Office Building in Moffett Park District

Culminating Project

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FPE 596
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Keywords: Life Safety Code, Performance Based Design, Egress, Water Based Suppression
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1 Abstract

The objective of this review is to analyze and evaluate the fire safety of a 5-story office building located in the Moffett Park District in Sunnyvale, California. The building is constructed largely of mass timber and classified as a Type IIIA building used primarily as office space. The first section of the report focuses on the building’s defining characteristics and use cases. The second portion of the report presents a comprehensive review of egress design, fire alarm systems, fire suppression systems, structural design, implementation of mass timber elements, and flammability requirements. The results of the analysis show that the building complies with current prescriptive requirements.

The ensuing section of the report provides a performance-based analysis that reviews two design fire scenarios. The first design fire scenario involves a fire lobby, which is an intervening space along a primary egress path in the building. The analysis showed that the space reaches untenable conditions within 40 seconds. The RSET for the building is 26 minutes. Since this fire opens occupants to significant hazards, it is recommended that the fuel loading in the space is reduced. The second design fire scenario explored sprinkler activation within a team work-pod on the second floor. This space restricted the size of a fire within an otherwise open environment with high ceilings. Sprinkler activation in this area occurred at 351 seconds and provides coverage within the space.

2 Introduction

The building being analyzed is a 5-story office building located in the Moffett Park District of Sunnyvale, California. It is currently under construction at the time of writing, slotted for occupancy mid-to-late 2023. The building’s primary use is for office space with meeting rooms, although there is a large portion of the first level that is a café. The building was reviewed due to the uniqueness of the construction type. Classified currently as a Type-III A building, the building is using exposed cross laminated timber (CLT), the first of its kind in Sunnyvale.

Within the following sections, the building’s code compliance and design will be analyzed for egress, water-based suppression, fire alarm notification, and structural design. Egress elements such as occupant loads, exit widths, exit separation will be analyzed at to understand the capabilities of the building to provide safe exiting in the event of a fire. Concerns over interpretation of certain code sections will be addressed to determine compliance.

2.1 Building Description and Key Characteristics

- Location: Sunnyvale California
- Building
  - 5 Stories, 85 feet tall
  - Highest Occupiable Level: 66 ft
    - Not considered a high rise building as it is under the threshold set forth by CBC section 403
  - Type III A Construction, Cross-Laminated Timber (CLT)
- Use: The building will primarily consist of office space (Group B Occupancy) with half of the first level being occupied by a café (Group A Occupancy). There are also incidental storage rooms throughout (S-2 Occupancy), with the largest being a room on the first floor being used for bike storage.
• The gross area of the building is 168,987 SF. Levels 3 and 5 have smaller occupiable footprints, allowing for lofted ceilings on portions of levels 2 and 4.

• Site: The site of this project is located on the north side of the city. The building is surrounded by lots that are owned and occupied by the same tenant. The intent is for the occupants of this building and surrounding buildings to move and meet between all builds in the area.

• Building has unique floorplan. Alternating floor plate sizes from levels 2 through 5 as seen in Figure 1.

2.2 Code Summary

The building is being constructed under California Code of Regulations Title 24 which includes, but not limited to the following codes:

• California Building Code 2019 (CBC)
• California Fire Code 2019 (CFC)
• California Mechanical Code 2019 (CMC)
• California Plumbing Code 2019 (CPC)
• California Electrical Code 2019 (CEC)

The building is also subject to the local code, Sunnyvale Municipal Code 2019 (SMC) and its amendments to the above codes.

A high-level code requirement summary can be found in section 2.3 Table 1.

Applicable NFPA standards as referenced in the above codes are, but not limited to the following:

• NFPA 14: Installation of Standpipe and Hose Systems – 2016
• NFPA 24: Installation of Private Service Mains and the Appurtenances – 2016
### 2.3 Code Summary Table

**Table 1: Applicable Code Sections**

<table>
<thead>
<tr>
<th>Code Topic/Section</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Construction</strong></td>
<td>Type IIIA</td>
</tr>
</tbody>
</table>
| **Building Height (CBC Tables 504.3 and 504.4)** | Allowable Height and Stories – 85 ft / 6 Stories  
Actual Height and Stories – 85 ft / 5 Stories |
| **Fire Resistance Ratings (CBC Table 601)** | Structural Frame  
Bearing Walls | 1 Hour  
Exterior Walls | 2 Hours  
Interior Walls | 2 Hours  
Floor | 1 Hour  
Roof | 1 Hour |
| **Occupancy Classifications** | A-2 Assembly: Café  
B Business: General office area, including conference rooms  
S-2 Storage: Incidental storage, bicycle storage |
| **Occupancy Separations** | Café and bike storage exceeds the allowable 10% floor area per CBC 508.2, so separation required per table 508.4  
A OCC to B OCC | 1 Hour  
A OCC to S-2 OCC | 0 Hour  
S-2 OCC to B OCC | 1 Hour, if sprinklered |
| **Means of Egress** | Common Path of Travel (CBC Table 1006.2.1):  
A-2 = 75 ft  
B, S-2 = 100 ft  
Dead-end corridor length (CBC 1020.4):  
A-2 = 20 ft  
B, S-2 = 50 ft  
Exit Access Travel Distance (CBC Table 1017.2):  
A-2 = 250 ft  
B = 300 ft  
S-2 = 400 ft  
Egress Component Width (CBC 1005.3):  
Stairs = 0.2 inch per person  
Other = 0.15 inch per person |
| **Fire Protection Systems** | Fully Sprinklered Building  
Emergency Voice/Alarm Comm System  
Class I Standpipe  
Two Way Communication System |
<table>
<thead>
<tr>
<th>Code Topic/Section</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Occupancy</strong></td>
<td><strong>Interior Exit Stairways and exit Passageways</strong></td>
</tr>
<tr>
<td>A-2</td>
<td>B</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>S</td>
<td>C</td>
</tr>
</tbody>
</table>

Interior Finish Schedule (CBC Table 803.13)
3 Egress Compliance

3.1 Introduction

This section addresses the buildings compliance with the California Building Code, most specifically chapter 10. The occupant loads of each floor will be addressed and the exiting arrangement of the floors as well as exiting capacity will be reviewed. The building’s unique floor plates means that floor occupant loads vary quite a bit from floor to floor, yielding interesting limitations (regarding the 5th floor). Possibly the biggest concern with the building is the arrangement of the interior exit stairway that discharges through the lobby. While the code does allow this, the configuration presented in this design takes some liberty in applying the section. This compliance will be analyzed as well.

3.2 Occupancies

The building includes 3 different occupancies, A-2, B, and S-2. The primary A-2 occupancy is found on the first level with a full-service café. There are A-2 occupancies on levels 2 and 4 but are small in comparison. The café on the first floor and lobby occupies about 13,900 SF of the first floor, which is greater than 10% of the aggregate floor area. Because of this, the area needs to be separated from the B occupancies that are present by a 1-hour fire barrier constructed in accordance with CBC section 707.
Similarly, the storage occupancy on the first floor is also over 10% of the floor area so it too needs to be separated from the B occupancy, but not the A occupancy. The fire barrier is constructed through the center of the building separating the A and S from the B occupancy, shown in red in Figure 2. Additionally, on level one the large and extra-large conference rooms present do not exceed 50 occupants, so they do not classify as A occupancies.

Level 2 and 3 are similar in layout and are largely used for business uses. There is no concentrated business area, with only open office and small conference rooms being present. A break room and balcony are present giving small assembly areas on the plan-south side of the footprint. There are incidental storage and mechanical occupancies on the floor. The overall plans can be seen in Figures 3 and 4.

![Figure 3: Level 2 Occupancies](image)

Level 3 and 5 are similar as well. These floors, as previously stated, do not have a lot of occupiable floor area. The floors take up about half of the levels area, then are separated from the lower levels with a 1-hour fire barrier, creating high ceilings over the open office on levels 2 and 4. Level 3’s floor plan is shown in Figure 4.
These floors contain mostly conference and huddle rooms (B Occupancies) along with some amenity spaces in the form of break area, game room, and team meeting rooms (A Occupancies).

Full Occupancy distinctions can be found in Appendix A.

3.3 Occupant Load Tables

Table 2: Applicable Floor Area Allowances per Occupant – Table 1004.5

<table>
<thead>
<tr>
<th>Applicable Occ Loads from CBC Table 1004.5</th>
<th>Occupant Load Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly- Unconcentrated (tables and chairs)</td>
<td>15 Net</td>
</tr>
<tr>
<td>Business Areas (offices)</td>
<td>150 Gross</td>
</tr>
<tr>
<td>Accessory Storage areas, mechanical equipment rooms</td>
<td>300 Gross</td>
</tr>
<tr>
<td>Locker Rooms</td>
<td>50 Gross</td>
</tr>
<tr>
<td>Kitchens, Commercial</td>
<td>200 Gross</td>
</tr>
</tbody>
</table>

Figure 4: Level 3 Occupancies
Fully Tabulated Occupant Loads with associated floor plans are given in Appendix B. The applicable occupant load factors (OLF) can be found in Table 2. Per CBC 1031.2 Small assembly spaces under 50 occupants shall be classified as B occupancies. The overall occupant load of each floor is found in Table 3 below, along with the number of exits required by CBC table 1006.3.2. It is worth noting that the assembly balconies on levels 2 and 4 each have around 75 occupants. These spaces require and are provided with 2 exits.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Occ Load</th>
<th>Required Exits</th>
<th>Provided Exits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>1481</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Level 2</td>
<td>721</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Level 3</td>
<td>481</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Level 4</td>
<td>749</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Level 5</td>
<td>483</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

### Table 3: Total Occupant Loads per Floor and Exits

3.4 Egress Capacity & Arrangement

This building is equipped with 3 interior exit stairways up to Level 4. The middle stair (Stair 2) does not extend up to level 5, leaving this level serviced with Stairs 1 and 3 as exits. Per CBC Table 1006.3.2, This allows for up to 1000 occupants on levels 2 through 4, and 500 occupants on level 5. Although this provides sufficient exiting for each floor in terms of stairwells, capacity is still limited by the width of each component.

The building is equipped with an emergency voice/alarm communication (EVAC) system and thus allows for egress capacities of 0.2 inches/occupant for stairways and 0.15 for all other components. By dividing the provided stairway width and door widths (52” and 40”, respectively) the allowable occupant load of each stairwell was determined. The design of the stairs doors allows for 267 occupants, where the stairs themselves only allow for up to 260 occupants. The stairs are most restrictive element of the egress system, limiting it 260 occupants per stairwell. This allows for a maximum total occupant load of 780 for levels 2 through 4, and 520 for level 5. The greatest occupant load on a floor in the building is 749 on level 4 which can be handled by the stairwells. The required exiting widths are shown in Table 4 below.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Occ Load</th>
<th>Required Total Exit Width</th>
<th>Provided Exit Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>1481</td>
<td>222.15”</td>
<td>470.0”</td>
</tr>
<tr>
<td>Level 2</td>
<td>721</td>
<td>144.2”</td>
<td>156.0”</td>
</tr>
<tr>
<td>Level 3</td>
<td>481</td>
<td>96.2”</td>
<td>156.0”</td>
</tr>
<tr>
<td>Level 4</td>
<td>749</td>
<td>149.8”</td>
<td>156.0”</td>
</tr>
<tr>
<td>Level 5</td>
<td>483</td>
<td>96.6”</td>
<td>104.0”</td>
</tr>
</tbody>
</table>

Exit separation between the 3 stairways meets the requirements of CBC 1007.1 for being separated by greater than 1/3 the diagonal in a sprinklered building. Exit separations for each floor, as well as exit separation for the assembly areas on each floor can be found in Table 5. Egress analysis diagrams can be found in Appendix C.
Table 5: Exit Separations

<table>
<thead>
<tr>
<th>Floor</th>
<th>Longest Diagonal</th>
<th>Req’d Separation Distance</th>
<th>Provided Separation Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 - Office</td>
<td>185’</td>
<td>62.7’</td>
<td>162’</td>
</tr>
<tr>
<td>Level 1 - Café</td>
<td>178’</td>
<td>59.3’</td>
<td>129’</td>
</tr>
<tr>
<td>Level 2</td>
<td>324’</td>
<td>108’</td>
<td>221’</td>
</tr>
<tr>
<td>Level 2 - Balcony</td>
<td>136’</td>
<td>45.3’</td>
<td>51’</td>
</tr>
<tr>
<td>Level 3</td>
<td>257’</td>
<td>85.7’</td>
<td>221’</td>
</tr>
<tr>
<td>Level 4</td>
<td>324’</td>
<td>108’</td>
<td>221’</td>
</tr>
<tr>
<td>Level 4 - Balcony</td>
<td>137’</td>
<td>45.3’</td>
<td>51’</td>
</tr>
<tr>
<td>Level 5</td>
<td>257’</td>
<td>85.7’</td>
<td>221’</td>
</tr>
</tbody>
</table>

There are two sets of convenience stairs within the building. One set connects levels 1 and 2 and is located within the café area. The other connects levels 2 through 5 and is located in the open office area (seen in Figure 5). These stairs are not used as egress components and just used for occupant movement through the building.

For level 1 café, the area is equipped with 3 exits with widths of 68”, 80”, and 40”. The café exiting allows for an occupant load of 1253, which is greater than the calculated load of 627. Exit separation is met.
3.5 Exit Access Travel Distance

Exit access travel distances and common path of travel are dictated by sections 1006.2.1 and 1017.2, respectively. These values are tabulated in Table 6 below. The longest exit access distance required in the building falls on the second and fourth floor, at 207ft of travel, below the threshold of 300ft required in a sprinklered B occupancy. Dead-end corridors exist on the third and fifth floors. They have a maximum length of 24.5 ft, which is less than the limit of 50ft per CBC 1020.4.

<table>
<thead>
<tr>
<th>Occupancy Classification</th>
<th>Common Path of Travel</th>
<th>Exit Access Travel Distance</th>
<th>Dead-end corridor length</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2</td>
<td>75 ft</td>
<td>250 ft</td>
<td>25 ft</td>
</tr>
<tr>
<td>B</td>
<td>100 ft</td>
<td>300 ft</td>
<td>50 ft</td>
</tr>
<tr>
<td>S-2</td>
<td>100 ft</td>
<td>400 ft</td>
<td>50 ft</td>
</tr>
</tbody>
</table>

3.6 Interior Exit Stairways

The building is equipped with 3 interior exit stairways. The stairways are constructed in accordance with CBC 1023.2 and have a 2-hour rating since they connect 4 stories or more with openings having a 90-minute fire protection rating. Stairways 1 and 3 are connected directly to the exterior of the building providing sufficient exit discharge. Stairway 2 (Figure 6), in the center of the building does not have exit discharge directly to the exterior of the building. This stairway takes advantage of exception 1 to CBC 1028.1 which allows up to 50% of the occupants to discharge into an open area within the building instead of the exterior if:

- Discharge of interior exit stairways and ramps shall be provided with a free and unobstructed path of travel to an exterior exit door and such exit is readily visible and identifiable from the point of termination of the enclosure.
- The egress path from the interior exit stairway on the level of exit discharge is protected throughout by an approved automatic sprinkler system.
- Where required interior exit stairways serve the same floor level and terminate at the same level of exit discharge the exit discharge door of the interior exit stairway shall be separated by a distance of not less than 30 feet or not less than one-fourth the length of the maximum overall diagonal dimension of the building, whichever is less.
The stairway, however, does not meet the first point of the exception, the door this leads to does not lead directly to the exterior of the building, but into an entry vestibule. It can be argued that this meets the intent of the code because a vestibule is commonly an unoccupied space that just serves as a portal to the building. The idea that the vestibule has a possibility of fuel loading, gathering of occupants and general increase of hazard as it introduces another point of complication leads to the conclusion that it isn’t code compliant.

3.6 Egress Conclusion

Overall, the building’s unique architecture mostly complies with the governing building code for egress design. The biggest question is the arrangement of stair 2 and how it discharges into the building. It is my opinion that it does not meet the presented exceptions since it does not lead directly to the exterior of the building. Vestibules commonly are not loaded with fuel, and not seen as a gathering spot so it should pose little additional risk. They generally act as a portal to the inside, generally used to separate the indoor/outdoor climates. With the design as presented, the fire safety strategy of the building could be compromised if these commonalities do not happen. This would be up to the building owner/tenant to ensure that these spaces stay uncluttered. I believe the intent of the code is clear in the wording to prevent any more compromises to the fire safety.
4 Water Based Suppression Compliance

4.1 Introduction

Water-based suppression systems are required in all new building's constructed in Sunnyvale. The intent is to raise the fire safety throughout the city. This also allows for less stringent structural and egress requirements because of their inclusion. This section of the report looks at municipal code sections that change their installation from the typical design for a B-occupancy. The design choices within the building will also be analyzed. Due to the unique layout of the building, the building required certain design requirements to provide compliant protection.

4.2 Water Supply

The building’s water supply is solely provided by city water. Flow data is provided by the city’s Environmental Services Department. The city supply can provide 1500 gallons per minute at 88 psi, with a static pressure of 90 psi. The hydrants used for this data and their locations are shown in Figure 7. The city main is 12” and runs under the street on the project’s frontage. From there, a 10-inch line feed to the RPDA Backflow assembly. After that connection, the building is fed by an 8” C900 PVC service. The city provided supply should be noted as very good, as it is very near the water treatment plant.

Sunnyvale requires a hydrant to be within 25 ft of the street or approved fire department access. The city also requires the fire department connection to be located within 50 feet of a hydrant (SMC 16.52.903.3.7). 4 onsite hydrants are being added, to provide a hydrant close to the FDC and to provide

![Figure 7: Jobsite and nearby hydrants](image-url)
water sources around the perimeter of the building. The FDC size is driven by city requirements, which state that fire lines over 6 inches in diameter will be equipped with a four-way FDC with 2.5" hose connections.

4.3 Hazard Classification

4.3.1 SMC 16.52.903.3.1.1

Normally, a building with mostly A and B occupancy classification would fall under the light hazard category. Sunnyvale requires spaces within a building having no designated tenant to be designed with minimum sprinkler density of Ordinary hazard 2. While this building has a designated use, the intent of the code is to protect future tenants from costly sprinkler upgrades. The idea is any of these spaces will be able to handle business or R&D tenants without having to increase the density of the system. Due to the nature of businesses in Silicon Valley, the city sees many tenants come and go from spaces. Many of the permit applications in the city are for tenant improvements.

In this building there are very few areas that are provided with light hazard designation. The only areas that are spaced at 225 sq.ft. are areas that have a drop or hard ceiling installed. These areas would be calculated at 0.1 gpm/ft² over 1500 ft². In most areas, the ceiling is open to the framework and these areas are provided with OH2 protection at 130 sq.ft. spacing and calculated at 0.2 gpm/ft² over 1500 ft².

4.3.2 SMC 16.52.903.2 (6)

Another intricacy of working in Sunnyvale is municipal code section 16.52.903.2(6). This requirement is that all accessible combustible and noncombustible sub-floors, attic space, areas above ceilings, which are greater than 6 inches in height and contain electrical or mechanical components shall be provided with sprinkler protection. What this means is that over all t-bar, or areas above hard lids that are accessible require sprinklers protection. The intent of this section it to stop fire spread through areas that contain possible fire source that may not readily visible to the occupants of the building. This requirement adds greatly to the complexity of the system. The systems in these concealed spaces are generally designed with Ordinary Hazard designation and heads are spaced at 130 ft². On the design and plan checking side, this can make plans difficult to read due to the complexity and overlaying heads.
4.3.3 Alternative Method and Means

The building uses sprinkler protection to create 1 hour fire barriers in a few locations. Tyco window sprinklers (TY3488) will be provided at windows to separate spaces to avoid an atrium condition connecting more than 2 stories. The building has a unique characteristic of having half of floors 2 and 4 being double height, with the 3rd and 5th floor having half the floor area. Floors 3 and 5 have a 1-hour fire barrier to completely separate the lofted zones to avoid having more than 2 stories open to each other. To keep the open feel, windows are provided on these levels, with the caveat that specialized sprinklers be used to maintain the barrier, shown in Figure 8. If these sprinkler/windows were not employed, a smoke control system would be required in the building due to the connections of the stories.

4.3.4 Requirements
Per NFPA 12 -2016: The required design criteria and hose stream allowance are listed in Table 7.

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Design Density</th>
<th>Design Area</th>
<th>Hose Stream Allowance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Hazard</td>
<td>0.1 gpm/ft²</td>
<td>1500 ft²</td>
<td>100 gpm</td>
</tr>
<tr>
<td>Ordinary Hazard Group II</td>
<td>0.2 gpm/ft²</td>
<td>1500 ft²</td>
<td>250 gpm</td>
</tr>
</tbody>
</table>

Figure 8: Location of TY3488 Sprinklers
4.4 System Components

4.4.1 Risers

The systems on each floor are under 52,000 ft\(^2\) meaning that only 1 riser is required for the building. The riser is a class 1 manual combination, located in the east side of the building. The riser is fed from the north side of the building by a 6-inch line schedule 10 steel pipe. The 6-inch line feeds all the standpipes in the building, with 3 located in the main stairwells of the building, and two in the middle of each floor to provide the required hose reach through the building. The locations of the hose connections, riser, and point of connection are shown in Figure 9.

The main riser is 6” schedule 10 pipe, which breaks into 4” cross mains on each floor, apart from floor 5, which has a 6” cross main. For each floor, the riser breaks into a 4” cross main that has a check valve, inspector test and drain, and a flow switch. A diagram of the riser configuration is shown in Figure 10.
4.4.2 Pipe Sizing

There are multiple sizes of cross mains in this building. The system has a combination of grided areas and small tree systems throughout due to the complexity of the floor layouts. After analyzing the floors, the easiest way to characterize the piping plan is to group the floors as the following: Floors 1 and 3, Floors 2 and 4, and Floor 5. Floor 5, although it is a “half floor” extends over the full footprint of the building and covers the open office area of floor 4. These full floor systems all have similar layouts, shown in Figure 11. All piping in the building 2.5” and greater is schedule 10 black steel pipe, and all pipe 2” and smaller is schedule 40 black steel piping.

Floors 1 and 3 systems span the whole floor. On the north side of the building the system is grided, on the south it is a tree system. There are two cross mains for the south of the building tree section and are both 4” pipe. For the north side grided section the cross main is 4” with the far side cross...
main being 3 inches. Branch line sizing also varies depending on location. Within the grid system, the branch lines are 1 ¼”. In the tree system, branch lines less than 15 ft in length are 1 ¼” pipe, between 15 and 25 ft in length they are 1 ½”, and greater than 25 ft they are 2” pipe. This trend is consistent on both floors.

Floor 2 and 4 systems span only a portion of the building footprint, similar to the size of the tree section of floors 1 and 3. The typical layout is shown in Figure 12. Like the other floors, these sections are designed with a tree layout with two 4” cross mains. The branch lines follow a similar pattern as well. Floor 5 differs from the other full coverage floor in that it has a large area with a skylight. This area is that because there are side wall sprinklers in the skylight. The gridding on the north side employs the same 4” and 3” cross mains, though the branch lines have been upgraded to 1 ½” pipe to deal with the extra demand. Similarly, on the south side of the building, the primary cross main is 6”. Branch lines on the south side are mainly 2” pipe, with some 1 ½” pipe in areas. These sizes are tabulated in Table 8.

<table>
<thead>
<tr>
<th>Location</th>
<th>Portion of building</th>
<th>Cross Mains</th>
<th>Branch Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floors 1 and 3</td>
<td>North Side Grid</td>
<td>4” primary, 3” secondary</td>
<td>1.25” lines within grid</td>
</tr>
<tr>
<td></td>
<td>South Side Tree</td>
<td>4” pipe</td>
<td>2” for long runs, 1.5” for med runs, 1.25” for short runs</td>
</tr>
<tr>
<td>Floors 2 and 4</td>
<td>N/A</td>
<td>4” Schedule 10 Pipe</td>
<td>2” for long runs, 1.5” for med runs, 1.25” for short runs</td>
</tr>
<tr>
<td>Floor 5</td>
<td>North Side Grid</td>
<td>4” primary, 3” secondary</td>
<td>2” lines within grid</td>
</tr>
<tr>
<td></td>
<td>South Side Tree</td>
<td>6” primary, 2” secondary</td>
<td>2” line, 1.25” for short runs</td>
</tr>
</tbody>
</table>

4.5 Hydraulic Calculations

Hydraulic calculations were performed for the most remote area. This area was located on the 5th floor south side tree section. Ideally, more areas would have been tested, though due to the limitations of iterating and pressure balancing with hand calculations, I was limited to the tree system section. The 5th floor was chosen because most of the pressure drop in this building is due to height, since large piping is employed throughout. Additionally, floor plans were very similar across all floors, so the highest floor will have the most demanding area. The 5th floor most remote area (Figure 13) chosen was in the light hazard designation at the end of the branch lines. The remote area includes 17 sprinklers, most of which are flex drops into huddle rooms and bathroom, but it does also include the
window sprinklers specified in the AMMR. Tyco concealed pendants (TY3531) heads were used in these light hazard areas. The window sprinklers (TY3488), as they don’t cover a floor area, but a span of glass, are required to floor 15gpm per their cutsheets. They have a K-Factor of 5.6, meaning they require 7 psi to operate.

![Figure 14: Hydraulic Calculation Results](image)

The calculation shown in Figure 14 (provided in the Appendix D) showed a required flow (after hose stream allowance) of 458.2 gpm at 81.8 psi. This gives about an 8psi, or 10% safety factor at the POC to the city main. It is also worth noting that the systems standpipes are fed by the FDC. Since the building lacks a fire pump, the requirement to meet 100 psi at the roof level standpipes will be met by feeding them from the responding engine.

4.6 Maintenance, Testing, and Inspection Criteria

Maintenance, testing and Inspection Criteria can be found in NFPA 25, which should be distributed to the property owner on commissioning the system. The pertinent tables are 5.1.1.2 (Sprinkler System), 6.1.1.2 (Standpipe and Hose Systems), 7.1.1.2 (Private Service Mains), and 13.1.1.2 (Valves, Valve Components, and Trim). See Appendix F for more information.

4.7 Fire Sprinkler Conclusion

The buildings fire sprinkler system provides compliant protection throughout the building. The protection provided exceeds what is realistically required by NFPA standards due to municipal code sections. Ordinary Hazard protection is provided in many areas of the building which is generally light hazard occupancy. This provides a robust backbone of protection, allowing it to be adjusted for possible tenant changes in the future. This, along with the excellent water service to the building, provides reliable fire protection for the building. Next, an analysis of the notification system in the building.
5 Emergency Voice/Alarm Communication System

5.1 Introduction and Requirements

Fire Alarm installation is governed by the California Building Code 2019 Edition Section 907. The building is a B Occupancy with an occupant load totaling over 500, thus requiring a manual fire alarm system installed in accordance with NFPA 72. The building does employ an automatic fire sprinkler system, thus meeting the exception for manual fire alarm boxes. While they meet the exception, two manual fire alarm boxes are employed, one at the panel and one at the annunciator.

As stated previously, although not required, an emergency voice/alarm communication system is employed in this building. This is due to an internal standard within the company that is occupying the building/speculatively used to reduce the size of egress components within the building. Since the building is not a high-rise, it is not a requirement within the CBC that the building be provided with paging zones, as such any calls over the microphone will act as an all call. This system is analogous to a regular notification system (Horns/Strobes) for our purposes. The reasoning is unclear as to why the tenant has decided to upgrade the system to voice. However, the advantage of the system is that it allows clearer communication to the occupants of the hazard. On any alarm signal, the system will provide notification throughout the building. The voice command given will be the following: “May I have your attention please; may I have your attention please. The fire alarm has been activated in the building, please proceed to the nearest exit, and leave the building.” The voice message is preceded by a temporal three pattern.

Although the system is capable of being used for hazards other than fires, this is not employed. The building is a general, non-high rise business occupancy. The building is at low risk of any human-caused events (terrorism, HazMat spills, etc.). While being in an area that is prone to earthquakes, they do not pose a large threat to the occupants in the building. Therefore, it is reasonable that the system as deployed will be adequate for the building.
5.2 Sequence of Operations

The building’s fire alarm system monitors several initiating devices within the building. Once a signal is received, it will transmit to a central station via an AES Mesh Radio communication system. The panel also monitors an Emergency Responder Radio Communication System (ERRCS) within the building. This system relays radio signals for responders and boost signals within the building.

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence of Operations</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*Figure 16: Sequence of Operations*
Full sequence of operations for the building can be found in Figure 16. Within the sequence, the applicable sections of the NFPA codes are listed next to the operation. Apart from the ERRCS monitoring points (these points come from NFPA 1221) the requirements are listed within NFPA 72. One notable sequence is that of elevator recall. Due to local ordinances, shunt trip for elevator power is not permitted within Sunnyvale. As such following California Building Code Chapter 30, a smoke detector is installed within the elevator shaft and machine room, in lieu of sprinklers and a heat detector. Upon activation, the elevators will recall to the first floor of the building.

5.3 Smoke Control Requirements

The building is not provided with a smoke control system. The building’s highest occupiable level is at 66 ft from lowest fire department access. According to CBC section 403 for high rises, this occupiable level would need to be 75 ft from lowest access to require a smoke control system. The atrium that is created due to the convenience stairs also only connects 2 stories. A smoke control system is required when more than 2 stories are connected per CBC 907.2.13.

Although the building does not require a full smoke control system based on the requirements of Section 907, the building is still equipped with some smoke control elements. Duct detectors are placed on rooftop air handling units. When smoke is detected by these duct detectors, the shutdown the AHUs to prevent the migration of smoke through the ductwork. Additionally, there are fire smoke dampers located at penetrations through rated walls. The dampers will close when activated by duct detectors placed within the ductwork near the penetration to prevent smoke from crossing the rated assembly. These FSDs also have heat-links that will activate the shutters to maintain the rated assembly in a fire scenario.

5.4 Fire Alarm Equipment

5.4.1 Fire Alarm Panel and Booster Panels

The building’s fire alarm panel is in an electrical room located on the southeast side of the building (Figure 15). This is also reflected in the floor plans in the appendix. The fire panel used Notifier NF2-3030. This panel supports over 3000 signaling devices on 10 SLCs. It also supports digital voice commands, mass notification, and in listed for gas detection. The panel is accompanied by a remote annunciator (LCD-160) located in the main lobby. The annunciator gives responding units access to vital information, rather than having to go to the panel. The annunciator also has a microphone, to manually notify occupants if the need arises. Digital Audio Amplifiers (DAA2-7575) are also employed in this system to drive the speaker system.

FCPS-24F6 remote power supplies are located throughout the building as well in order provide extra battery capacity and locations to lower wire runs to notification. 2 power supplies are provided per floor in electrical rooms located on the east and west sides of the building. Each panel can handle up to 4 NAC circuits.

This system is over-built for the building. There is a lot of extra capacity in both the power supplies and the panel. This seems to be common within these tech buildings. The reasoning believed is because of how often tenant improvement work happens within these structures. The system is provided with ample safety margin to account for any changes and expansion that needs to happen. With a strong foundation, it is easier to upgrade down the road.
5.4.2 Initiating Devices

The primary form of fire detection in the building will be in the form of fire sprinklers, and by extension, a flow switch. A Potter VSR flow switch (Figure 17) is employed on each floor of the building. This is required by the Sunnyvale municipal code in buildings over two stories in height. The purpose of this code section is to provide the response team a better understanding of where the hazard is. Flow switches will have a delayed activation to account for fluctuations in pressure. Generally, the jurisdiction requires between 40-50 second delay in activation time. This delay is allowable by NFPA 72 Section 17.13.2. by This will be accounted for in detection time in later sections.

Along with fire sprinkler monitoring systems, the building is equipped with 3 other forms of alarm initiation: Pull stations (NBG-12LX), Photoelectric smoke detection (FSP-951), and monitoring modules on an ANSUL Hood suppression system. Pull stations are located at two locations; One pull station is at the main panel and the other is located at the annunciator in the lobby. Smoke detection is provided in the battery room, above FACP's and BPS's, and in elevator lobbies and elevator shaft. All smoke detectors are provided in areas where they protect small rooms/equipment, where 30 x 30 ft spacing provides adequate coverage. Smoke detectors in the elevator lobbies, to facilitate elevator recall are located within 21ft of each door, as required by NFPA 72 section 21.3.5.1. Lastly, a Type I hood is located within the café area, meaning it will be equipped with a kitchen hood suppression system. The installation of the system is per NFPA 92 and is required to be monitored by NFPA 72 Section 17.14. On activation of the system, the building’s fire alarm will notify the occupants to evacuate.

There is also the presence of duct detectors (DNR/FSR-951) shown in Figure 18 within air handling units, at FSD's, and make up air units. These devices will initiate a supervisory signal and shut down associated units/close associated FSD's if smoke is detected. These are set to supervisory rather than alarm to avoid the nuisance/false alarms that could occur due to dust moving through the ducting.
Other supervisory signals include tamper valves, OS&Y valves, and monitoring modules on other life safety elements (ERRCS, Two-Way Communication, AES Radio Communicator).

5.4.3 Notification Devices

Notification throughout the building is provided by a combination of strobes, speaker/strobes, and speakers. Notifier SCWL (Strobe), SCWK (Waterproof Strobe), SPSCWL (Speaker Strobe), SPSCWK (Waterproof Speaker/Strobe) are employed to provide full coverage notification throughout the building. Locations of the appliances within the building can be seen on the drawings in the appendix. Spacing is handled a bit differently for use of speakers, as opposed to using horns. Notifier’s horn counterpart to these models (PC2WL) Sound pressure output at a Temporal High setting of 89 dBA at 10 ft. With the speakers, there is a Wattage selector switch to control the output levels.

<table>
<thead>
<tr>
<th>Setting</th>
<th>UL Reverberant (dBA @10 ft)</th>
<th>UL Anechoic (dBA @10 ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼ W</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>½ W</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>1 W</td>
<td>83</td>
<td>83</td>
</tr>
<tr>
<td>2 W</td>
<td>86</td>
<td>86</td>
</tr>
</tbody>
</table>

*Figure 19: Sound Pressure levels based on Wattage*

The levels can be set from ¼ W to 2 W, which can adjust sound level settings from 77 dBA to 86 dBA at 10 ft, respectively. These values are provided by the manufacturer and shown in Figure 19. The building is a business occupancy meaning average ambient sound levels are assumed to be at 54 dBA as prescribed by Table A.18.4.4 in NFPA 72. With the design criteria for sound levels through the building will be about 70 dBA. It is assumed that sound levels in open areas will be reduced by 6 dBA when the distance between the device and listener is doubled.

Visual notification through the building is determined by NFPA 72 Table 19.5.5.5.1 (b) for ceiling mount devices. Within corridors, the spacing of the devices are within 15 ft of the end of the corridors and have no more than 100ft in between. This is seen on the first floor where all devices within the business areas. The devices are placed in a way to maximize coverage by putting them at intersections.

5.5 Power Requirements

Power and Battery requirements were determined for two panels in the building. The first, is the fire alarm panel shown in Figure 20. Notifier provides a program to tabulate parts and current draw of all the parts. 24 hours of standby power is required per section 10.6.7.2.1. In addition to the standby requirements, 15 minutes of power draw must be account for in buildings with emergency voice evacuation systems per section 10.6.7.2.1.2. This varies from normal systems, where the required time is only 5 minutes. In addition to the draw of the system, the secondary power supply must also have at least a 20% safety margin.
A second calculation (Figure 21) was performed for one of the booster panels located on the third floor. This booster panel has the most devices on it, as well as having the highest current drawing devices (4 177cd speaker/strobes). These panels calculations were performed similarly to the main panel. The panel has an extreme excess of capacity. It is unclear why the design deploys 2 FCPS per floor, though it is most likely to account for voltage drops for some of the further/higher current draw wiring runs.

5.6 Installation, Acceptance Testing, Maintenance and Records

Once plans of the system are approved, inspections can be conducted. Initial inspections will be done to verify correct wiring, wiring support, and device locations are installed per plan. Additional consideration will be taken in field to inspect and roughly verify 100% coverage is obtained. If, while on the job site, new obstructions are installed, devices may need to be moved or added if necessary.
Upon completion of installation, NFPA 72 section 14.3 outlines how acceptance testing will be carried out. Functional testing and acceptance of the system will be conducted. A 24-hour battery test will be conducted, following with a 15 minute “ring-out” of the notification devices to verify that the batteries are sufficient to power the system during the required time. Functional testing of all initiating devices will be done to ensure that everything installed meets the sequence of operation. Candelas and wattage will be verified on all notification devices. Once testing is complete, signals will be verified with central station to make sure that the signals reported on site match those that the monitoring station receives. Upon completion of the acceptance testing, As-Builts and Record of Completion will be submitted to the AHJ for records, as well as a copy being kept on site in a document box. The owner will be provided with an operation manual for the systems components.

As an aside, it is worth noting since the system is built in mind for future upgrades, that there are specific requirements for this. When changes are made to site specific software, all functions of new devices added will be tested. In addition, a 10% retest of initiating devices will be conducted as well. This is a requirement laid out in NFPA 72 14.4.2.4.

Testing of the system after acceptance also falls under the guidelines of Table 14.3 of NFPA 72. The initiating devices present in this system apart from water flow switches, are required to be tested on a semiannual basis, with the latter being tested on a quarterly basis. Notification appliances are to be tested on a semi-annual basis as well. Power extenders, remote power supplies, and the two-way communication system are required to be tested on an annual basis. If any of these areas found to be deficient, the owner’s representative is to be notified within 24 hours. Maintenance is to be carried out following manufacturer’s guidelines.

5.7 Fire Alarm Conclusion

The buildings fire alarm system is standard all things considered. Apart from the superfluous inclusion of a voice system, the system is installed to provide occupant notification throughout. There are no areas of concern with the system or its capabilities or its compliance with NFPA 72.

Structural Compliance

6.1 Introduction

To preface, it is worth noting the applicable code editions and the construction type chosen. This building’s construction is largely constructed with mass timber, that is manufactured wood materials. Whether that is cross laminated timber panels, glulam beams and columns, etc.; most material is wood. In the interim code adoption cycles and impending codes, this building would fall under the umbrella of Type IV construction. At the time of this project’s submittal, these provisions were not adopted, therefore it was submitted at Type IIIA construction. The analysis of this building will be done with that criterion.
6.2 Building Height and Area Limits

6.2.1 Allowable Heights

The maximum allowable heights and number of stories for Type IIIA construction are as shown in Table 9:

<table>
<thead>
<tr>
<th>Occupancy Classification</th>
<th>Allowable Height (Table 504.3)</th>
<th>Allowable Stories (Table 504.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-2</td>
<td>Type IIIA 85 ft</td>
<td>Type IIIA 4 stories</td>
</tr>
<tr>
<td>B</td>
<td>Type IIIA 85 ft</td>
<td>Type IIIA 6 stories</td>
</tr>
</tbody>
</table>

The separated A occupancy of the building is located on the first floor; thus, the building is within the limitations of both height and number of stories for all occupancies.

6.2.2 Allowable Areas

The floor areas, allowable floor areas (as adjusted per CBC 506.2.4), and floor area ratios can be seen below in Table 10:

<table>
<thead>
<tr>
<th>Level</th>
<th>Actual Floor Areas (sq.ft.)</th>
<th>Allowable Floor Area (sq.ft.)</th>
<th>Area Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Floor</td>
<td>A-2 13,880</td>
<td>28,940</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>B 17,448</td>
<td>105,735</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>S-2 11,220</td>
<td>144,690</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>1st Floor Subtotal</td>
<td></td>
<td>0.83</td>
</tr>
<tr>
<td>2nd Floor</td>
<td>49,655</td>
<td>105,735</td>
<td>0.47</td>
</tr>
<tr>
<td>3rd Floor</td>
<td>14,799</td>
<td>105,735</td>
<td>0.14</td>
</tr>
<tr>
<td>4th Floor</td>
<td>44,778</td>
<td>105,735</td>
<td>0.44</td>
</tr>
<tr>
<td>5th Floor</td>
<td>15,344</td>
<td>105,735</td>
<td>0.15</td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
<td>2.03</td>
</tr>
</tbody>
</table>

The building meets the requirements of CBC 506.2.4 as the total floor area ratio is below 3.

6.2.3 Separated Occupancies

The first floor is separated into 3 occupancies, A-2, B, S-2. Per CBC 508.4, the sum of the ratios of actual building area of each separated occupancy divvied by the allowable building area of each separated occupancy shall not exceed one. The total ratio for floor 1 is 0.83. Required separations between occupancies per Table 508.4 for these occupancies is shown in Table 11:

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Allowable Height (Table 504.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A OCC to B OCC</td>
<td>1 HR</td>
</tr>
<tr>
<td>A OCC to S-2 OCC</td>
<td>0 HR</td>
</tr>
<tr>
<td>B OCC to S-2 OCC</td>
<td>1 HR</td>
</tr>
</tbody>
</table>

Note: these separations are only required in the separated occupancies, when the occupancies are accessory, these separations are 0 HR.
6.2.4 Accessory Occupancies

Floor 1 has separated occupancies, on floors 2-5, the A-3 and S-2 occupancies are considered accessory to the B occupancies if the aggregated accessory occupancies account for less than 10% of the floor area. The floor areas and their percentages are shown in Table 12 below.

<table>
<thead>
<tr>
<th>Level</th>
<th>A-3 Occupancy Floor Area (sq.ft.)</th>
<th>S-2 Occupancy Floor Area (sq.ft.)</th>
<th>Floor Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1,103</td>
<td>1,469</td>
<td>5.2</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>647</td>
<td>4.3</td>
</tr>
<tr>
<td>4</td>
<td>1,095</td>
<td>981</td>
<td>4.4</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>768</td>
<td>5.1</td>
</tr>
</tbody>
</table>

6.2.5 Fire Resistance Requirements

Table 13 below summarizes the required fire resistance requirements for a Type IIIA building per CBC Table 601. Fire resistance based on separation distance (CBC Table 602) do not have any extra requirements as the buildings separation from neighboring properties far exceeds 30ft. A fire rating of 0 hours is required for all construction types when separation distance is greater than 30ft.

<table>
<thead>
<tr>
<th>Building Element</th>
<th>Required Rating</th>
<th>Provided Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Frame</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bearing Walls (Exterior/Interior)</td>
<td>1</td>
<td>No Ext. Bearing Walls Present</td>
</tr>
<tr>
<td>Nonbearing Walls and Partitions</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Floor Construction</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Roof Construction</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

6.3 Building Construction Elements

6.3.1 Foundation

The foundation of the building is comprised a pile and foundation on grade system. The concrete used is 5000psi concrete. The concrete slab sits on compacted structural fill with filter fabric, vapor barrier, sheet water proofing to protect from environmental factors.

6.3.2 Columns

The columns throughout the building are constructed of mass timber glulam. Two sizes are used throughout the building: 14 ¼ x 29 ¾ columns which are used on the north side of the building. These columns are located largely on the north side under the areas that are absent of slabs on floors 3 and 5. The building also employs larger, 17 ¾ x 29 ¾ columns on the south side of the building. These columns are upsized because of the larger load from the slabs on 2-5. The columns are located on spacing of about 30’ x 30’.

Brace frames are located between the stairwells and on the north side of the building for shear strength. The brace frames are of steel construction. They are supported by W18x97 frames.

6.3.3 Beams

Like the columns, most of the girders and joists that support the CLT panels are glulam beams. The girders run the long dimension of the building and have multiple sizes. To support floors 2-5, 14 ¼ x
31 ¼ beams are used, to support the roof 12 ¼ x 31 ¼ beams are used. As for joists, two sizes of glulam beams are used. Around the rated shafts, 10 ¼ x 25 ¼ beams are used. Per the fire rating plans, these were upsized to allow for a larger sacrificial layer in the beams to allow for fire protection without affecting structural integrity. Throughout the rest of the building, in support of the panels, 8 ¼ x 23 ¼ beams are used. The columns are notched, allowing the girders to slot in. The girders are then secured by 2 5/16” x 22” screws. The holes are then plugged with wood to protect the screw and provide fire resistance.

Steel beams are used to support the second-floor section over the south entrance of the building. The main girders are built-up W40x297 beams with W21x122 joists spanning between them.

6.3.4 Floors and Roof

Flooring assemblies for the building are made from cross laminated timber panels. There are three different thicknesses of panels used. The first is a 3-layer (4 1/8” thick) panel. This panel is composed of 2 layers of spruce-pine-fir layers, with a Douglas-fir layer on the bottom. The layers alternate orientation by 90 degrees to provide some strength in both directions. The second panel type has 7 layers (9 5/8” thick). The makeup of this panel type is similar with the first, being mostly SPF with the 7th layer being Douglas fir. The last type is a 9-layer panel that is 12 3/8” thick. The floors are reinforced with a 3 ½” concrete topper. The roof construction has the same materials as the floors along with the concrete topping layer.

6.3.5 Exterior Walls

Exterior walls are constructed using 6” metal studs. The interior is lined with 1 layer of 5/8” gypsum board and a layer of insulation. On the exterior, there is a layer of 5/8” gypsum sheathing followed by a ¾ plywood sheet. Following that, a vapor barrier is provided with fiber board insulation. The wall is finished with a 1” layer of pressure-treated wood to attach the wood siding. These exterior walls are mostly found by the entrances, whereas the rest of the building is cladded by windows.

6.3.6 Interior Walls and Partitions

Interior walls and partitions are constructed using metal stud assemblies. The walls are insulated, and depending on the required rating, the layers of 5/8” gypsum are adjusted. For unrated and 1 hour rated partitions, 1 layer of Type X 5/8” gypsum is used. For 2 hour rated assemblies, 2 layers are used to achieve the rating. On fire rated walls, fire stop is present at the joints to provide rating to the floor/ceiling.

6.3.7 Fire Rated Doors

Fire doors are present throughout the building. For the large amount of door openings, they are non-rated. Huddle rooms, conference rooms, bathrooms; many of the B-group occupancies include non-rated doors. These spaces do not require any separations from each other, so neither do the openings. Fire rated doors are in areas that require these separations. 45-min, 60-min, and 90-min doors are found throughout. For openings into the stairwells, 90-min doors are employed. This is consistent with CBC requirements for 2-hour fire barriers. 60-min doors are employed for the 1 hour rated shaft enclosures. These shafts serve as mechanical transfer through the floors. For all other 1-hour rated partitions, 45-minute doors are used. This includes electrical rooms, IDF rooms, the café stair circulation doors, and the doors for the convenience stairs on floors 3 and 5.
6.3.8 Penetrations and Joints

Penetrations through fire rated assemblies are required to uphold the rating. Mechanical venting and ducting that penetrates these assemblies are provided with fire smoke dampers. These dampers activate on smoke detection and close automatically. They are tied into the buildings fire alarm system. For piping and cabling runs through these assemblies the gaps around are filed with fire caulking.

Joints between panels and gypsum panels are provided with fire caulk or fire stop. Glulam beams and structural components are upsized to provide suitable char layers for protection. The fasteners used for connections are provided with wooden plugs to provide fire rating for them. Between beams and the CLT flooring, intumescent caulking is used.

6.4 Interior Finish Requirements

Interior finishes requirements are detailed in chapter 8 of the CBC (table 803.11), Applicable columns and rows are detailed in Table 14 for sprinklered A, B, and S occupancies.

<table>
<thead>
<tr>
<th>Occupancy Group</th>
<th>Interior Exit Stairs, Exit Ramps, and Passageways</th>
<th>Corridors and Enclosures for Exit Access Stairways</th>
<th>Rooms and Enclosed Spaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>S-2</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>

The interior finishes of the building are restricted the most in the Café and the exit stairs, which require class B material. Materials receive their classification based on ASTM E84 testing. Class B materials have a Flame spread index between 26-75, and a smoke developed index of 0-450. The rooms and enclosed spaces other than listed above require a material of Class C. Class C, while having the same smoke developed index, have a flame spread index of 76-200.

6.5 Structural Conclusion

Structural design of the building complies with the California building code. building was analyzed for code compliance and building materials. It meets the code requirements it was checked under. Restated the previous points, this building now would fall under the requirements of type IV if plan checked under current codes and could require different elements or construction. This was not covered under this analysis.
7 Performance Based Analysis

7.1 Objectives

The fire protection strategy for the building employs the use of both passive and active systems to protect the building and its contents. The building’s footprint is fairly small, with adequately spaced stairwells and many options to exit the building. This provides quick exit from the building in case of emergencies. Additionally, the building is equipped with a voice evacuation system, aiding in the alert of the occupants. The caveat to this, is the primary activation to the fire alarm system is a water flow switch. This means that occupants will only be notified after a fire has fully developed.

The contents of the building property-wise is largely non-essential. Aside from café appliances and office furniture, there are few extras. There are a few IDF/server rooms, however these are most likely just for building networking, rather than storage of valuable data. For that reason, the intent of the designers is most likely that of occupant protection versus property protection. This is further supported by the inclusion of the voluntary upgrade to an EVAC system versus just a normal fire alarm system.

Two design fire scenarios were hypothesized. The first of these scenarios provides a look at how a fire could easily disable one major egress route in the building. Since the design uses CBC 1028.1 to have the stair 2 exit through the lobby, this opens building occupants to a fire hazard in this intervening space. Generally, stairwells are constructed and finished to be very fire resistant to the point where once entered, the occupants are safe. This hampers overall safety by introducing an area with fuel loading prior to exiting the building. The design fire proposed analyzes the effects of this fuel load on the egress scheme and then proposes solutions. To better understand this impact, available and required safe egress times were calculated (ASET/RSET) to ascertain if the building could accommodate exiting during the fire.

The second design fire scenario takes place in a team space pod on the second floor. These pods have seen an uptick in popularity in the jurisdiction over the past few years. Since this building largely exists in the core and shell state at the moment, it is not beyond reason that this space can be filled with these types of structures in the future. This provides a different challenge for the space. The second floor has high ceilings. In the event of a traveling fire, there may be good odds of the ceiling jets at the deck to reach suitable temperatures for sprinkler activation. Alternatively, isolating the fire to a small room that is still protected by sprinklers high above, the efficacy of the fire suppression was questioned. This design fire was chosen to stress the system not with an overwhelming fire, but a reasonable one in an unfavorable situation.

7.2 Design Fire 1: Lobby Fire

The exiting for the central stairwell comes through the main lobby to reach the public way. While allowed through prescriptive design criteria, this does open occupants to the possibility of more risk, versus a completely sealed egress passageway. The lobby is the main entry and distribution point for the building. It has a reception desk, waiting area, doors to connect to the café and offices, the stairwell, and elevators. All doors are access controlled (free flowing in the direction of egress). The scenario in question is one where a fire starts from the waiting area, igniting the upholstered furniture. The location is highlighted in Figure 22.
The fuel load modeled consisted of a couch and 3 chairs. The ignition source was assumed to be a laptop electrical fire. While the laptop was considered part of the fuel package, it ultimately was not included in further analysis due to its insignificant heat release compared to the rest of the items. The model heat release curves are shown in Figure 23a and 23b.

![Laptop HRR](image1)

**Figure 23a: Laptop Representative Heat Release**

![Couch/Chair HRR](image2)

**Figure 23b: Couch/Chair Representative Heat Release**

The ignition of the couch was assumed to be concurrent with the laptop’s ignition. From there the ignition of secondary items was calculated assuming the radiative heat flux from the couch was from a point source as shown in Figure 22. From literature\(^1\), a critical heat flux of 7 kW/m\(^2\) was chosen to represent the chairs ignition point. Radiative heat flux from the fire was found using the following equation:

\[ H = \frac{Q}{A} \]

---

\(^1\) Chen, Flora F. (2001). *Radiant Ignition of New Zealand Upholstered Furniture Composites*
The distance to the chairs was assumed at 1.5 m, which would be reasonable spacing for lobby furniture. The radiative fraction of the HRR required to ignite the chair is 126.6 kW. It is assumed that this is 30% of the total HRR of the fire, meaning the fire would need to reach a heat release rate of 422 kW to ignite the chairs. This shows that the first chair ignites 58 seconds later with the second and third chair following shortly after. The heat release peaks at 8850 kW at about 3 minutes. The cumulative HRR of the design fire is shown in Figure 24.

Alpert ceiling jet correlation was used to analyze sprinkler activation times. First, the temperature change was calculated using the following:

\[
T - T_\infty = 5.38 \frac{Q^2}{H^{5/3}} \left(\frac{r}{H}\right)^{2/3}
\]

Once the temperature change due to the fire was calculated at each point of the fire, the velocity of the ceiling jet was determined with the following equation:

\[
u = 0.195 \frac{Q^{1/3}}{H^{2/3}} \left(\frac{r}{H}\right)^{2/3}
\]

Using these two quantities, detector temperature and by extension, detector activation time was found based of spacing and RTI values of the sprinkler heads.

\[
\frac{dT_d}{dt} = \frac{\sqrt{u}}{RTI} (T_j - T_d)
\]
The fire was centered in two squares: a light hazard, 15 ft by 15 ft and an ordinary hazard, 10 ft by 13 ft square. The approach was to analyze both possible scenarios in Sunnyvale. This methodology also represents the worst-case scenario and longest sprinkler activation time. The difference between activation times was within 10 seconds depending on the RTI of the bulb. The sprinkler bulb temperature was plotted over time and is shown in Figure 25.

![Sprinkler Bulb Temperature](image)

<table>
<thead>
<tr>
<th>Sprinkler Activation Time (seconds)</th>
<th>Light Hazard, Quick Response</th>
<th>Ordinary Hazard, Quick Response</th>
<th>Light Hazard, Standard Response</th>
<th>Ordinary Hazard, Standard Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary Temperature</td>
<td>76</td>
<td>70</td>
<td>79</td>
<td>72</td>
</tr>
<tr>
<td>Intermediate Temperature</td>
<td>101</td>
<td>85</td>
<td>102</td>
<td>88</td>
</tr>
</tbody>
</table>

*Figure 25: Sprinkler Activation Time in Lobby*

The area of concern within the lobby is its effect on egress. Next tenability was looked at in the area to see how long it would take for the smoke layer to descend below 1.8m. This was done by considering the volume of smoke created and then tracking the decent of the smoke layer over time. The Zukoski Plume correlations were used.

\[
\dot{m} = 0.21 \left( \frac{\rho_\infty g}{c_p T_\infty} \right)^{1/3} Q^{1/3} Z^{5/3}
\]

\[
u = 1.94 \left( \frac{\rho_\infty g}{c_p T_\infty} \right)^{1/3} Q^{1/3} Z^{-1/2}
\]

\[
\Delta T = 5.0 \left( \frac{\rho_\infty g}{c_p T_\infty} \right)^{1/3} Q^{2/3} Z^{-5/3}
\]

The fire was modeled as uncontrolled and sprinkler-controlled fire to see the difference as shown in Figure 26. However, do the ferocity of the fire, this did not yield any significant benefit. The difference in the smoke layer decent is only a few seconds. The fire builds in size and production so quickly that both scenarios reach untenable conditions within seconds of each other.
Aside from hand calculations, this fire was also modeled in Pyrosim to verify the hand calculations. Like the calculations, the fire was assumed to be sprinkler controlled in the simulation. The lobby was modeled to replicate the scenario. Figure 27 and 28 show the layout of the lobby and location of the fire. The walls were assumed inert and would not add to the fire’s fuel load. For the fire, it was modeled as a burner that matches the heat release rate curve determined above. The model inputs for soot and CO yield are tabulated in Table 15:
The model encompassed the entire closed area of the lobby, the doors entering this space were modeled as inert walls for simplicity. There is a structural beam present over the location of the fire, this was included as it may have affected the plume and heat distribution, possibly affecting sprinkler activation. It is important to note that that these sprinklers also stopped HRR growth upon activation in the model. The overall floor plan and sensor locations are shown in Figure 28. The fire cell size used by FDS to perform the fluid flow and thermodynamic equations have a size of 0.2m cubed. Full parameters are found in Table 16.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soot Yield</td>
<td>0.198 g/g</td>
<td>SFPE Handbook Table A.39</td>
</tr>
<tr>
<td>CO Yield</td>
<td>0.042 g/g</td>
<td>SFPE Handbook Table A.39</td>
</tr>
<tr>
<td>Fuel</td>
<td>Polyurethane (CH$<em>{1.3}$O$</em>{0.37}$N$_{0.074}$)</td>
<td>Fuel load from couches and chairs</td>
</tr>
</tbody>
</table>

Figure 28: Overall Pyrosim Floor Plan and Sensor Locations
Table 16 – Pyrosim Environmental Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Temperature</td>
<td>293</td>
<td>K</td>
</tr>
<tr>
<td>Density of Air</td>
<td>1.2</td>
<td>kg/m$^2$</td>
</tr>
<tr>
<td>Specific Heat of Air</td>
<td>1</td>
<td>kJ/kgK</td>
</tr>
<tr>
<td>Gravity</td>
<td>9.8</td>
<td>m/s$^2$</td>
</tr>
<tr>
<td>Cell Dimension</td>
<td>0.2</td>
<td>m</td>
</tr>
</tbody>
</table>

The simulation confirmed the findings from the hand calculations. The sprinklers activate at 72 seconds capping the HRR at 1119 kW to simulate a sprinkler-controlled fire shown in Figure 29.

Further analysis was done regarding the smoke layer. Since the decent is so quick, visibility within the compartment was considered. The idea is that there is a possibility that occupants could quickly move through to egress if conditions allow. Occupants, as discussed, could be transient due to the campus-like environment. For this reason, the visibility was set to 30ft based on guidance from The Handbook of Smoke Control Engineering. Visibility within the compartment was partially compromised at 40 seconds into the simulation, with it being fully compromised at 100s (Figure 30). Additionally, the smoke layer was observed to drop below 6 ft within 100s, also falling in line with hand calculation. The 6ft criteria is found in the CBC section 909 for smoke control systems. While a smoke control system is not present, this criterion provides a good guideline in areas that would require occupant travel in a fire scenario. For this lobby to be considered a viable exit, egress would have to happen within 100 seconds.

---

2 Handbook of Smoke Control Engineering, p186
of the start of the fire. Since the main form of detection within the building is the fire sprinkler system, this is unrealistic with the delay added to the water flow switch and pre-movement times.

**Figure 30: Visibility within the compartment at 93 seconds.**

### 7.2.1 ASET vs. RSET Analysis

To calculate the required safe egress time (RSET), hand calculations were used to estimate the egress time for an uncompromised building. Time to detection was determined through the pyro sim simulations, yielding a sprinkler activation time $t_d=72$ seconds. Time to notification, per NFPA 72 17.12 allows for a time delay on waterflows. In Sunnyvale, most waterflows are set at $t_n=45$s.

To determine pre-movement times, a representative set of data needs to reflect the building’s predicted occupants. The building is a single tenant is own and operated by a tech company. The company also owns buildings in the immediate vicinity of this building. As such, the expectation is the occupants of this building will be both transient and non-transient workers. It is predicted that many of the non-transient workers will occupy the upper floors. The transient workers are expected to make use of the café on the first floor and attend larger meetings in the office spaces on the first floor. Occupants of the building are predicted to be majority young tech workers. The building is in a warm climate, with very little deviation from fair weather. Furthermore, the building itself has open sightlines and an EVAC system.

For pre-evacuation times, the SFPE Handbook 2016, chapter 64 was referenced. The representative data set chosen is from Gwynne’s 2007 study\(^3\). The data set comes from the first trial of the study. The evacuation was a partial evacuation of 2 floors with a mean time of 141 seconds, and a range of 40-426 seconds, over 72 occupants. The data is a good representation for a few reasons:

- The participants of the study had not recently practiced the drill, nor were very familiar with the building. This would give an analogous situation to both transient and non-transient workers in a building where some may not be familiar with procedure.
- The floors evacuated had similar arrangement with 3 stairwells spaced throughout the floor.

---

• The building was equipped with a voice evacuation system.

There are three limitations of this data that must be considered. The first was the environment. The study was conducted in a cold weather climate. Observers noticed that pre-evacuation times were extended because occupants went to grab cold weather wear prior to leaving. The other short comings are due to the partial evacuation and relatively small number of participants.

This data set provides a slightly longer pre-movement time vs. the SFPE Handbook’s Table 64.4 time for a midrise building (0.9 minutes). However, a slightly longer time is expected due to the nature of its occupants.

To determine evacuation time, effective width needs to be calculated for each element. The SFPE handbook was reference and boundary layers widths were taken from Table 59.1. Then Maximum specific floor was determined using values for each element from Table 59.5.

\[
\begin{align*}
W_{e,\text{stairs}} &= 52 \text{ in} - 12 \text{ in} = 40 \text{ in} \\
F_{s\text{m,stairs}} &= 18.5 \times 3.33 = 61.67 \text{ persons/min} \\
W_{e,\text{doors}} &= 40 \text{ in} - 12 \text{ in} = 28 \text{ in} \\
F_{s\text{m,doors}} &= 24 \times 2.33 = 56 \text{ persons/min}
\end{align*}
\]

This confirms that the controlling element or pinch point is the doors of the stairwell. The next step taken was for how fast the 3 stairwells can exit the 2434 occupants of level 2-5.

\[
T = \frac{2434}{3 \times 56} = 14.49 \text{ minutes}
\]

Egress out of the upper floors will take 14 minutes and 30 seconds. The upper floors will take the longest time to evacuate. Each of the lower floors use separate exits, therefore will exit independently of the upper floors, and should not affect this egress time.

The evacuation time for the building is predicted to be \( t_{\text{evac}} = 14.5 \text{ minutes} \). The hand calculation makes a few assumptions. First, the ableness of the evacuees. It is assumed that the occupants of the building are young and able-bodied tech workers that have no special needs and can use the stairwells effectively. This also assumes that the exits will be evenly used by all occupants, which may not be the case.

Following the SFPE Handbook, the RSET is calculated as: \( RSET = (t_d + t_n + t_{pre}) + 1.5(t_{\text{evac}}) \). For the hand calculations, total RSET equals roughly 26 minutes.

To observe the impact of this fire, Pathfinder simulations were run. The first simulation was run with all 3 exit stairs being available to see the unobstructed capabilities of the system. The above simulation shows there is an available safe egress time (ASET) of about 40 seconds, as that is when tenability is first compromised. For inputs into pathfinder, the occupant loads calculated in section 3 were used. The occupants of each floor were randomly distributed. This decision was made assuming that most the occupants time in the building will be from queuing at the choke points in the egress system.
The first analysis yielded a total egress time of 16 minutes, 40 seconds. The following simulation run disabled the central stair. Since tenable criteria is lost before occupants are notified, it is assumed that it cannot be used as an exit. This resulted in an increase of 41% to the exiting time, to 23 minutes, 30 seconds.

Table 17 – RSET Analysis Summary

<table>
<thead>
<tr>
<th>Scenario</th>
<th>RSET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Calculations</td>
<td>26 minutes</td>
</tr>
<tr>
<td>Pathfinder Uncompromised</td>
<td>29 Minutes</td>
</tr>
<tr>
<td>Pathfinder Compromised Stair 2</td>
<td>40 Minutes</td>
</tr>
</tbody>
</table>

All scenarios and their resulting RSET are tabulated in Table 17. The simulations and hand calculations show that the RSET is much higher than ASET. The building’s design is unable to meet required egress times. To increase the ASET, the time to untenable conditions must be increased. Limiting fuel loading in the lobby is the most actionable method of increasing available time. Reducing furniture in the lobby or going to noncombustible/limited combustible fuel loads would reduce the size of the fire and the rate of smoke production.

7.3 Design Fire Scenario 2: A Fire in the Second Floor Open Office

The second-floor open office and for that matter, the fourth-floor open office, take up a large portion of the building. The ceilings in these areas are much higher than the rest of the building. A fire in this area was a concern because sprinkler activation may be compromised and without any smoke control or detection in the area, an unattended fire could grow. The jurisdiction has seen an increase in phone booths/team pods over the past few years following return to office after the COVID-19 pandemic. It is feasible that once this space gets built out, the open office spaces will have many more of these. They would represent a more segmented office space, rather than an open space where a traveling fire would prove to be a better analysis. The main objective of this analysis is to confirm that sprinkler activation would occur and trigger an alarm signal.

Figure 31: Design Fire 2 - Team-space Pod Fire Location
The fire location (Figure 31) was chosen to be a team pod workspace located near the convenience stairs on the second floor. The reason behind the choice was because of its semi closed off design, while still having an open top. The pod’s construction is unknown currently but is a pre-manufactured solution. For the purposes of this analysis, the pod was considered as non-combustible without the fire spreading beyond its enclosure.

The contents of the pod consist of 8 workstations. The stations were arranged in 2 four-station arrangements as that created a higher peak heat release. If the furniture were arranged as shown, the fire would have not peaked as high, but lasted longer.

Using the model data for engineering workstations a combined heat release curve was developed. The study conducted the test with a group of four workstations. For this design fire, although the floor plan shows three groups of desks (two groups of two, and one group of four), they will be modeled as two groups of four workstations. The initial fire starts on workstation group 1 close to the edge and is idealized as a point source fire. The workstation groups are separated by 1 meter. A diagram of the setup can be seen in Figure 32. Similar methodology as Design Fire 1 was used to determine the time to ignition of the second work station group. In the original study, the researchers observed that the fire moved from desk to desk by the chair igniting. For that reason, a critical heat flux of 7 kW/m² for the textile/foam composite used in the office chairs. The chairs are located about a meter apart. Again, the heat release was idealized from a point source. Ignition of the second workstation group occurred after 301 seconds. The cumulative HRR curves are shown in Figure 33, showing a peak HRR of nearly 3900 kW.

Location of Point Source

![Figure 32: Design Fire 2 Layout](image)

---


The chief concern with the area is the ceilings. The ceiling height in these areas is 27.75 ft which is substantially different from what is found on other floors (13.3ft). Alpert ceiling jet correlation was used to determine sprinkler activation times. As seen in Figure 34, sprinkler activation times are quite different from the previous design scenario. Sunnyvale municipal code was considered in this scenario as well. Sprinkler activation in light hazard spacing in nearly 1 minute longer than ordinary spacing, regardless of the RTI. The interesting point is if intermediate temperature heads are used. In this scenario, with light hazard spacing, sprinklers would fail to activate.

![Team Space - Pod Heat Release vs Time](image)

**Figure 33: Design Fire 2 Combined Heat Release Curve**

![Sprinkler Bulb Temperature](image)

**Sprinkler Activation Time (seconds)**

<table>
<thead>
<tr>
<th></th>
<th>Light Hazard, Quick Response</th>
<th>Ordinary Hazard, Quick Response</th>
<th>Light Hazard, Standard Response</th>
<th>Ordinary Hazard, Standard Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary Temperature</td>
<td>404</td>
<td>351</td>
<td>415</td>
<td>355</td>
</tr>
<tr>
<td>Intermediate Temperature</td>
<td><strong>No Activation</strong></td>
<td>690</td>
<td><strong>No Activation</strong></td>
<td>597</td>
</tr>
</tbody>
</table>

**Figure 34: Design Fire 2 Sprinkler Activation Time**
Following sprinkler activation, the fire heat release would be capped at around 1250 kW (Figure 35), as opposed to 3900 kW, however due to the height of the ceilings, this does not prevent the fire from spreading to the additional workstation group. Burnout time was increased about 160% of the original time.

![Figure 35: Adjusted Heat Release vs. Time after Sprinkler Activation](image)

8 Conclusion

The building reviewed is unique in many ways. From being built from cross laminated timber elements to its floor layouts opening the ceilings the building tends to follow what is allowed by code. The building employs typical egress practices, fire sprinkler designs, and fire alarm notification designs. The building has an element that is not completely code compliant, depending on the interpretation of “exiting to the public way”. Is a vestibule part of the lobby? In my opinion, it meets the intent of the code. The vestibule does not increase the hazards of exiting. While going through the analysis of the performance-based designs, the focus was not on this vestibule. The focus ended up being on the exiting through the lobby and what inherent risks are introduced to occupants when employing exceptions from section 1028.

Interior exit stairways provide safe egress from the floor to the public way, and extension of safe travel to each floor in the building. Allowing them to empty into a lobby introduces inherent risks to the fire safety strategy for the occupants. This exception exists to design buildings with more cohesive floor plans and sensible navigation. It is important to acknowledge the risks introduced by this design. The fire modeled consisted of furniture that is typical within lobbies. The scenario quickly grows to a peak of 1119 kW prior to sprinkler activation at 72 seconds. While sprinklers activate, the compartment reaches untenable conditions by 100s, and occupant notification does not occur until 117s.

As shown in the first design fire, fuel loading along the egress path greatly reduces the available safe egress time. The ASET is essentially zero, as the occupant notification does not activate by the time the compartment becomes untenable. The RSET in this scenario is also affected due to the central stair being unusable. There is a 37% increase in time as 11 extra minutes are needed to evacuate the building.
when only 2 stairs are used. A reduction in fuel loading, or even a ban on furniture within the lobby would improve conditions and extend the ASET. This measure would need to be implemented in the fire safety plan for the building since it is not implicitly restricted by code. With the ASET being roughly 2% of the RSET and as this intervening space is crucial for the exiting scheme of the building, it is recommended that this restriction is put in place.

The second design fire reviewed explored compartmentalized office space in an otherwise open office environment. As pods and phone booths become more common, exploring this paradigm shift of how this floor plan is laid out. With high bay ceilings, restricting the size of fires could hamper sprinkler activation. Sprinkler activation in this design fire occurred after almost 6 minutes, meaning the compartmentalization of a team space did not hinder fire protection systems. This design fire was large for a compartmentalized area, with the capability of reaching a peak of 3900 kW. For smaller spaces, NFPA 13 2022 edition address small, temporarily occupied spaces now. Section 9.2.10 states that these small temporarily occupied spaces no longer require sprinkler coverage, if they do not exceed 24 sq.ft. The intent in this section is to limit sprinkler installation in scenarios where fuel loading is small and may not even activate a sprinkler when ignited.

Overall, it is my conclusion that although the lobby-adjacent vestibule does meet the intent of the code, while not meeting the letter of the code. This vestibule does not introduce any additional hazard to the space. The lobby itself is of greater risk to the occupants with the introduce fuel loading in the egress path. Beyond this, the rest of the building demonstrates code compliance in exiting, suppression, notification, and structural components. The design fires provide understanding how the building’s code compliant elements handle reasonably determined fuel loadings and their effect on the occupants.
9 Appendix A: Occupancy Classifications

9.1 Level 1 Floor Plan
9.2 Level 2 Floor Plan
9.3 Level 3 Floor Plan
9.4 Level 4 Floor Plan
9.5 Level 5 Floor Plan
## 10 Appendix B: Occupant Loads

**Table 18: Level 1 Occupant Load**

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11 Appendix C: Egress Analysis Diagrams

11.1 Level 1 Egress Analysis
11.2 Level 2 Egress Analysis
11.3 Level 3 Egress Analysis
11.4 Level 4 Egress Analysis
11.5 Level 5 Egress Analysis
# 12 Appendix D: Hydraulic Calculation

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**Notes:**
- D = 0.1 gpm/sqft, k' = 5.6
- K = 24.9

---

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**Notes:**
- HSA Added at Hydrant
- FIXED LOSS PER MANUFACTURER
- p= 81.8
13 Appendix E: Sprinkler Layout

13.1 Sprinkler Layout Level 1
13.2 Sprinkler Layout Level 2
13.3 Sprinkler Layout Level 3
13.4 Sprinkler Layout Level 4
13.5 Sprinkler Layout Level 5
### Table 5.1.1.2 Summary of Sprinkler System Inspection, Testing, and Maintenance

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

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### Table 7.1.1.2 Summary of Private Fire Service Main Inspection, Testing, and Maintenance

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<tr>
<td>Hose houses</td>
<td>Annually</td>
<td>7.2.2.7</td>
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<td>Hydrants</td>
<td>Annually</td>
<td>7.4.2</td>
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<td>Mainline strainers</td>
<td>Annually and after each operation</td>
<td>7.2.2.3</td>
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<tr>
<td>Monitor nozzles</td>
<td>Annually</td>
<td>7.4.3</td>
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