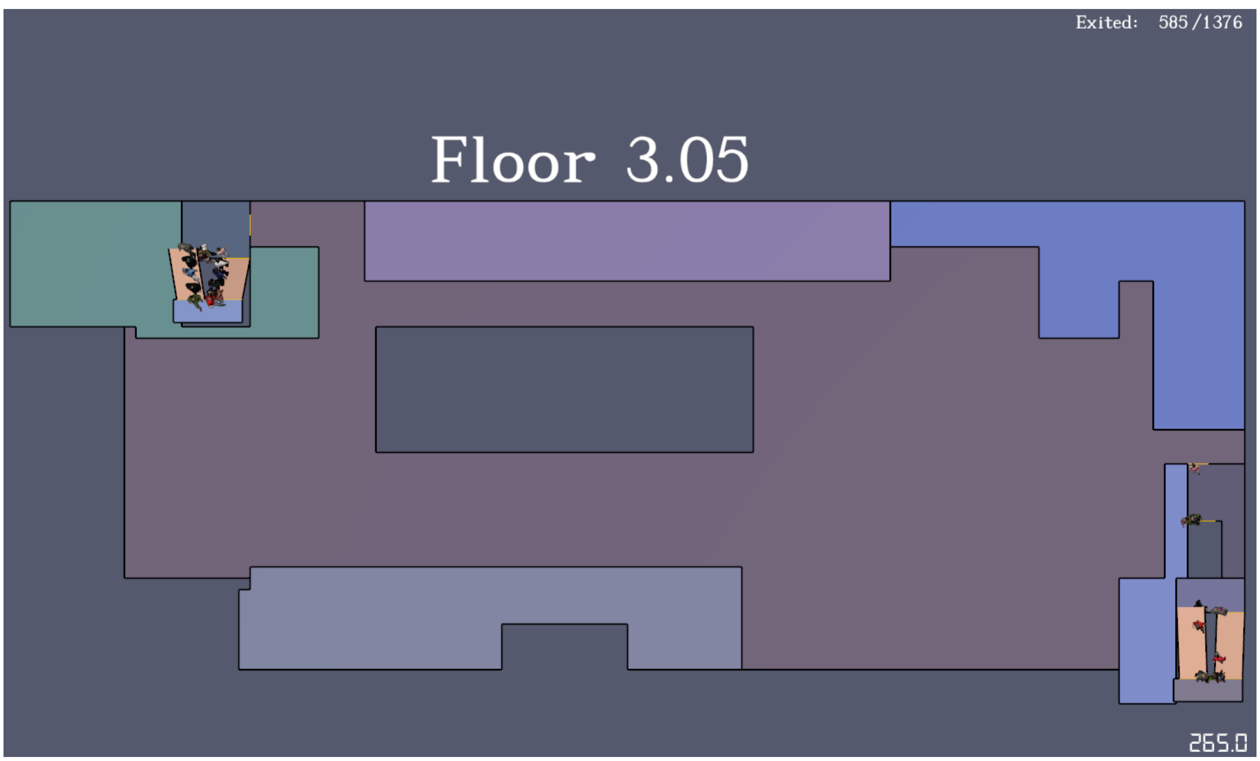

Figure 48. Occupant Density: 2nd Fl -Time when all occupants have cleared the level = 265 s

16.4 3rd Floor

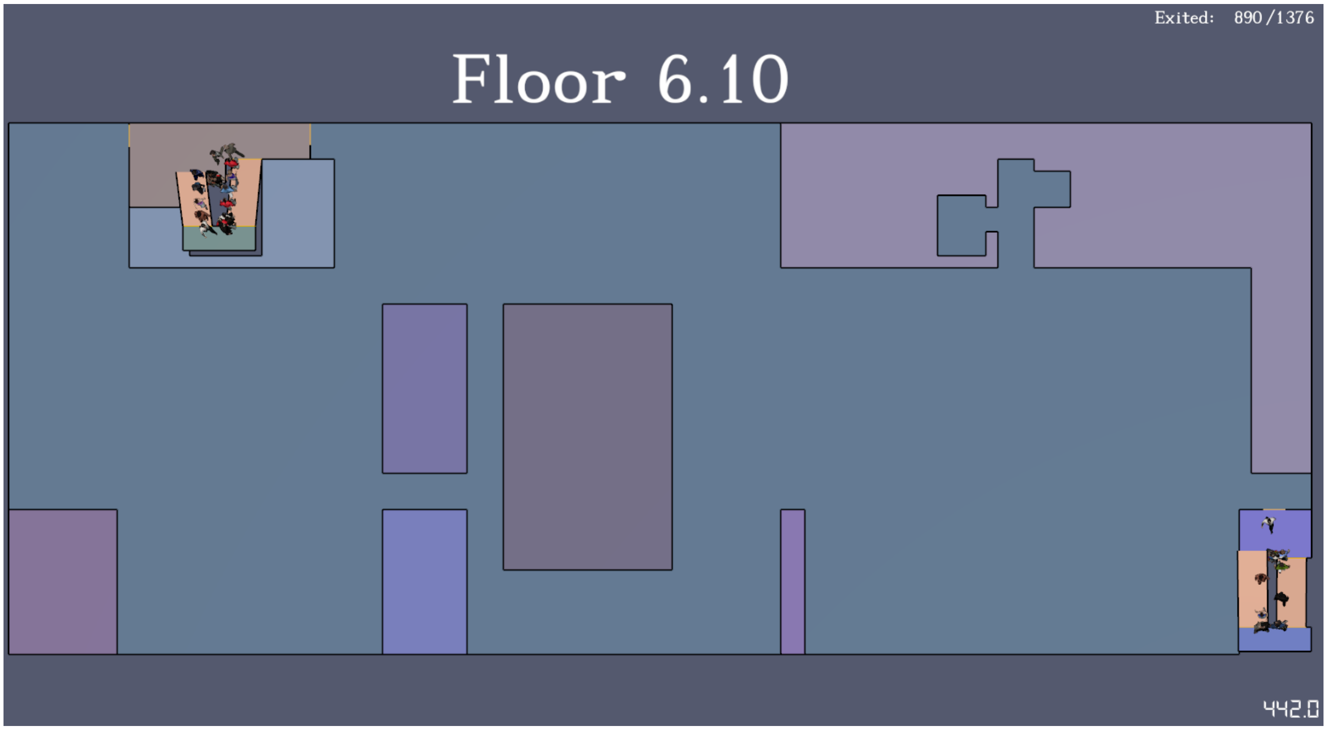

Figure 49. Occupant Density: 3rd Floor - Time = 0 s

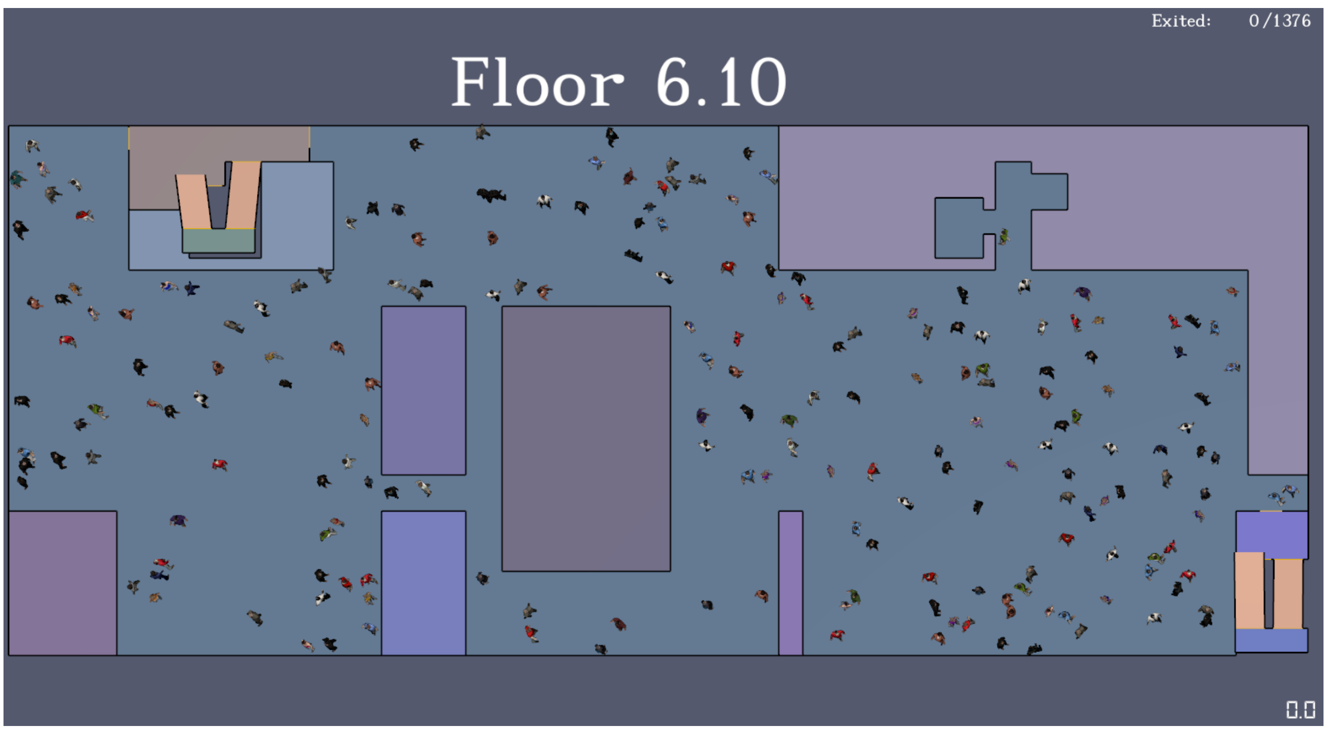

Figure 50. Occupant Density: 3rd Fl -Time when all occupants have cleared the level = 442 s

16.5 4th Floor

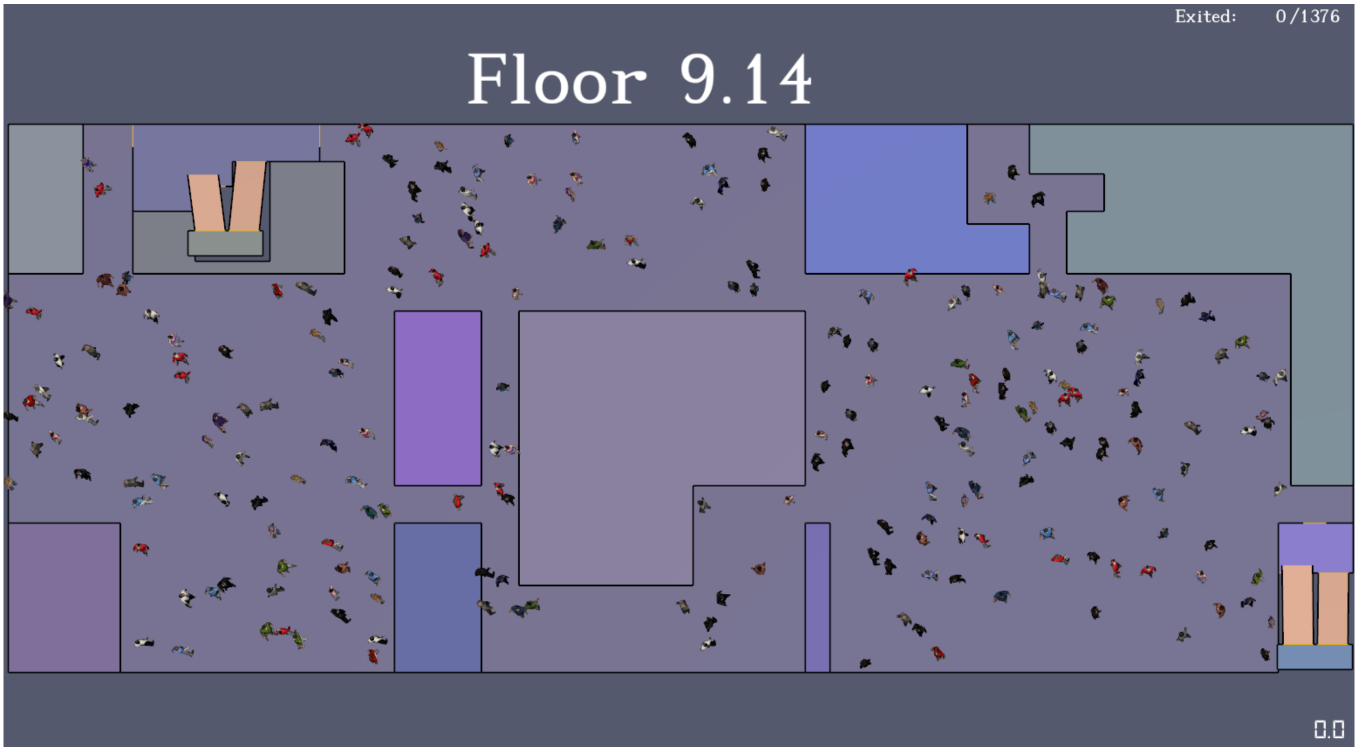

Figure 51. Occupant Density: 4th Floor - Time = 0 s

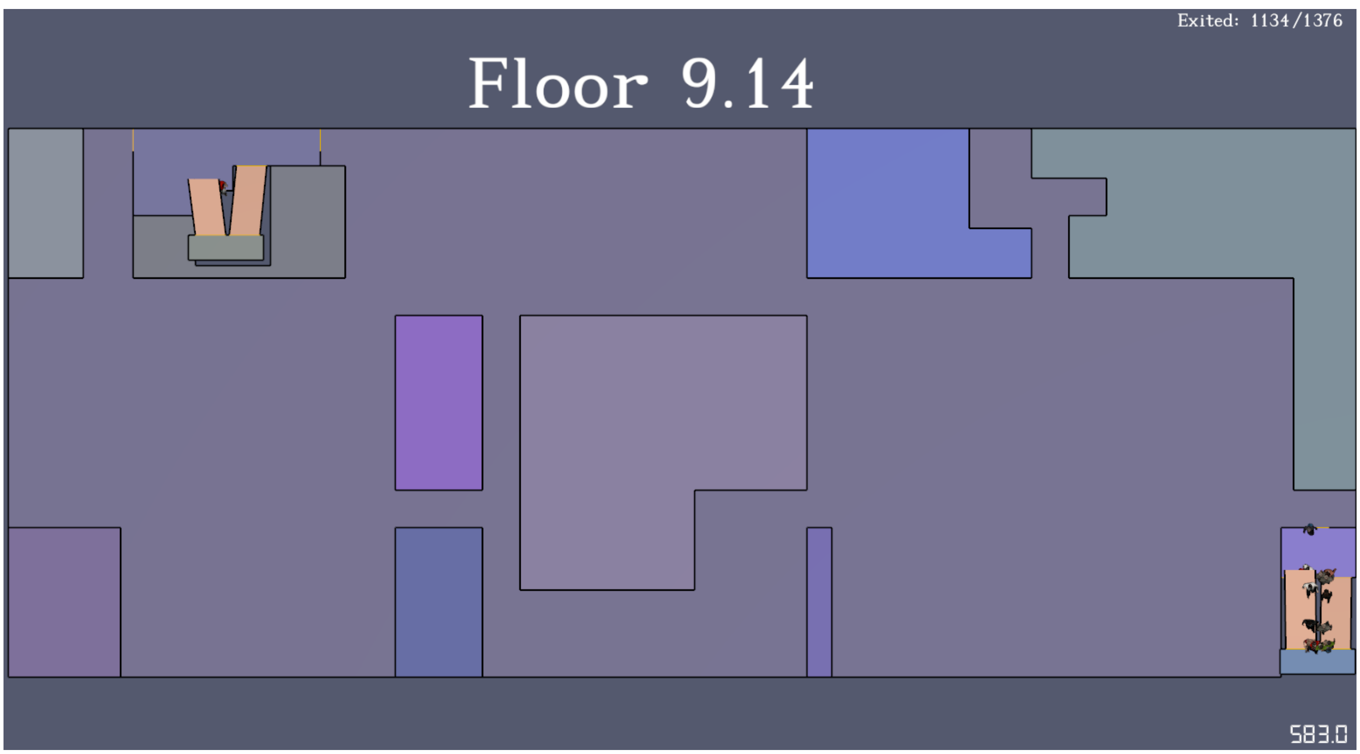

Figure 52. Occupant Density: 4th Fl -Time when all occupants have cleared the level = 583 s

16.6 5th Floor

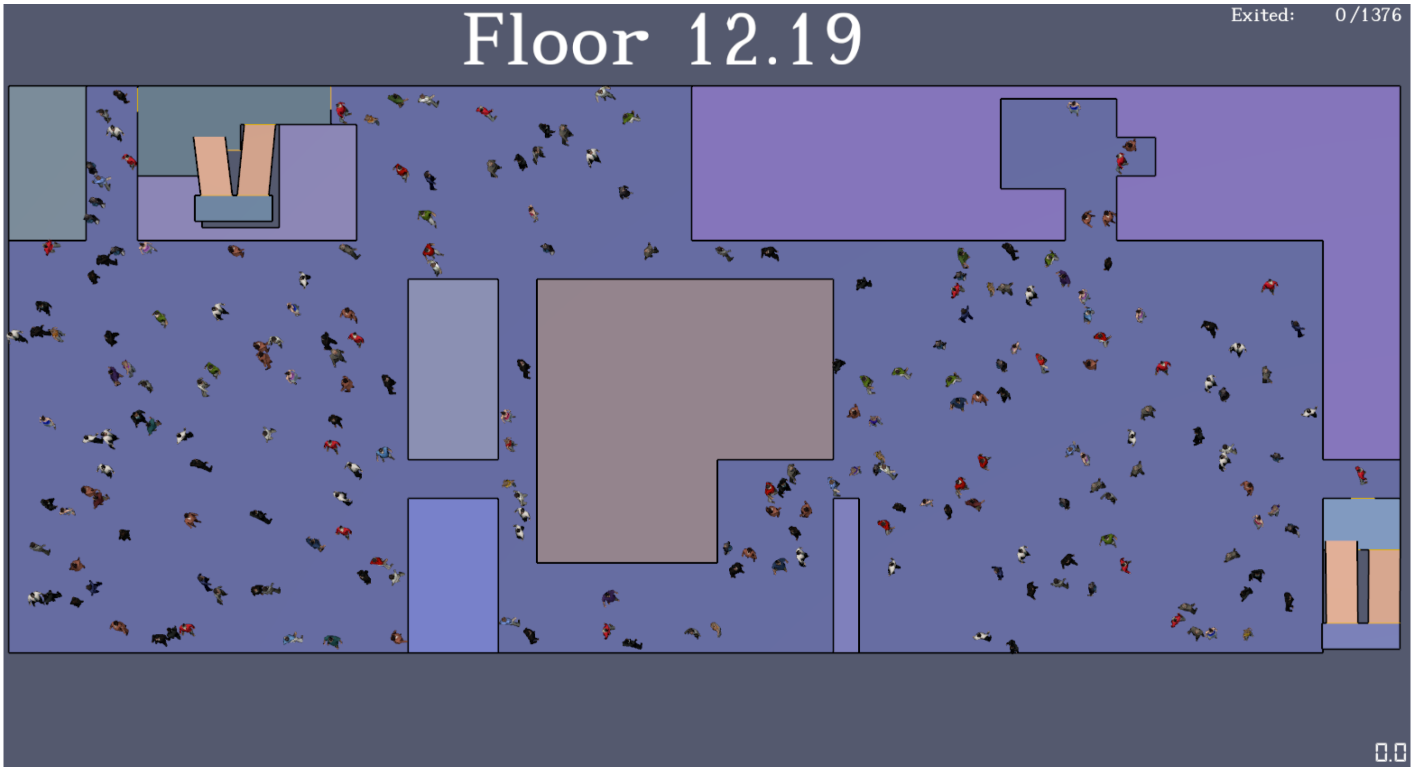

Figure 53. Occupant Density: 5th Floor - Time = 0 s

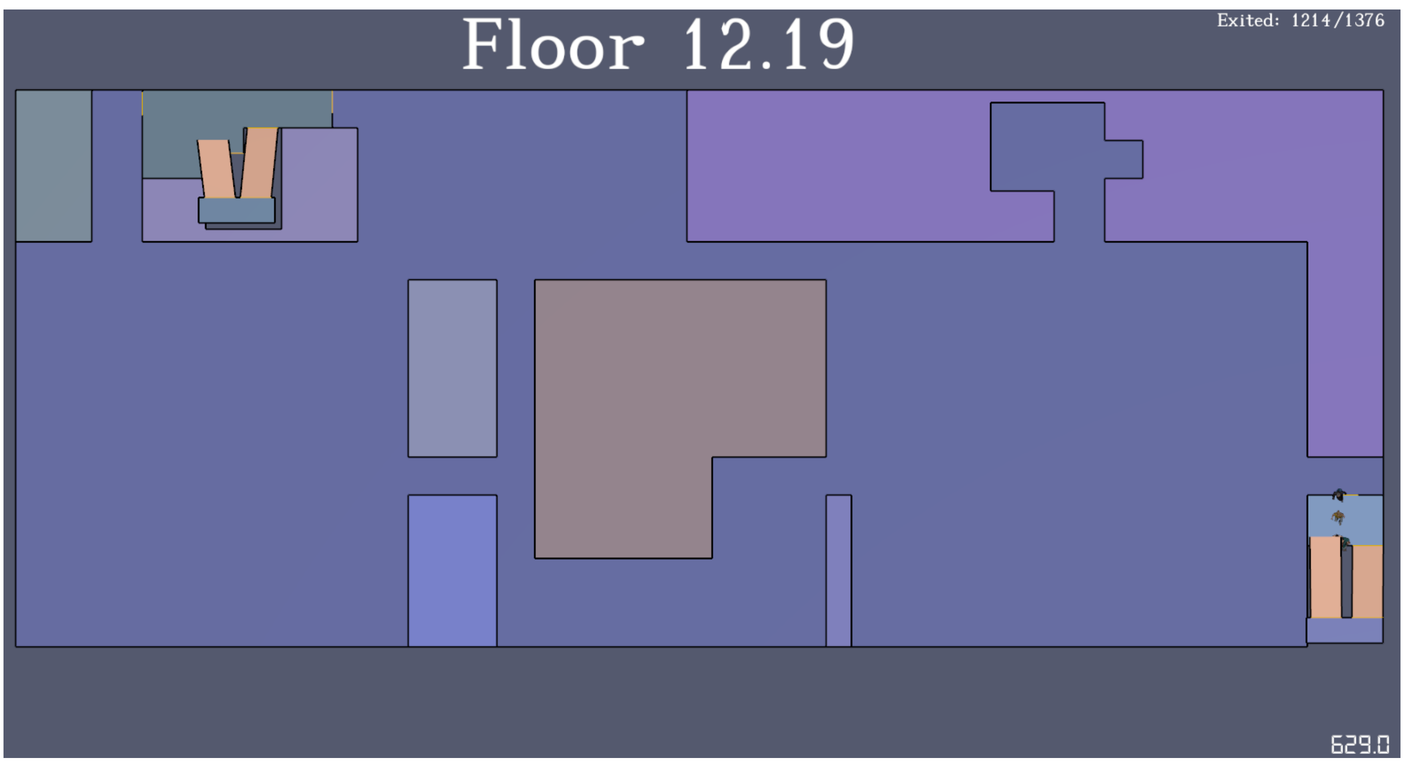

Figure 54. Occupant Density: 5th Fl -Time when all occupants have cleared the level = 629 s

16.7 6th Floor

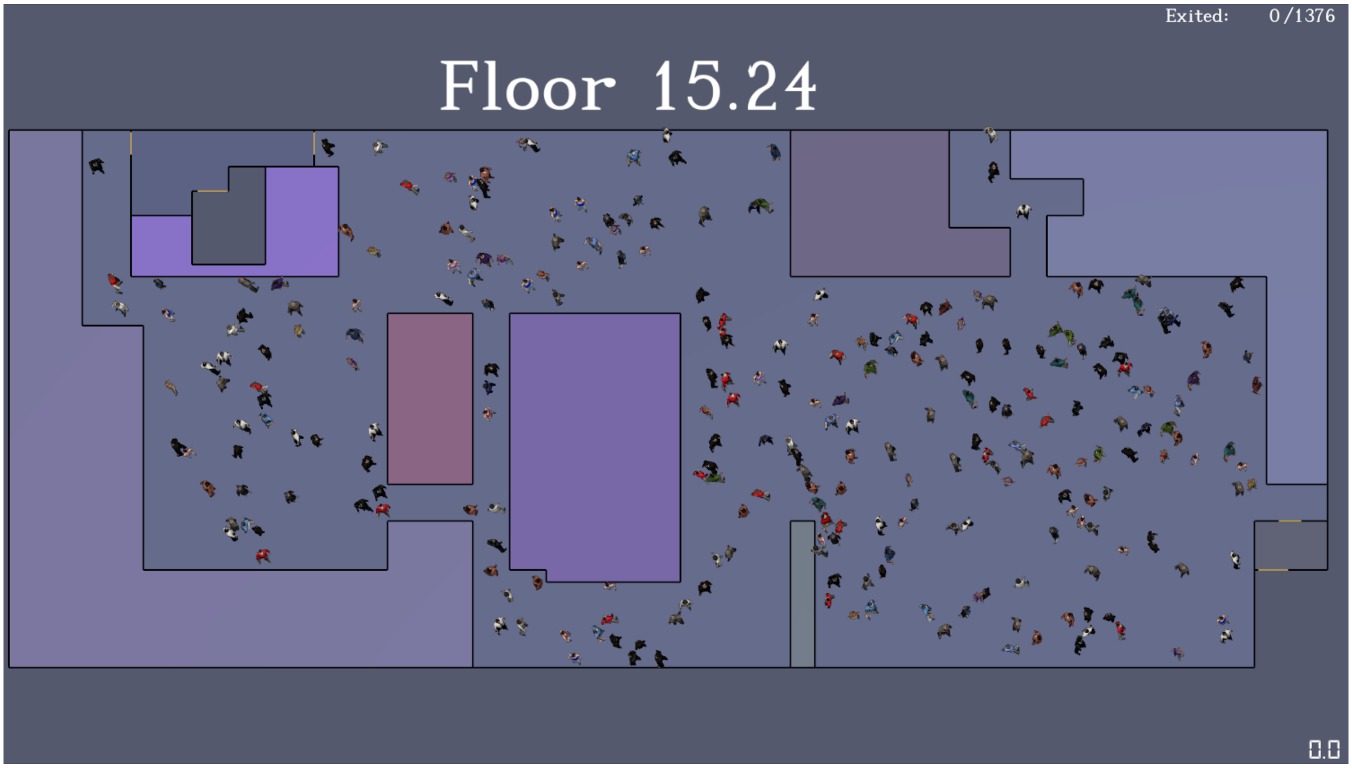

Figure 55. Occupant Density: 6th Floor - Time = 0 s

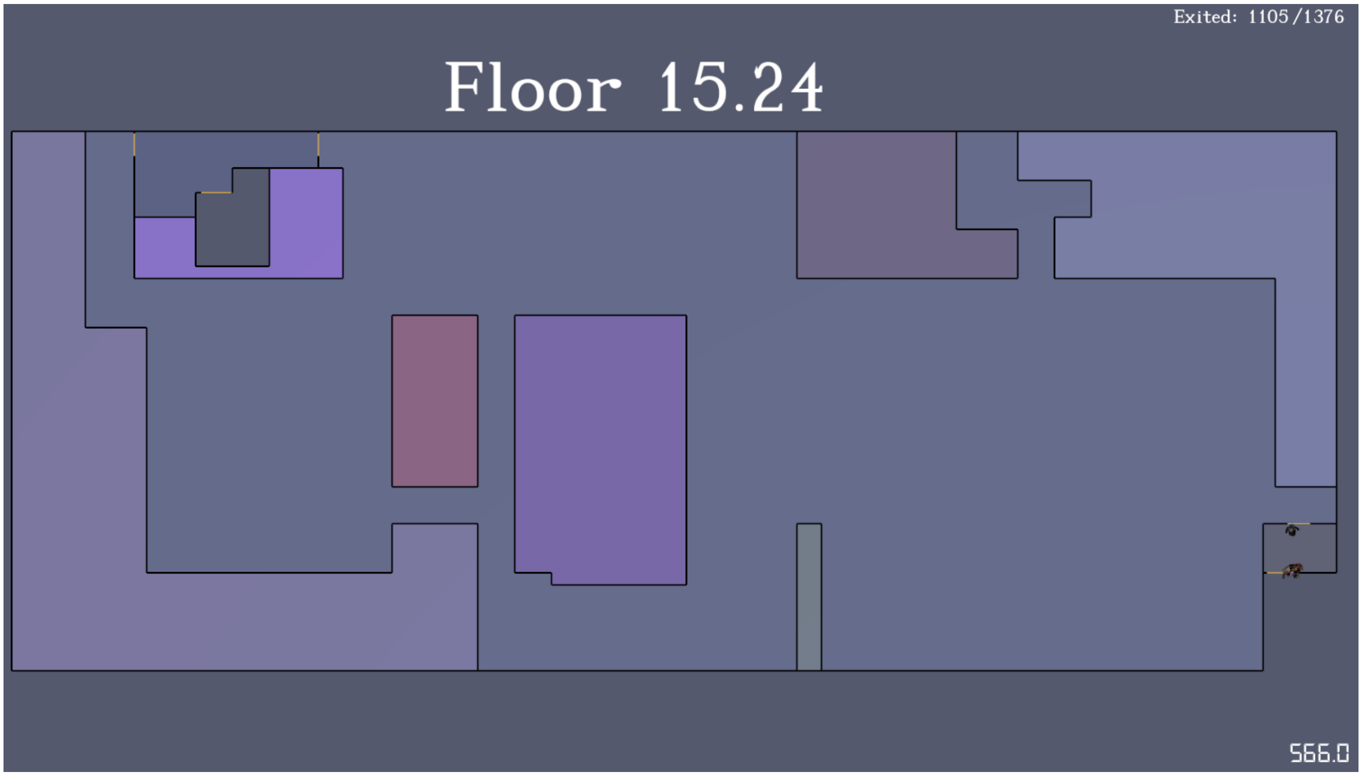

Figure 56. Occupant Density: 6th Fl -Time when all occupants have cleared the level = 566 s