Fire Protection Analysis:
Engineering IV, Building 192, Cal Poly State University, San Luis Obispo

By
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**Keywords:** Atrium, Available Safe Egress Time (ASET), Design Fire, Fire Dynamics Simulator (FDS), Required Safe Egress Time (RSET)
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Executive Summary:

Introduction:

This report is an analysis of the fire protection capabilities of Engineering IV (Building 192) at Cal Poly University in San Luis Obispo, CA. The overall objective of this report was to assess whether the building and its fire protection systems supported the evacuation of occupants from the building in a safe manner before conditions became untenable during a fire event. The assessment was accomplished by performing a prescriptive and performance analysis.

Prescriptive Summary:

The purpose of the prescriptive analysis was to determine whether the building egress components and fire protection systems were designed, built, and installed in compliance with all the applicable safety and building codes. The prescriptive analysis portion of this report compares each fire protection system with the requirements of the appropriate National Fire Protection Agency (NFPA) and International Building (IBC) codes. This report specifically analyzes the following areas of Engineering IV’s fire protection capabilities:

1) Structural Fire Resistance
2) Egress Compliance
3) Fire Suppression System
4) Fire Alarm System
5) Smoke Management System

This building was built in 2008 as a Type IIA construction in accordance with the 2001 California Building Code (CBC) which closely follows the International Building Code (IBC) requirements. This type designation requires specific fire resistance ratings for structural and other key components of the building. For the structural and structural supporting components, the fire resistance rating is two hours. This requires fireproofing throughout the steel frame structure of the building. The construction as-built drawings show that this was done in accordance with the appropriate codes. Although, the building was designed and built in accordance with 2001 building codes, the requirements regarding the structural fire resistance remain the same and are therefore compliant with existing code.

The egress aspects of Engineering IV are compliant with the current NFPA 101, Life Safety Code (LSC). The number of exits on each of the floors are appropriate relevant to the designed occupation quantity. The first floor has 15 exit discharges many of which are available through individual classrooms, laboratories, and assembly rooms. The second floor has three
exits to external stairwells that are unenclosed to the outside environment. This is appropriate for the designed occupancy of 500 people. The third floor has two exits to the external stairwells which are also appropriate for occupancies of below 500. Travel distances for common path (<100 ft) and distance to exit discharges (<300 ft) are in accordance with the current NFPA LSC (see Chapter 39). Other various egress requirements such exit signage, panic hardware for example are also compliant to code.

The building has a water-based fire suppression sprinkler system installed throughout the building. The location, spacing, and type of sprinklers used are compliant relative to the occupancy type of the building in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems. The water supply was adequate for the sprinkler water demand calculated by the fire protection engineer at the time of construction. A current sprinkler system survey and demand calculation should be performed and compared to the latest hydrant flow test to verify system performance requirements.

There is an appropriate fire alarm and notification system installed in the building compliant with the NFPA 72 National Fire Alarm and Signaling Code. Although, the current NFPA 72 edition is 2019 and the building was designed using the 1999 edition, the fundamental components of the current system are compliant with current code. The fire alarm control panel is connected to a network of initiating devices such as smoke detectors, and notification devices such as horns and strobe lights. In addition, the as-built wiring diagram shows the fire alarm panel to be connected through relays to critical components of the building such as the elevator, HVAC, and smoke barrier systems.

Finally, the building includes a passive smoke management system as required by the IBC for buildings with atrium features connecting three or more floors. This is compliant with both the IBC and NFPA 92, Standard for Smoke Control systems. The smoke management system of the building includes a smoke housing compartment at the top of the main stairwell on the third floor. There is a smoke release door installed for the entrance and exit of this compartment onto the main stairwell of the building. The smoke release doors are normally open and will close upon a signal from the fire alarm system. There are also architectural openings on the second and third floor corridors that provide natural lighting throughout the three-story building. These natural lighting features on the third floor have hidden smoke barriers that actuate and close upon fire alarm signal from the building’s fire alarm control panel.

The prescriptive analysis of this report will show that the building is compliant relative to the applicable building and safety codes regarding fire protection safety. However, this aspect alone does not guarantee that occupants of a building can evacuate the area of the fire or the building before they encounter hazardous or untenable conditions. The performance analysis will provide data that will or will not support this premise.
Performance Summary:

The performance analysis portion of this report is meant to prove whether occupants can safely exit the area of the fire or the building before untenable conditions occur. A final comparison of the Required Safety Egress Time (RSET) and Available Safe Egress Time (ASET) will help support the overall assessment. The results of this report vary in accordance with the Design Fires as developed in this report. In some cases, the RSET overlap the ASET meaning that there is a significant potential of development of untenable conditions before all occupants can leave the building. In other Design Fires, the ASET exceeded the RSET and support the premise that occupants could evacuate in a safe and timely manner. These untenable conditions consist of effects from temperature, heat flux, carbon monoxide poisoning, and diminishment of smoke visibility as described in the Society of Fire Protection (SFPE) Handbook 5th edition, through various studies. The complexity of this analyses required the use of computer modeling applications which in this case was the Fire Dynamics Simulator (FDS) \(^1\) and PyroSim\(^2\) applications. FDS provides the calculations to support the modeled results, while PyroSim provides the front end to operate FDS and visualization of the results.

The Design Fires included in this report and used as input to the FDS application will provide the scenarios and fire characteristics that are believed by the author to be most likely within the guidelines of NFPA 101, Life Safety Code. The Design Fires used in this report are the following:

1) Design Fire 1 – Atrium Lobby  
2) Design Fire 2 – Classroom on 1st Floor  
3) Design Fire 3 – Faculty Office on Second Floor  
4) Design Fire 4 – Atrium Lobby with Smoke Management System Failure

Assumptions are provided along with these design fires to limit the range of the many variables to a reasonable level. The fire model results in this report are estimates of how a design fire will react. The results are meant to be used to assess what actions could be taken to improve fire emergency reaction. Exact fire scenarios cannot be predicted.

The RSET estimating method for this building was calculated using the hydraulic flow method as identified in the SFPE Handbook (Chapter 59). This report estimates that occupants should be able to evacuate the entire building in less than 90 seconds. This is an optimum estimate based on the assumption that occupants can move at the maximum estimated speeds. The first untenable condition that appeared in all the Design Fire scenarios through FDS are the diminished smoke visibility. Studies have shown that visibility due to smoke densities less than approximately 10 meters may lead to hesitation of occupants during egress. This has a potential of delaying evacuation. Using a model simulation time of 480 seconds, the diminished visibility

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1 Fire Dynamics Simulator Version 6, National Institute of Standards and Technology  
2 PyroSim Version 2019.3.1204, Thunderhead Engineering Consultants, Inc.
condition became the earliest untenable factor in these design fires. Figure 1 summarizes the final results through a comparison of ASET vs RSET based on FDS simulations. In the scenarios of Design Fires 1 and 4, untenable conditions in the form of diminished visibility occur before occupants can evacuate the building. Design Fires 2 and 3 show that occupants should be able to completely evacuate the building before untenable conditions occur. In these scenarios, diminished visibility is the first untenable condition to occur again.

These RSET vs ASET quantitative results alone should not be used as a definitive answer to the question of whether occupants will evacuate the building safely or not. This analysis is meant to identify areas of needed improvement to support successful protection of occupants trying to evacuate the building during a fire event. These results are based on assumptions of a specific fire with a specific fuel, occupant movement, whether doors are open or not, and many other variables. Actual fire events cannot be predicted with that kind of precision. However, these results can be used to help improve the probabilities of preventing harm from a fire event. That analysis will be provided in the body of this report.

Specific recommendations relative to each Design Fire are provided later in this report. General recommendations that effect Engineering IV are as follows:

1) Hire an independent Fire Protection Engineer to perform an entire building survey.
2) Perform new Hydrant Flow Tests.
3) Establish or review Emergency Management Plans.
4) Train University staff for fire emergency events.
Building Overview:

Engineering IV (Building 192) is an academic engineering facility at Cal Poly University in San Luis Obispo, California. San Luis Obispo is situated close to the central California coast (see Figure 2). Constructed in 2008, it is a three-story facility with a modern architectural style with various facades made from different materials. The perimeter is unique in that it does not have a symmetrical perimeter shape such as the common rectangular or square shape. The building hosts several of the engineering disciplines of the university. There are many classrooms that double as laboratories or project areas. In addition, there are several assembly areas and faculty offices as well. The building was designed and constructed using the applicable California (2001 edition) and International Building Codes at the time.

The fire protection systems and components were designed and installed per available National Fire Protection Agency (NFPA) Codes at the time of construction. There is 104,361 ft² of occupiable space in the building among the three floors. The building is designed as a Type IIA construction in accordance with the California Building Code (CBC) which is very similar to that category as described in the International Building Code (IBC). This means that the structural frame and load bearing supports of the building require a two-hour fire resistance rating and that the main elements of the building are non-combustible. The overall height of the building is 56 ft. There is 87,190 ft² of Type B (business) occupancy floor space, and 17,441 ft² of Type A-3 (assembly). In accordance with the International Building Code, Type A-3 is an Assembly category for spaces that can occupy up to 50 occupants. Type B is the Business category that identifies educational use for above the 12th grade as a sub-category. The allowable building height for this type of construction and occupancy use is 65 ft with an allowable area of 119,600 ft² for Type A-3 and 159,600 ft² for Type B (for fully sprinklered building). Engineer IV was designed well within these limits.

The space usage of the building is typical of many academic engineering facilities. The building is full of classrooms and laboratories as well as faculty spaces. Figure 3 shows how the spaces are used on each floor. The building has an atrium lobby area that opens to the third floor through the main stairwell in the central corridor and several architectural openings throughout the main hallways on the second and third floors. The lobby areas have main entrance doors on the south side of the building as well as the north. There are exterior fire exit stairways on the west and east ends of the building that lead to the upper floors. The perimeter
of the building is unique in that the shape is similar to a golf club (see photo 1) and but also varies from floor to floor. This unique aspect makes it more challenging to estimate and model how fire and smoke might move through the building. There is a roadway on the north end of the building, and walkway and grass areas that surround the other sides of the building.

Figure 3, Space usage by floor starting from 1st to 3rd
Prescriptive Analysis:

Structural Characteristics:

Engineering IV was designed and built in accordance with Type II Fire Resistant construction requirements of the 1999 edition of the California Building Code (see Table 1). These 1999 requirements are most equivalent to a Type IB construction type as described in the current International Building Code (2015). This means that the critical structural components of the building are made of noncombustible materials. It also means that these components are required to have specific fire resistance ratings relative to time (see Table 1). There are some differences in resistance ratings of some building components, however. Current International Building Code fire resistance ratings for Shaft Enclosures allows for a one-hour rating for buildings with less than four floors.3

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>REQUIREMENTS BASED ON CONSTRUCTION TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. BEARING WALLS - EXTERIOR</td>
<td>2 HR (N.A.)</td>
</tr>
<tr>
<td>2. BEARING WALLS - INTERIOR</td>
<td>2 HR (N.A.)</td>
</tr>
<tr>
<td>3. NONBEARING WALLS - EXTERIOR</td>
<td>1 HR</td>
</tr>
<tr>
<td>4. STRUCTURAL FRAME</td>
<td>2 HR</td>
</tr>
<tr>
<td>5. PARTITION - PERMANENT</td>
<td>1 HR</td>
</tr>
<tr>
<td>6. SHAFT ENCLOSURES</td>
<td>2 HR</td>
</tr>
<tr>
<td>7. FLOOR AND FLOOR CEILINGS</td>
<td>2 HR</td>
</tr>
<tr>
<td>8. ROOF AND ROOF CEILINGS</td>
<td>1 HR</td>
</tr>
<tr>
<td>9. EXTERIOR DOORS AND WINDOWS</td>
<td>SECT. 603.3.2</td>
</tr>
<tr>
<td>10. STAIRWAY CONSTRUCTION</td>
<td>SECT. 603.4</td>
</tr>
</tbody>
</table>

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3 2015 International Building Code, Section 713.3
Many of the building components that structurally support the building require a two-hour fire resistance rating. This theoretically allows enough time for occupants to evacuate the building before structural failure occurs. The IBC requires fire proofing on the structural frame steel elements to ensure the fire resistance time is met. Figure 4 provides an example of the Engineering IV’s steel structure and its fireproofing application detail from the post construction as-built drawings.

The non-bearing exterior walls have a 1-hour fire resistance rating in accordance with Section 601 of the International Building Code for a Type IB construction. The purpose of this requirement is to support a building separation factor, and to protect against heat radiation from another fire source such as a separate building.

NFPA 101 Life Safety Code, Chapter 39 requires a specific flame spread resistance rating for all existing business occupancy interior finishes. Figure 5 is from the as-built drawings. As shown, the flame spread index is identified in three different classes, and the relevant interior components of the buildings are assigned those classes. The flame spread designations are another way to ensure the spread of fire is delayed as much as feasible to allow safe occupant evacuation relative the time.
Egress Assessment:

A prescriptive analysis of the egress components of the building calls for ensuring compliance with NFPA 101, Life Safety Code. In the context of fire protection, egress is the means and paths to get out of the building during a fire event. NFPA 101 provides the fundamental requirements of egress and is meant to facilitate the evacuation of people out of the building in a safe manner. Engineering IV is compliant with the current edition NFPA 101 in terms of egress. Some of the main egress components, as called for by NFPA 101, are:

1. Capacity of egress
2. Number of means of egress
3. Travel distance to exits
4. Illumination and marking of means of egress

Means of Egress:

The building has an overall square footage of just over 104,000 ft² spread over three floors. Each floor has a mixture of classrooms and laboratories for various engineering academic disciplines such as Civil, Mechanical, Biomedical, and Aerospace Engineering. There are also faculty offices on each floor as well as many common building support spaces such as storage and janitorial closets, restrooms, etc. The building has a unique multi-trapezoidal shaped perimeter with a large central corridor running through the lengthwise center of the building making it easy to be aware of one’s location.

The first floor has 15 exit discharges to the exterior of the building (see Figure 6). There are two main entrances on the north and south sides of the building towards the middle or core of the building. The remainder of the exits are at various classrooms and laboratories to the...
exterior as well as some other exits near the exterior stairwells, and one exit on the western end of the corridor.

Figure 6, Exits to the exterior of the building on the 1st floor.

The second floor has three exits which lead to exterior fire escape stairwells (see Figure 7). The third floor is similar to the second floor except that there are no exits on the southwest end of the building (see Figure 8). This differs from the second floor in that there is an exit on the northwest end, and an exit on the southwest end of the building leading to the fire exit stairwell. The number of egresses on the both the second and third floors correctly follows section 7.4.1.1 of the NFPA 101 Life Safety Code (LSC) in that there are not less than two egress points on each floor. Furthermore, the number of exits on the second floor meets section 7.4.1.2 of the NFPA LSC which requires three exits for an occupancy load between 500 and 1000 occupants. The third floor has only 2 exits which are adequate since the occupant load is less than 500. Current NFPA 101 LSC requires that existing buildings or building locations that require more than one exit, the exits should be remotely located from each other and be arranged to minimize the possibility that more than one has the potential to be blocked by any one fire or other emergency condition (see sections 7.5.1.3.1, 7.5.1.3.3, and 7.5.1.3.5 of NFPA 101). Engineering IV is compliant with these requirements. Section 7.5.1.3.3 requires that exits in fully sprinklered buildings should be a distance within one-third the length of the maximum overall diagonal dimension of the building. However, section 7.5.1.3.5 provides an exemption for existing buildings regarding the exit separation distance as long as exits are remotely located in accordance with section 7.5.1.3.1. The exits on the second and third floors of Engineering IV do not meet the current requirements of section 7.5.1.3.3, but is compliant with sections 7.5.1.3.5 regarding and existing building.
The occupancy load is accurately calculated as originally designed. There may have been some minor changes to uses of some spaces since the building was originally put in use, but we will assume that the occupancy load has not changed significantly enough for the purpose of this report. As can be seen in the tables of Appendix A, the occupancy loads for the 1st, second, and third floors respectively are 663 persons, 500 persons, and 367 persons. These were calculated as part of the original design.

On the first floor of the building, the exit capacity is more than adequate for the maximum occupancy (663 persons) of the floor. There are 15 exits to the exterior of the building. The corridor runs the entire length of the building, and there is an exit on each end of the building lengthwise. There is also a main entrance on the southside of the building at about the center. There is an entrance on the northside of the building on the opposite side of the main entrance. The exit on the east end corridor is a 36in wide door. Assuming a 32in clear width, and a Life Safety Code doorway capacity of 0.2in/person, the exit capacity is 160. The west end exit of the building is a double door exit. Assuming a 64in clear width, the exit capacity would be 320. The north exit of the building is also a double door, so that is another exit capacity of 320. The main front entrance are two sets of double doors, and the exit capacity
would be 640. As previously discussed, there are 12 other exterior exits. Many of these exits are at the classrooms and labs. With the typical clear width of 32 or 64 depending on whether there were single doors or double doors. Whether students evacuating the first floor use the exits through the corridor and/or the doors directly exiting to the exterior of the building, the capacity is adequate.

The second floor is entirely different in the number of exit accesses as well the paths. There are four ways to exit the second floor which includes the three exits to fire escape stairwells, and the stairwell in the main corridor that leads to the 1st floor. The three exits to the fire escapes of the second floor are 36in width exits which will allow each to have an exit capacity of 180 each. This will accommodate the 500 person occupancy load as defined by design. The exterior exits of the second floor are adequately placed around the building as they have a fair distance between them. There are adequate evacuation exits in case any one or two other exits were blocked off by smoke or fire. The third floor has two exits to the exterior of the building each with 36in width openings, so each exit has a capacity of 183 persons. One exit on the east end of the building, and the other is on the Northwest end of the building. This configuration is adequate as there are less occupants and square footage on the west end of the building.
Other Egress Components:

Other satisfactory egress requirements throughout the building are listed below:

- Exit lighting is adequately placed throughout the building. There are LED lit and provide directional arrows where needed (see Figure 9).
- Appropriate panic hardware is included on all emergency exit doors.
- Travel distance requirements
  - Common paths of travel to nearest exit access are less than 100ft.
  - Distances from any point in the building to any exit on any floor are less than 300ft.

![Figure 9, Exit Signs typical throughout the building](image)

Summary:

The egress system of Engineering IV is overall acceptable. The building meets the current LSC, but it also provides a practical means of efficient egress from the building. There are plenty of fire exits on the 1st floor, so the means and efficiency of evacuation is very good. The second and third floors have enough exits leading out of the building per code but they are also situated with enough distance between each other in case any exits are closed off by a fire event. The building has a mass notification system for emergencies as well as a fully sprinklered system.

One area of risk on the first and second floors was the configuration of the faculty office areas on the east end of the building. There were dead end areas that might confuse people during an actual fire with heavy smoke in the office hallways. This configuration may be mitigated with clear exit signs and the existing sprinkler system. However, a significant fire in one of the offices closest to the corridors may block off the other occupants from escaping.

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Those occupants may come in direct contact with the fire if it spreads or be harmed by the smoke while traveling down the hallway. This risk may be mitigated with proper emergency management training for the occupants as well as ensuring notification alarms are in good working order.

Fire Suppression System:

Water Sprinkler System Design:

The Engineering IV building was built with a water-based fire sprinkler system. The sprinkler system was designed for Cal Poly by COSCO Fire Protection in 2007 and built in place in 2008. There are 1468 sprinklers (K-Factor 5.6) installed over the three floors of the building spaced in a range from 8 ft to over 14 ft apart throughout (see Table 2). As can be seen most of the sprinklers are Reliable Model G4A concealed pendent style rated at 155°F (see Figure 10). These are installed throughout the building in most areas where there are finished ceilings such as in the main entrance of the building throughout the atrium, in several classrooms, and offices. The second most abundant sprinklers installed are the Reliable F1FR upright style which are installed in many classroom/laboratories that have high exposed ceilings. There several higher temperature rated sprinkler heads used for specialty areas such as the smoke compartment on the third floor on top of the main stairwell.

### Table 2, Sprinkler Heads by type and floor throughout Engineering IV

<table>
<thead>
<tr>
<th>Bldg</th>
<th>192 Floor</th>
<th>Quantity</th>
<th>Model</th>
<th>Orifice</th>
<th>K-Factor</th>
<th>Temp (F)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>618</td>
<td>Reliable Model G4A Concealed Pendent SIN #5414</td>
<td>1/2”</td>
<td>5.6</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>242</td>
<td>Reliable Model F1FR Upright On 1” SPRIG / SIN #3625</td>
<td>1/2”</td>
<td>5.6</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>28</td>
<td>Reliable Model F1FR Upright On 1” SPRIG / SIN #3626</td>
<td>1/2”</td>
<td>5.6</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>Reliable Model F1FR Horizontal Sidewall</td>
<td>1/2”</td>
<td>5.6</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>254</td>
<td>Reliable Model G4A Concealed Pendent SIN #5414</td>
<td>1/2”</td>
<td>5.6</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>43</td>
<td>Reliable Model F1FR Upright On 1” SPRIG / SIN #3625</td>
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<td>5.6</td>
<td>155</td>
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<tr>
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<td>200</td>
<td></td>
</tr>
<tr>
<td>3</td>
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<td>155</td>
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<tr>
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<td>30</td>
<td>TYCO Model WS Vertical Pendent SIN # TY3488</td>
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<td>155</td>
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<td>7</td>
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<td>1/2”</td>
<td>5.6</td>
<td>200</td>
<td></td>
</tr>
</tbody>
</table>
Figure 10, Number of each type of sprinkler

All the sprinklers are Quick Response (QR) sprinklers. An example can be seen in Photograph 2. This sprinkler is typical of many classroom and/or laboratory spaces where there seems to be many potential obstructions to the sprinkler spray from HVAC ducting, structural beams, lights, etc. This arrangement is compliant with the 15 ft spacing limit as stated in NFPA 13, chapter 10 for obstructed ceiling areas such as these.

There is a unique feature of a smoke containment compartment on the third floor of the building, at the top of the building’s main interior center stairwell. The smoke containment consists of 4 walls that surround the stairwell with normally open smoke release doors on the approach side to the stairwell. Upon alarm the smoke release doors will close and therefore prevent potential smoke from entering the third floor. There are 30 Tyco vertical sidewall sprinklers that are meant to keep the glass cool during a fire to prevent damage from heat. This helps to contain smoke below the third floor while people evacuate from the exterior fire escape stairwells (see photo 3).
The water supply in the building is carried through a standpipe riser which is a schedule 40, 4” steel pipe. It splits at the first floor to the second floor, and then again on the second floor to the third floor (see Figure 11). At each floor, the riser feeds 4” cross mains throughout each floor. All concealed pendent sprinkler branch lines are a consistent size of 1-1/4” throughout, while the upright sprinklers are fed through 1” lines. As noted in the general notes of the as-built sprinkler shop drawings, the 1-1/4” branch lines, and 4” cross mains are schedule 10, while the 1” through 2” branch lines are schedule 40.
Occupancy Classification and Sprinkler Design Criteria:

In general, the designer of record fire protection engineer designated the occupancy classification of the administration offices and several classroom areas with low combustible materials throughout the building as Light Hazard. Many of the classroom/laboratory areas were designated as Ordinary Hazard 1 (OH1) which means the intent was that these spaces would have moderate quantities of low combustible materials not stored more than 8ft high. These appear to be the correct classifications in accordance with Chapter 4 of NFPA 13, *Standard for the Installation of Sprinkler Systems, 2019 edition*.

The fire protection engineer used the requirements as outlined in NFPA 13, Chapter 19 to calculate density area of the sprinkler heads. Light Hazard areas require sprinkler head output to have 0.10 GPM/ft². The minimum area of operation for Light Hazard sprinklers are 1500 ft. However, NFPA 13 allows a 40% reduction in the area of operation criteria if Quick Response sprinklers are used and the height of the ceiling is equal to or less than 10ft. Ordinary Hazard 1 areas require 0.15 GPM/ft sprinkler head output in accordance with NFPA 13, which also allows for a 40% design area of operation based on the same requirements at previously stated.

Sprinkler System Demand:

The fire protection engineer calculated the sprinkler system water supply demand from several areas of different floors of the building using both Light Hazard and Ordinary Hazard area designations. The flow and residual pressures differed slightly in each area. For example, on the west end of the third floor, the engineer calculated a system demand flow of 341.8 GPM with a 58.3 residual psi. On the east end of the building, the engineer calculated a demand flow of 210.8 GPM with a residual pressure of 67.2 psi (see Figure 12). The required outside hose allowance needed for the potential fire department’s truck is 250 gpm.

![Figure 12, System Demand Calculation of East End of third floor](image-url)
Water Supply Characteristics

The water supply source is from the Whale Rock Reservoir and the local groundwater. The water is managed and delivered by the City of San Luis Obispo. The water main through the campus is delivered through an 8” line which branches off in a 6” line to Engineering IV buried 3 ft underground.

![Figure 13, Water supply to the building shown on the left and Fire Department Connection location shown on the right.](image)

The 6” pipe runs through a typical double check valve assembly before entering the building where it transitions to a 4” schedule 40 riser pipe (see Figure 13). The water supply to the building at the time was measured at a static pressure of 80 PSI, and a residual pressure of 65 PSI at a flow of 1244 GPM. When comparing one of the fire protection engineer’s hydraulic calculations on the third floor

![Figure 14, Hydraulic Graph of Sprinkler Demand](image)
of the building, it can be seen in Figure 14 that the water supply characteristics meet the building’s sprinkler demands including the required Hose Stream Allowance of up to 250 GPM for an OH1 occupancy area in accordance with Chapter 19 of NFPA 13. The fire department connections (FDC) are on the south west end of the building (see Figure 13). NFPA 14, Standard for the Installation of Standpipe and Hose Systems, chapter 4 requires a 2-1/2 inch connection.

Summary

Overall, Engineering IV’s sprinkler systems were designed and constructed as intended. The Occupancy Classification is in accordance with NFPA 13 requirements, and the fire protection engineer accurately calculated the system’s water supply demand. It is not uncommon for large institutional facilities such as this one, that the use and intent of spaces, or the entire building, change throughout the building’s lifetime. It is important that when this happens, that the sprinkler system design is re-evaluated. Even if a change to an occupancy type or intent in just one classroom or laboratory occurs, an inadequate sprinkler design may not be able to control a different sized fire in an emergency. Many times, occupants change storage buildings or spaces into office or even residential spaces without considering the sprinkler system design at all. The sprinkler requirements for these occupancies may be entirely different.

Sprinkler systems should be regularly evaluated and maintained in accordance NFPA 25, Standard for the Inspection, Testing, and Maintenance (ITM) of Water-Based Fire Protection Systems. See Appendix D for recommended ITM of various sprinkler system components. It is not uncommon for large facility organizations to not have regular design assessments or a routine maintenance and testing process. It assumed that these systems are always working and that they are designed for all facility types and uses. This is a dangerously wrong assumption. Fire main damage and pipe bursts happen commonly in severe weather parts of the world. Freezing temperatures and heavy rain areas can cause pipe damage both below and above ground. Corrosion is a constant danger to all piping systems. Costs to maintain, test, and modify changes to the fire protection are often high initially. However, when performing a cost analysis comparison to potential damages and liabilities, the initial capital costs are typically small. More importantly, the life and safety to occupants outweigh the costs of maintaining a proper sprinkler protection system.
Fire Alarm System

Introduction:

The objective of a proper fire alarm system is to alert occupants and responders to a fire emergency within the facility. A secondary goal is to protect the facility. Many people have witnessed fire alarms go off in their office buildings, but they may not be aware of the components installed throughout their workplace that make up a modern fire protection system which includes a fire alarm system network. This report provides a summary of the fire alarm system installed in this building which has a common network system architecture as many modern academic and office buildings.

It is important to ensure that the various building codes are met, but it is more important to be aware that the real objective is to prevent harm to or loss of life. NFPA 72, National Fire Alarm and Signaling Code® is the reference most used by industry for compliance. This building was designed using the 1999 Edition, but this version is not available anymore. This report will be assessed using the 2019 Edition as a reference and comparison with the acknowledgment that there have been many updates to NFPA 72 since 1999.

Fire Alarm System Objectives:

The primary objective of any fire alarm system is to alert occupants and first responders that there is a fire emergency in the building. The faster and more accurate the system is, the faster occupants can evacuate the building, and responders such as the fire department and police, can react to the incident. If a fire occurs in a facility, every second counts in terms of life safety and damage control. Fires can grow fast depending on the fuel source and space configuration. In the early stages of a fire, the biggest danger to most people is most likely smoke inhalation. Smoke can spread quickly throughout a building so it’s not surprising that early smoke detection is one of the key elements to be able to get people out of the building quickly. There are other indicators of a significant fire such as rising heat levels or the activation of a fire sprinkler. Once a fire is detected, then actions must be taken. In terms of a fire alarm system, those action include notifying responding authorities such as building managers, police, or the fire department. Other actions may be to shut down air circulation and elevators to prevent people being trapped. The system may also need to activate the sprinkler system or smoke barriers as in this case of Engineering IV.

Fire alarm systems must be robust and reliable. This requirement means that fire alarms systems need to work as intended and require backup power in case of a primary outage. If there is a malfunction in the fire alarm system such as faulty smoke detector or if there is a loss
to the sprinkler water pressure, building managers must be alerted to this. Fire alarm systems must be maintained properly. Alarm devices need to be tested regularly and updated when necessary. Even in the world of facility managers, the fire alarm system is many times neglected as it is not an easily visible feature of a facility. Many facility managers may never think about the fire alarm system until there is a problem such as a trouble alarm or a water pressure problem. This can be a problem when an actual fire event occurs. The designer and facility manager must keep the objective of optimizing the life safety of building occupants when thinking about design and maintenance of the fire alarm system.

Fire Alarm System Overview:

The fire alarm system installed in Engineering IV is a modern design consisting of a Notifier NFS-640 brand mass notification fire alarm control panel (FACP) that networks out to a building wide network of initiating devices and notification appliances as well as various other components. The majority of initiating devices are smoke detectors and manual pull stations. Sprinkler heads are also initiating devices and a water flow switch will send a signal to the FACP. There are also many wall mounted strobe lights and horn strobe appliance throughout the building. As can be seen in Figure 15, the fire alarm system component schedule of Engineering IV shows a system that is typical of a large academic or office building with similar occupancy use.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>QTY</th>
<th>DESCRIPTION</th>
<th>PART NUMBER</th>
<th>CSFM LISTING NUMBER</th>
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<td>NOTIFIER NFS-640</td>
<td>7170-0028:216</td>
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<tr>
<td>FCPS</td>
<td>4</td>
<td>FIRE ALARM POWER SUPPLY</td>
<td>NOTIFIER FCPS-24S8</td>
<td>7315-0028:225</td>
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<td>FIRE ALARM ANNUNCIATOR</td>
<td>NOTIFIER FDU-80</td>
<td>7120-0028:209</td>
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<td>NOTIFIER FST-851</td>
<td>7270-0028:196</td>
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<td>22</td>
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<td>NOTIFIER FSP-851</td>
<td>7272-0028:206</td>
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<td>12</td>
<td>MANUAL PULL STATION</td>
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<td>7150-0028:199</td>
</tr>
<tr>
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<td>29</td>
<td>MONITOR MODULE</td>
<td>NOTIFIER FMM-101</td>
<td>7300-0028:202</td>
</tr>
<tr>
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<td>29</td>
<td>RELAY MODULE</td>
<td>NOTIFIER FRM-101</td>
<td>7300-0028:202</td>
</tr>
<tr>
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<td>2</td>
<td>DUCT SMOKE DETECTOR</td>
<td>NOTIFIER FSD-751P</td>
<td>3240-0028:205</td>
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<td>SYSTEM SENSOR S1224MCW</td>
<td>7125-1653:162</td>
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<tr>
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<td>7135-1653:163</td>
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</tr>
<tr>
<td>2</td>
<td>2</td>
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<td>BY OTHERS</td>
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<td>2</td>
<td>CONTROL VALVE TAMPER SWITCH</td>
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<td>BY OTHERS</td>
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<td>2</td>
<td>ONSY SWITCH</td>
<td>PROVIDED BY OTHERS</td>
<td>BY OTHERS</td>
</tr>
</tbody>
</table>

Figure 15. Engineering IV As-Built Fire Alarm System Schedule

Fire Alarm Code. The type of system as indicated on the as-built drawings is an “AUTOMATIC AND MANUAL FIRE ALARM SYSTEM WITH SPRINKLER MONITORING, ELEVATOR CONTROL INTERFACE AND HVAC SHUTDOWN”. This essentially means that the fire alarm can be activated by the automatic detection of the smoke or heat detectors or manually activated using the manual pull stations. The activation of the sprinkler system also notifies the main panel. Upon an alarm, the elevators will shut down, move to the bottom floor or the lowest floor without smoke, and open the doors until the system is reset. The HVAC system includes fire dampers that close upon smoke detection in the air handling system. This feature prevents unnecessary smoke movement to other parts of the building.

Another important aspect of this building’s fire alarm system communication sequence is that upon an alarm signal the Fire Alarm Control Panel (FACP) will notify the Cal Poly campus police station through a remote fire alarm panel located at the station. This is known as a protected premises system. A police officer will be dispatched to investigate the situation and decide if the fire department needs to be called. The FACP will send a signal directly to the local fire station if the alarm is a sprinkler system water flow issue. The Cal Poly facilities department states that the estimated Fire Department response time is approx. 3 minutes. Different facilities and organizations will manage this type of communication differently. Some facilities let building managers be the first investigators, some let third party companies do the work. It is important that whoever takes on this responsibility must be trained to assess whether a fire emergency warrants a call to the fire department or not.

Fire Alarm Control Panel

The Fire Alarm Control Panel (FACP) is the brains of the fire alarm system. Modern FACP systems are powerful computers with software programs that have input and output capabilities. All fire alarm devices are connected to the FACP. The initiating devices such as smoke alarms, heat detectors, and water flow switches signal to the FACP that a fire emergency is detected. Upon these signals, the FACP then activates notification appliances such as strobe lights, horns, and voice messages to alert occupants. The FACP can also communicate to relay switches to shut off air circulation, shut down elevators, and activate smoke barriers among other actions. It also signals or calls remote systems or responders such as the building manager, police station, or fire station. The FACP also signals when there is a problem in the system such as a sprinkler system malfunction or a bad smoke detector. The FACP has a keypad for input programming and an output to identify different alarms and
alerts. A separate laptop computer can also be connected the FACP to download software updates or adjust how the panel is programmed.

The model used in Engineering IV is the Honeywell Notifier NFS-640 (see Photo 4). The fire alarm devices are connected through wire circuits that are run from the devices to the FACP through conduit. This particular FACP has the capability to connect up to 64 circuits. The wiring connections for the various system devices are labeled. As can be seen in Appendix C there is an input keyboard for system analysis and program adjustments. There is also a graphic display. Although designed over 10 years ago, this system is still very sophisticated and includes a high level of capabilities. Also included in the FACP box is a phone and 2-way radio system. A responder such as a building manager or fire department personnel will likely come and observe the fire alarm panel early in a fire alarm situation. That person will be able to communicate using the box phone or radio to fellow responders. As is typical for multi-story facilities, the main FACP is located in a utility room on the 1st floor. The FCPS’s (see Photo 5) act as a junction box, device circuit extender, and back-up power sources for the device circuits on the different floors. They are connected directly to the primary building power source but there are also backed up by batteries in the boxes in case of primary power outages.

Another accessory to the FACP are the annunciator displays. These are display panels that are mounted in places that are easier for responders to look at, such as separate floors. There are two of these for each floor of Engineering IV. They provide a condensed format of information that is displayed on the FACP graphic display. However, the annunciator displays could be located in other places that a fire department responder might be able to get to quicker for various reasons.

An important aspect of the fire alarm system is its programmed sequence of operations. The fire alarm control panel has a computer installed with a programmable software application that controls the sequence in which the fire alarm system will process. Once a fire alarm initiating device such as a smoke detector activates, the fire alarm performs several actions in a sequential order. In the case of the alarm system in Engineering IV, the sequence would be as follows:

1. Annunciate on FACP
2. Annunciate at Remote Annunciator
3. Sound the General Alarm
4. Activate All Roll Down Doors and Fire Shutters
5. Recall Associated Elevators
6. Shutdown Associated Air (HVAC) Unit
7. Annunciate at Remote 24 Hours Attended Location

The full Sequence of Operation matrix is included in Appendix E.

Initiating Devices:

Initiating Devices are fire alarm components that alert people and the fire alarm control panel if available, that there is an emergency due to a fire. There are two types of typical initiating device. Manual initiating devices are typically manual pull stations that one might see at egresses from rooms or buildings. These pull stations are used by building occupants who theoretically would pull the lever that would sound the space or building fire alarm and if available the main fire control panel. Another type of initiating device actuates automatically such as heat and smoke detectors, or water-flow detectors from a sprinkler system. Once a fire starts, these automatic initiating devices sound and alarm and/or send an alarm signal to the fire control panel based on a set activation temperature.

There are 22 Notifier Brand NBG-12LX Manual Pull Stations throughout the building (see Photo 6). In accordance with article 760 of the National Electric Code, these pull stations are to be mounted 48” above the finished floor. These pull stations or “alarm boxes” are located throughout Engineering IV in accordance with chapter 17 of NFPA 72:

17.15.9.4 Manual fire alarm boxes shall be located within 5 ft (1.5 m) of each exit doorway on each floor.

17.15.9.5 Additional manual fire alarm boxes shall be provide so that the travel distance to the nearest manual fire alarm box will not exceed 200 ft (61 m), measured horizontally on the same floor.

17.15.9.6 Manual fire alarm boxes shall be mounted on both sides of grouped openings over 40ft (12.2 m) in width, and within 5 ft (1.5 m) of each side of the grouped opening.
There are 243 Notifier FSP-851 Smoke Detectors installed throughout the building (see Photo 7). The number of these devices relative to all other fire alarm system components reflects the high dependency on these for notification of a fire emergency. These are photoelectric type smoke detectors that have a fixed activation temperature of 135°F (57°C). NFPA 72 specifies that these detectors are to be spaced no more than 30 ft (9.144m) from each other for ceiling heights of 10 feet or more, with smooth ceilings. There are some smooth ceilings in the staff offices, classrooms, some common areas, and other spaces in Engineering IV. There are also many classrooms, laboratories, and combinations of the two that have exposed ceilings. These detectors in these cases are mounted on structures or side walls that are located in optimum locations.

Duct smoke detectors are another important initiating device that are installed in the air handling units (AHU). These AHU’s are apart of the building’s HVAC system, and they normally supply conditioned air throughout. The majority of the supplied air is returned to the AHU through return air systems located through vents that are often located near the supply registers. If a fire develops somewhere in the building, the smoke could potentially enter one of the return vents, then travel to the AHU. The duct smoke detector would then initiate a fire alarm through the fire alarm panel which would in turn shut down the AHU thus preventing smoke from being pushed back into the building. Engineering IV has two AHU’s mounted on the roof of the building. Both of these AHU’s contain two Notifier FSD-751P duct smoke detectors.

Alarm Notification Appliances:

There are 61 and 69 wall mount strobes and wall mount horn strobes respectively throughout the building. The intent is to provide visual and/or audible alerts to building managers and occupants during a fire emergency. The strobe lights provide the visual alert and horn strobes provide a visual and audible alert. Both the strobe lights and horns must provide a range of visual and audible alerts to be effective. It is not possible to provide the exact same light and sound levels at every square inch of a facility. The objective is to optimize the ability to alert occupants without harming them or expending resources more than necessary. The requirements of
how to space and locate these devices are in Chapter 18 of NFPA 72, 2019 Edition. Strobes
lights should be spaced and located based on the amount of the device light output (candelas),
and the space area. The strobe lights used in this building are System Sensor brand,
S1224MCW, see Photo 8. The strobe lights specification sheets indicate that these devices can
put out up to 75 candela or (cd’s) of light. In accordance with table 18.5.5.1 (a) of NFPA 72,
2019, a single 75 cd strobe is adequate for a 45 x 45 sq ft. The objective is to make sure
occupants can see the strobe light flashing from any point in the space. The strobes installed in
Bldg. 192 seem to generally follow the NFPA requirements give or take a few feet. Most
classrooms and laboratories throughout the building have single strobe lights or horn strobe
lights. Most of the rooms are within the space limits of the light output of these strobes,
however there are some rooms that may need to be revisited and analyzed to ensure strobe
visibility is available throughout the space. The horns can be set to various dBA levels up to 86
dBA in accordance with the vendor data sheets. For a business or educational occupancy, NFPA
72, 2019 Edition, Table A.18.4.4, indicates an ambient sound level to be 54 and 45 dBA
respectively. Tests have shown that noise dBA levels drop 6 dBA every distance doubled. NFPA
72 requires that the horn device provides a minimum dBA level of 15 over the ambient. The
horns installed in Building 192 are adequate for this buildings application if adjusted correctly.
This installation should be surveyed in the field for accuracy.

Location and Spacing:

The location and spacing of the various fire alarm system components should be based
on NFPA 72. The design of Engineering IV was based on
the 1999 edition as noted on the as-built drawings.
NFPA only published as far back as the 2007 edition,
however. In general, it appears that the locations of the
fire alarm devices are adequate, but it is recommended
that a survey be done as soon as possible to identify any
areas that are significantly different from the current
codes. In accordance with NFPA 72, 2019 edition,
initiating devices should be located in accordance with
Chapter 17 and Annex B. The design, height and slope of
ceilings have significant impacts to where smoke and
heat detectors can be mounted and located. In the case
of Engineering IV, there are a few different types of
ceilings. Many of the classrooms and laboratories have
high exposed ceilings that have HVAC ducts, hanging lights, and wiring conduits as well as a
sprinkler piping system. In this case, the smoke detectors are mounted on hangers positioned
just below all of the equipment in the ceiling (see Photo 9). There are also some classrooms, administrative areas, and various other common areas that have drop down ceiling grids. Paragraph 17.7.3.2.3.1 states the following:

17.7.3.2.3.1* In the absence of specific performance-based design criteria, one of the following requirements shall apply:

(1) The distance between smoke detectors shall not exceed a nominal spacing of 30 ft (9.1m) and there shall be detectors within a distance of one-half the nominal spacing, measure at right angles from all wall or partitions extending upward to within the tip 15 percent of the ceiling height.

(2) All point on the ceiling shall have a detector within a distance equal to or less than 0.7 times the nominal 30 ft (9.1m) spacing (0.7s).

The smoke detectors throughout the building generally follow this location and spacing scheme. Although there are only a few heat detectors in the buildings, these should be mounted in accordance with Table 17.6.3.5.1.

The notification appliances, strobes and horn/strobe combination devices are located in accordance with NFPA 72, Section 18. Strobe lights need to be able to provide the proper light output based on the space dimensions, and the horns must provide the proper alarm volume for all occupied areas.

The System Sensor strobe lights provide various adjustable candela levels based on the power voltage. For 12 or 24 voltage applications, the strobe can be adjusted from 15 to 75 candela. At a 24 volt application, the strobe can be adjusted from 30, 75, or 110 candela. In accordance with Table 18.5.5.5.1(a) of NFPA, 2019 edition, these settings are adequate for a 20 x 20 ft, 45 x 45 ft, and 54 x 54 ft areas respectively.

Wiring:

Having the right wiring connecting the fire alarm devices to the FACP is an important aspect not to be overlooked. It should not be assumed this is a simple action as it involves understanding the voltage used and the amperage capacity of individual devices and system components. Table 3 shows the wire type designation and description that is used in the fire alarm system for this building. This is a typical design drawing format. As can be seen in this

<table>
<thead>
<tr>
<th>WIRE DESIGNATION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>16/2 FPL SIGNALING LINE CIRCUIT (SLC) CABLE</td>
</tr>
<tr>
<td>B</td>
<td>14/2 FPL NOTIFICATION APPLIANCE CIRCUIT (NAC) CABLE</td>
</tr>
<tr>
<td>C</td>
<td>3 - 18/2 FPL ANNUNCIATOR CABLES</td>
</tr>
<tr>
<td>D</td>
<td>16/2 FPL INITIATING CIRCUIT CABLE</td>
</tr>
<tr>
<td>E</td>
<td>14/2 FPL 24VDC SETTABLE POWER CABLE</td>
</tr>
<tr>
<td>F</td>
<td>14/2 FPL 24VDC NON-SETTABLE POWER CABLE</td>
</tr>
</tbody>
</table>

Table 3, Wire Designation from Engineering IV As-Built Fire Alarm Diagram
case, two sizes of wire are used which are 14 AWG and 16 AWG. Components that need lower current to operate are typically data transmissions such as a Signaling Line Circuit (SLC) cable. Devices such as horns or voice message speakers typically need more current to operate so those wires may be a larger gauge. Current and voltage capacity requirements should be calculated to ensure that circuits are designed within their capacity. An example of this calculation is shown Table 4. Two different circuits of two separate Fire Alarm Power Supply (FCPS) panels are calculated for current and voltage capacity. These two circuits have several components attached and therefore good examples of whether the wire used meets the requirements. Two different Notification Appliance Circuits (NAC) were assessed as shown. NAC circuit 6 is connected to a panel on the first floor. There are several strobe and horn/strobe combination devices on this circuit, and it can be seen the voltage drop from all those components is about 3.103 v, which is about a 12.9% drop. NAC circuit 9 which is on the second floor of the building is similar to NAC circuit 6. There are a few less components and this is reflected in the lower voltage drop. Again, these requirements are within the listed component parameters.

Table 4, Voltage Drop Calculations

<table>
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<tr>
<th>NAC Circuit</th>
<th>Strobe (110 cd, 0.209 amp)</th>
<th>Strobe (75 cd, 0.160 amp)</th>
<th>Strobe (30 cd, 0.090 amp)</th>
<th>Strobe (15 cd, 0.059 amp)</th>
<th>Horn/Strobe (110 cd, 0.167 amp)</th>
<th>Horn/Strobe (75 cd, 0.167 amp)</th>
<th>Wire Size</th>
<th>Resistance (ohms)</th>
<th>Length (feet)</th>
<th>Total Current (amps)</th>
<th>Voltage Drop</th>
<th>Voltage Drop %</th>
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Secondary Power:

A fire alarm system must work when there is a primary power outage. Building power outages can last for minutes or they can last for days, maybe even weeks. This depends on the various situations such as how bad the damage that caused the outage is and how fast the power company and contractors can fix the situation. Regardless of the power outage situation, the fire alarm system must be able to work at all times while there are occupants in the building. Otherwise there is a situation where lives can be in danger because the occupants of the building may not know a fire has happened. In a building with multiple floors, this risk of casualties is greater, as their egress paths and times are more difficult and longer the higher the floor.

Because of this situation, back up batteries are typically included in the Fire Alarm Control Panel box and the remote Fire Alarm Power Supply boxes to provide Secondary Power. NFPA 72, 2019 Edition requires that a secondary power source can provide 24 hours of standby power service and 5 minutes of alarm service. FCPS 2 of Engineering IV is analyzed in the Figure.
7 to provide an example of a required battery capacity given in amp-hours. In this case, the battery capacity needed is over 4.3 amp-hours for this particular FCPS. The specification for the FCPS-24S8 provides a minimum battery capacity of 7.0 amp-hours. However, this unit is capable of housing up to 18 amp-hour batteries that are available for order through Notifier. It is assumed that the minimum battery life of 7 amp-hours are adequate for all of the panels in Engineering IV since the quantity of devices are similarly distributed in all of the panels. However, it is recommended that a full calculation of the FACP and FCPS panel circuits be assessed and recalculated as soon as possible to ensure that the correct battery capacities are provided.

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<thead>
<tr>
<th>Description</th>
<th>Standby Current Per Unit (AMPS)</th>
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<th>Total Standby Current Per Unit (AMPS)</th>
<th>QTY</th>
<th>Total System Standby Current (AMPS)</th>
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<td>0.209</td>
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<tr>
<td>Horn/Strobes</td>
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<td>8.778</td>
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</table>

**Figure 16, Battery Capacity Calculation**
Installation and Maintenance Documentation:

NFPA 72 requires initial testing and commissioning of the fire alarm system before the building is turned over to the owner by the general contractor. This should have been included in the System Record of Completion as shown in Chapter 7 of NFPA 72, 2019 edition:

1) Property Information
2) Installation, Service, Testing, and Monitoring Information
3) Documentation of Software
4) Description of Service
5) Power Requirements
6) Circuits
7) Remote Annunciators
8) Initiating Devices
9) Notification Appliances
10) System Control Functions
11) Interconnected Systems
12) Certifications and Approvals (with signatures from the associated authorities)
13) Other supplementary information

Having the record of completion is important to have available for building managers to be able to maintain the system in the future. Facilities personnel can change over frequently, and the System Record of Completion would be the most comprehensive document of the system details. This was not available for this report, but it is recommended that this be either retrieved, and compared to the current system in case there have been modifications since the initial construction completion. If the initial records cannot be retrieved, then it is recommended that a fire protection consultant be hired to survey the system to create a new document. This document should include a recommissioning of the system.

Commissioning is an important practice for building management systems. These systems are complex as they often involve a central computer that takes in data then make decisions based on the that data. In the case of fire alarm systems, the commissioning requirements are identified in NFPA 4. Commissioning efforts help to ensure that when initiating devices such as a manual pull station or smoke detector are activated, the signal is reliably sent to the FACP. The FACP must then reliably send signals to the notification devices such as strobe lights, horns, or sprinkler systems for example. This must all be methodically tested up installation of the system to make certain the components work when they are supposed to. For example, a horn may be activated in test mode. All relevant building stakeholders which include the building owner, contractor, consultant, and others must concur on record that the horn operates as intended. Every component of the system must go through this rigorous testing. Otherwise the installation effort is wasted. Take another complex system
such an automobile. Imagine during the construction of a car if the engine was installed and then sold without any testing. Would a consumer be confident that everything was going to work the first time the ignition was turned?

Summary:

Engineering IV has an adequate and reliable designed Fire Alarm System. The design meets the requirements of NFPA 72. Even though the original design was based on the 1999 edition, it still appears to meet the 2019 edition in terms of the requirements for location and spacing of alarm devices. It also meets the requirements for the secondary power requirements. The Fire Alarm Control Panel is still modern and sophisticated enough for today’s requirements. The initiating devices such as smoke detectors are located within NFPA 72 current code. The secondary power system appears to meet requirements.

The aspect that requires more investigation is the condition of the system today. Initial commissioning certifications and maintenance records were not available for this report. These should be assessed by a consultant including field surveys if necessary. Re-commissioning of the system is recommended in the near future. Maintenance logs should be reviewed if available and assessed for necessary updates.

Smoke Management:

A unique feature of this building is the smoke barriers between the second and third floors (see Photo 10). The three floors of the building are connected by the main central stairwell of the building and several openings in the east corridors of the second and third floors. These features help define these connected areas as an atrium in accordance with the

Photo 10, Smoke barriers and smoke enclosure on 3rd floor
International Building Code (IBC), section 201. Section 404 of the IBC states that atriums that connect more than two stories are required to have smoke control system and section 909 states that this can be a mechanical or passive system.

The smoke barriers and enclosure on the third floor, act as a passive smoke control system. The corridor openings have steel barriers that are actuated by motors closing off the openings when signaled by the alarm system. The smoke barrier/enclosure at the top of the middle building stairwell on the third floor becomes fully enclosed when the smoke release doors actuate. The door to the barrier is magnetically released when signaled by the Fire Control Panel upon smoke detection. Sprinklers are located around the exterior and interior perimeters of the smoke enclosure glass for the sole purpose of keeping the glass cool so as not to break at high fire heat rates. There are also smoke curtains that drop down from the ceiling in front of the elevators to protect elevator occupants from being engulfed with smoke as the doors open. These are also actuated upon a signal from the Fire Alarm Control Panel.

Prescriptive Analysis Summary:

Engineering IV was designed and built in accordance with all the appropriate safety and building codes meant to aid occupants in evacuating Engineering IV promptly during a fire event. The proper alarm and notification system is available to let occupants and first responders know when there is a fire event. There is a water sprinkler system throughout the building designed to try to suppress any fires that might happen. A smoke management system is installed to limit smoke spread throughout the building. The structure of the building is designed to resist failure due to a significant fire for 2 hours to provide adequate time for occupants to evacuate the building. The building is designed with the required amount of exits on each floor and provides them within the required distances from any point.

The next phase is the Performance Analysis which will help to understand whether all of the fire protection components of Engineering IV will help occupants evacuate during a fire event before conditions become too hazardous, or untenable. The prescriptive analysis does not answer this question. It is sometimes assumed that as long as a building is built to code that the occupants will be protected from fires. This might be because many of the fire and life safety codes have been developed as a solution from the result of fire disasters. While it is true that building in accordance with fire safety codes will likely provide a level of safety for some occupants, it may not provide safety for all occupants. Providing safety to all occupants is the objective.
Performance Analysis

Introduction:

The objective of the performance analysis is to assess whether occupants of Building 192 can exit the premises before harmful untenable conditions occur due to a fire event. We’ve concluded thus far that fire protection components of Engineering 4 are compliant with the appropriate building and safety codes through the prescriptive analysis. However, the performance analysis helps to support whether it is probable that all of those fire protections components and systems of the building will help get occupants out safely.

This analysis will show that in general, occupants can evacuate the facilities in a safe manner before untenable conditions occur. This is based on the estimated design fires developed and results of simulation modeling. Design fires were developed on what is estimated to be the most probable types of fires that could occur in the facility. These design fires are subject to the experience and knowledge of the fire protection engineer. While the design fires provide characteristic information about the fires, it is necessary to model this fire due to the complexity of all the possibilities during a unplanned fire event. The optimum way to model these design fires is through the NIST’s Fire Dynamic Simulation (FDS) application. The FDS application allows complex calculations based on the inputs provided. The outcomes of this model can be visually represented through several applications. The application used for this report is Pyrosim.

Fuel Sources:

A discussion of potential fuel sources is necessary when developing Design Fires. This is because fire modeling requires understanding of the characteristics of a fire in terms of size and growth rate. For academic engineering facilities, the potential fuel sources vary greatly. Some examples of potential common fuels are wood cabinets, various plastics in such forms of furniture and laboratory equipment, flammable liquids and chemicals, stored cardboard, and the list goes on and on. Goals for design fire characteristics is to simulate a combination of highly probably and highly dangerous potential fire scenarios.

Published data is available for heat characteristics of many materials based on standard laboratory tests. While tests in a laboratory can be much different than an actual fire event, these data points provide a basis for estimation. Kim and Lilley’s Heat Release Rates of Burning Items\(^5\), includes several data tables containing fire growth rates of several materials such as

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wood cabinetry, chairs, desks, and other materials that might be found in Engineering IV. Fire sizes and growth vary from single digit kW fires up to around 6 MW fires with slow to fast growth rates relative to a standard t-squared fire growth.

Table 5 shows a sample of heat release data tables from Kim and Lilley’s data. Heat release vs fire growth rates were recorded for many materials associated with furniture. Materials vary greatly in their maximum heat release rates and growth rates.

Table 5, Hyeong-Jin Kim and David G. Lilley, Jan 2000, Heat Release Rates of Burning Items in Fires, AIAA 2000-0722

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<th>CODE</th>
<th>DESCRIPTION</th>
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<th>$t_{120}$</th>
<th>$Q_{max}$</th>
<th>$M_{10}^c$</th>
<th>$M_{100}^c$</th>
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<td>Fig A2</td>
<td>Wardrobe 2</td>
<td>1% Plywood wardrobe, clothing on 16 hangers</td>
<td>0</td>
<td>30</td>
<td>60</td>
<td>90</td>
<td>500</td>
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<td>Fig A3</td>
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<td>1% Plywood wardrobe, clothing on 16 hangers</td>
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<td>40</td>
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<td>1% Plywood wardrobe, clothing on 16 hangers</td>
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<td>80</td>
<td>400</td>
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<td>Chair, urethane foam frame, urethane foam, polyethylene fabric</td>
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<td>70</td>
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<td>340</td>
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<td>Loveseat, wood frame, urethane foam, polyurethane fabric</td>
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<td>Metal wardrobe 1</td>
<td>Metal wardrobe, clothing on 16 hangers</td>
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<td>125</td>
<td>125</td>
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<td>Fig A29</td>
<td>Patient lounge chair</td>
<td>Patient lounge chair, metal frame, urethane foam, cotton fabric</td>
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<td>Fig A31</td>
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<td>Sofa, metal frame, California foam, polyurethane fabric</td>
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<td>100</td>
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<td>Fig A32</td>
<td>F21 Chair</td>
<td>F21 Chair, wood frame, polyurethane foam, cotton fabric</td>
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<td>Fig A33</td>
<td>F31 Loveseat</td>
<td>F31 Loveseat, wood frame, polyurethane foam, cotton fabric</td>
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<td>Fig A34</td>
<td>F32 Sofa</td>
<td>F32 Sofa, wood frame, polyurethane foam, cotton fabric</td>
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<td>150</td>
<td>200</td>
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Figure 17 shows several graphs of tested materials of heat release rates vs time. As can be seen, there are several types of materials that were tested, this is only an example of the data in this reference. Other heat release data are available. As can be seen, there is a wide variety in the maximum heat release rates and fire growth rates.

![Graphs of tested materials](image)

Fig. A25. Loveseat, wood frame, California foam, polyolefin fabric

Fig. A31. Sofa, wood frame, California foam, polyolefin fabric

Fig. A10. Red oak, 7/8 in. thick (1469), Board

Fig. A16. PMMA 1" black (cb) w/frame (test 1470), Sheet

*Figure 17, Examples of potential materials that may be fuel sources in Engineering IV, Note: HRR data from Hyeong-Jin Kim and David G. Lilley, Jan 2000, Heat Release Rates of Burning Items in Fires, AIAA 2000-0722*
RSET vs ASET:

An understanding of the Required Safe Egress Time (RSET) and Available Safe Egress Time (ASET) are necessary to provide a performance assessment of the building. The RSET is an estimated time of how people move and evacuate the building during an emergency fire event. This involves the time from when a notification of fire is given to the time it takes for people to start moving towards the emergency exits, or pre-movement. There have been many studies regarding human behavior in this area. Along with collected empirical data, this information can be used to estimate RSET. ASET is the time it takes for conditions to become untenable for occupants during a fire as characterized in a specific design fire. Untenable conditions include high temperatures, heat fluxes, toxicity from smoke, and visibility diminishment. ASET needs to be greater than RSET to support evacuation of all occupants in a safe manner. To put this in other words, the analyses need to show that people can evacuate the building before the proposed fire causes conditions that can harm or kill occupants.

RSET Analysis:

Introduction:

The method of calculating RSET involves understanding human behavior relative to occupant movement in an emergency situation, and the effects of different aspects of the building such as exit path capacities, stairways, and others. The following paragraphs will discuss the aspects of the building and the methods used to estimate human movement. Although there has been much data through various studies developed, the methods used to estimate human movement cannot determine actual events. This information will help in identifying possibly shortcomings and therefore improve risk mitigation during emergency events.

Impediments to efficient egress:

The first floor provides many exits out of the building. If exit signs are in the correct places and easily visible, then egress during an emergency should be successful. There are a few areas of concern such as the faculty hallway on the east end of the building. As shown in Figure 18, there are some dead ends that might be a problem if smoke obscurity is present. Also, a significant fire in the office closest to the east end fire exit could block off all the offices from escape.
On the second floor of the building as shown in Figure 19, the west end of the building has two very easily accessible exit passageway to the northwest and southwest fire exit stairwells. The east end of the building has similar dead-end issues as the first floor. A significant fire in the office closest to the fire exit could cut off the remaining offices to the north. The remaining classes and laboratories in the middle and west side of the building have adequate alternative evacuation means.

The third floor has some similar potential escape route blockages on the east end of the building (see Figure 20). The west end of the building only has an exit to the northwest fire escape stairwell. There is no fire exit on the southwest fire escape stairwell. The path from the
southwest corner of the building has several turns before getting to the northwest stairwell. Exit signs in the area need to be clear to lead occupants in the right direction. Students in the eastern side of the building have a long way to travel to the northwest stairwell if the east end of the building is cut off. Once students get to the west end of the building, they would have to traverse a few turns to get to the exit. The middle stairwell of the building on the third floor is cutoff to go downstairs as it has a smoke containment built on to the stairwell area that will close off automatically in case of a fire.

Figure 20. Third floor has potential egress problems

*Occumant Characteristics:*

The number of students in the building will vary throughout the week with the peak probably during typical working hours such as 8:00 am to 4:00 pm. Students will occupy the building during night classes also, and there will probably be students working in laboratories during the weekend also. Faculty personnel will probably be in the building either teaching or working in their offices on a regular basis. Other personnel will probably stagger in and out of the building.

Most of the time, students will probably be clustered together in classrooms. However, there will be many times when students will be by themselves or with just a few people working on projects in laboratories. It cannot be assumed that the normal population is fully familiar with the building layout at any given time. There are a wide range of people with various knowledge of the building. There will be many freshman students who are new to the building as well as senior students who have been in the building for several years.

The majority of the building’s population at peak hours should be mostly students and their alertness should be high as they are in general, young and in good health. There may be an assumption that college students may be impaired by lack of sleep, however this will not be a factor considered for this report. The faculty in the building would need to be relied on to ensure that the students follow the correct protocol in evacuating during an emergency. It is
difficult enough for older adults to leave buildings during fire alarms, young adult students may find it very difficult to make the right decisions in that scenario.

Total Evacuation Time:

The time it takes to evacuate a building is a key element in assessing the egress effectiveness. The analysis for this report is based on the hydraulic method of egress as described in Chapter 59, *Employing the Hydraulic Model in Assessing Emergency Movement* of the SFPE Handbook. Required Safe Egress Time (RSET) is made up of the different phases of evacuation as follows:

$$RSET^6 = t_d + t_n + t_{p-e} + t_e$$

- $t_d =$ Time from fire ignition to detection: That is the detection phase
- $t_n =$ Time from detection to notification of occupants of a fire emergency; that is, the notification phase
- $t_{p-e} =$ Time from notification (or cue reception) until evacuation commences; that is the pre-evacuation phase
- $t_e =$ Time from the start of purposive evacuation movement until safety is reached; that is, the evacuation phase.

Both $t_d$ and $t_n$ are determined by the individual fire scenarios and technical capabilities of the fire alarm system in place. Fire detection can be activated by persons activating manual pull down stations, a sprinkler head activating, HVAC smoke detector activations, or smoke detectors as well as by other means. In the design fires of this report, the fire detection is activated by smoke detectors. The smoke detectors installed throughout Engineering IV are a photoelectric type. This means that particles of smoke will deflect a light beam in the smoke detector to a sensor which triggers a signal to the fire alarm system. The detection of the smoke for these smoke detectors depend on how fast smoke rises or moves to the detector. To model the time of smoke detector activation in the FDS simulation application, the program allows input parameters for photoelectric smoke detectors. The Notifier FSP-851 brand smoke detectors installed in Engineering IV have a 0.5% to 2.35% per foot obscuration. This metric output is provided in the FDS results for every period of simulated time listed throughout the model.

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Time from detection to notification, $t_n$, will be assumed as happening instantaneously. The pre-evacuation phase, $t_{p-e}$, is very complex metric to estimate. Empirical data based on emergency drills is one of the better sources of information for this purpose.

The time when occupants begin to move, $t_e$, will be estimated using the Hydraulic Model from SFPE Handbook which estimates the movement speed of occupants based on the density of the occupants compared to the square footage. If the population density is less than 0.05 persons/ft$^2$, then it is estimated that people will move freely without any impedance through corridors, exit passages, stairways, etc. Between 0.05 and 0.35 persons/ft$^2$, then empirical formulas estimate the movement speed. Above 0.35 persons/ft$^2$, people are unable to move adequately. In this case, the population density is 1530 people divided by 104,631 ft$^2$ of useable space which is 0.0146 persons/ft$^2$. Due to this density, we can assume that occupants can evacuate the building at a speed independent of other people’s movement speeds. The maximum flow speeds according to the hydraulic model is 235 ft/min along a corridor, aisle, ramp, or doorway. Using these maximum flow speeds and estimated pre-evacuation times, the RSET is estimated as the following:

$$t_d = \text{Based on simulations models for individual fire scenarios}$$
$$t_n = \text{Base on technical capabilities, assume instantaneous reaction}$$
$$t_{p-e} = 69.9 \text{ seconds (see footnote)}$$
$$t_e = 52 \text{ seconds based on SFPE Handbook Hydraulic Method}$$

This analysis is based on the assumption that flow speeds of occupants during evacuation is at maximum levels due to the low population density of the building. In this case, it can be deduced that the occupants on the third floor will take the longest to evacuate the building. Therefore, the time to evacuate the building is based on the time to evacuate the third floor. This RSET time of 121.9 seconds from detection of a fire will be used to compare to the ASET which will be explained for each design fire later in this report.

ASET Analysis:

Tenability Analysis:

The overall performance criteria is to make sure that “Any occupant who is not intimate with ignition shall not be exposed to instantaneous or cumulative untenable conditions”, (NFPA 101, Life Safety Code, Section 502). This means that any persons not in direct contact with a fire should be adequately protected from untenable conditions. Those untenable conditions as defined in the SFPE Handbook as the following:

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7 SFPE Handbook of Fire Protection Engineering, 5th Edition, Table 64.9, using Gale et al. data
• Temp > 120°C – Temperatures above this threshold can lead to Heat Stroke (SFPE Handbook, Chapter 63).
• Heat Flux > 2.5kW/m² - This is the radiant heat threshold before a persons’ skin starts to burn (SFPE Handbook, Chapter 63).
• Carbon Monoxide Exposure - Well ventilated fire with 0 to .2% carbon monoxide concentration causes incapacitation in “a few minutes” (SFPE Handbook, Chapter 63, Table 63.3).
• Visibility through smoke < 10m – Human Behavior studies as described in Chapter 61 of SFPE Handbook suggest that visibility impairment below this threshold starts to impair occupant movement (SFPE Handbook, Chapter 61).

These factors were used to analyze the probability of occupants of the building to evacuate before untenable conditions occur. These conditions were analyzed through the Fire Dynamics Simulator application and visualized through Pyrosim. The following sections are the results of the FDS and PyroSim model simulation runs for the Design Fires previously described.

**Design Fires:**

The design fires developed for this assessment are based on the format as described by NFPA 101, Life Safety Code, and the most probable fires that could happen in accordance with the author of this report. The design fires for this report are fires in the atrium lobby of the building, a classroom on the first floor, a faculty office, and an atrium lobby fire with a failure of the smoke management system.

**Assumptions:**

There is no way to know exactly how or when a fire is going to happen. The use of theoretical, empirical, and historical data is used to try to forecast the conditions in which a fire can happen and the conditions that can occur due to that fire. A large part of trying to forecast how a fire will develop and its effects on a building, is to develop adequate Design Fires using all of the available data possible. An important factor for developing Design Fires is to develop justified assumptions.

For example, there is no exact way to know whether a water sprinkler suppression system will work at any given time. However, one could assume that if regular maintenance and testing in accordance with the appropriate instruction is applied to the sprinkler system, then that sprinkler system will activate as expected during a fire event. These assumptions can be compiled and included into a risk analysis and mitigation plan.
The following assumptions for the analysis of Engineering IV are as follows:

1. The fire alarm system is in proper working order. Initiating and notification devices are installed and located in their proper locations and are in working order.
2. The water-based fire sprinkler system of the building is in working order. The fire main water flow and pressure are adequate for the sprinkler system requirements.
3. Building faculty are trained to lead occupants to evacuate the building upon a notification of a fire.
4. Occupants will begin to move to evacuate the building in a reasonable time frame.

Assumptions need to be applied to occupant’s behavior during an emergency also. In these fire scenarios, it is assumed that occupants will begin evacuation procedures within 10 seconds of notification of an emergency. The majority of the occupants will be students and therefore at a younger age. With some exceptions, it is expected that the majority of occupants in the building will move at the fastest speed. Further assumptions may be established for specific Design Fires.

Design Fire 1:

Design fire 1 is a fire scenario that happens in the atrium lobby of the building (See Photo 11). The key characteristics are as follows:

- Fire Source – Furniture in lobby
- Fire Growth – Based on heat release rate (HRR) data from Kim and Lilley (See Figure 22)
- Maximum HRR – 2.5MW
- Soot Yield – 0.198 g/g (polyurethane flexible foam, SFPE Handbook, Table A.39)

Design fire assumptions:

- Lobby is unoccupied.
- Lobby smoke detector initiates fire alarm.
- Smoke Barriers on third floor activate and close off third floor from smoke.
Design Fire 1 (Atrium Lobby) Analysis:

Figure 21 shows the FDS model setup of the atrium lobby. The view in this case is from the south face looking at the lobby and then the first and second floor corridors. The light openings in the corridors as well as main stairwell are incorporated. The simple model of a sofa is shown against the back wall of the lobby.

Figure 22 is the heat release rate versus time based on the data from running this simulation in FDS. The heat release rate was based on the data from Kim and Lilley.
Figure 22, HRR vs Time for Design Fire 1 (FDS). Note: Inset HRR data from Hyeong-Jin Kim and David G. Lilley, Jan 2000, Heat Release Rates of Burning Items in Fires, AIAA 2000-0722
In this simulation, the maximum temperature reached in the lobby and corridors is 80°C in several areas at 296 seconds into the program run (see Figure 23). These temperatures are high, but occupants are estimated to be out of the building within two minutes. Temperature should not reach an untenable condition in this scenario before occupants can evacuate. The heat radiation does not reach untenable condition before evacuation either (see Figure 24).

Figure 23, The temperature peaks at around 80°C locally to the fire but does not exceed 70°C in the corridors of the 1st and second floors.

Figure 24, Heat Flux at maximum at 284 seconds into FDS run
Figure 25 shows that maximum carbon monoxide concentration happens at about 381 seconds. The levels of CO are too low, and occupants will evacuate the building before any significant rate exposure is incurred. Figure 26 does show that visibility through the smoke starts to reduce to 10 meters at 55 seconds into the model run. The RSET estimates that with a pre-movement time of up to 10 seconds that it could take over 65 seconds to get to the east end stair well exit from the middle of the second floor. This movement speed is based on optimum conditions so there is a possibility of occupants being impaired by smoke visibility diminishment if movement is slowed down for any reason.

Figure 25, CO levels reach 0.03% at 381 seconds.

Figure 26, Relative visibility at 55 seconds
Figure 27 represents the ASET vs RSET results based on FDS simulation. As shown, untenable conditions could occur in the building before all occupants would begin to actually move out of the building. That untenable condition begins to occur on the second floor when visibility reduces to a hazardous state in just under a minute. The FDS results show smoke moving from the sofa in the lobby quickly to the ceiling of the lobby and toward the second floor corridor. If some occupants can begin movement towards a building exit immediately upon notification, they might avoid harm. However, using the empirical data for pre-evacuation time, there is a high risk of occupants encountering below threshold visibility limits and therefore being harmed.
Design Fire 2 (1st Floor Classroom):

Design fire 2 is a fire scenario that happens in a classroom on the first floor of the building near the atrium lobby (See Figure 28). The key characteristics are as follows:

- Fire Source – Laboratory Cabinet
- Fire Growth – Based on heat release rate (HRR) data from Kim and Lilley (Figure 30)
- Maximum HRR – 1.2MW
- Soot Yield – 0.03 g/g (Using MDF data from Table 62.18 of SFPE Handbook, 5th Edition)

Design fire assumptions:

- Classroom is unoccupied.
- Classroom smoke detector initiates fire alarm.
- Classroom door from corridor side is open.

Design fire 2 is a proposed classroom fire on the first floor of the building near the lobby of the main corridor. The assumption is that the classroom is unoccupied at the time of fire ignition and therefore allowed to grow until a smoke detector initiates the building fire alarm system. Based on empirical heat release data from Kim and Lilley, the scenario is a fire ignited by use of hot work equipment of some sort and cardboard products. This ignition fire which is expected to be quick burning ignites the laboratory cabinets. In regards to the use of the FDS model, this fire has a fast growth rate with a peak HRR of 1.2MW. The assumption for this design scenario is that no occupants are in the classroom. In addition, another part of the scenario is the double doors leading into the classroom from the corridor are propped open. The smoke is expected to...
spill out of the classroom and rise up from the first floor corridor and immediately to the second floor through openings in the second floor corridor. The FDS analysis will show that there is plenty of time for occupants to evacuate the area and the building before both the classroom and second floor corridor become untenable. Figure 29 shows the initial FDS setup for this Design Fire scenario.

![Figure 29, Initial FDS model setup for Design Fire 2. The left photo is facing the classroom from the south side of the building. The right photo is facing the north side showing the lobby and corridor areas.](image)

Figure 29, Initial FDS model setup for Design Fire 2. The left photo is facing the classroom from the south side of the building. The right photo is facing the north side showing the lobby and corridor areas.

Figure 30 shows the HRR from the FDS simulation. The heat ramp input into FDS used the particle board HRR data from Kim and Lilley. As a note, the fuel description input into FDS was MDF, however the simulated HRR results did not match up with that of the Kim and Lilley’s results. This is likely the result of sprinkler activations at approximately 162 and 178 seconds into the simulation.

![Figure 30. HRR Data from FDS simulation of Design Fire 2, Note: Inset HRR from Hyeong-Jin Kim and David G. Lilley, Jan 2000, Heat Release Rates of Burning Items in Fires, AIAA 2000-0722](image)

Figure 30. HRR Data from FDS simulation of Design Fire 2, Note: Inset HRR from Hyeong-Jin Kim and David G. Lilley, Jan 2000, Heat Release Rates of Burning Items in Fires, AIAA 2000-0722
The temperatures in the corridor outside of the open classroom door get to a maximum of approximately 40°C at around 449 seconds (see Figure 31). Temperatures will not meet untenable conditions before occupants can evacuate the building.

Figure 31, Maximum temperatures at 449 seconds

Figure 32 shows that heat flux never becomes an issue in the paths of travel of the corridors as it does not reach untenable condition. This is also the case for carbon monoxide exposure (see Figure 34).

Figure 32, Heat flux at end of simulation run.
Figure 33, Carbon monoxide levels at end of simulation.

Diminished visibility starts to reach an untenable condition on the second floor corridor at approximately 331 seconds into the simulation (see Figure 34).

Figure 34, Initial untenable condition due to visibility at 331 seconds.
Figure 35 reflects that the effects of the fire are contained in the classroom itself for several minutes. Eventually, smoke starts to leave the classroom and immediately move to the second floor corridor through the architectural opening. As the fire progresses through its cycle in the classroom, the smoke eventually starts to enter the corridors of the first or second floor until visibility starts to diminish after 350 seconds into the simulation. Occupants should have been able to get out of the building and to safety well before the first untenable condition occurs. The first untenable condition occurs as visibility diminishment from the smoke starts to effect the second floor corridor.
Design Fire 3 (Faculty Office):

Design fire 3 is a fire scenario that happens in a faculty office on the east end of the second floor (See Figure 37). The key characteristics are as follows:

- Fire Source – Oak Desk
- Fire Growth – Based on heat release rate (HRR) data from Kim and Lilley (Figure 38)
- Maximum HRR – 250 kW/m²
- Soot Yield – 0.15 g/g (Wood (red oak), SFPE Handbook, Table A.39)

Design fire assumptions:

- Office is unoccupied.
- Office smoke detector initiates fire alarm.
- Office door is propped open.

Design fire 3 is a faculty office located on the north east end of the building (see Figure 36). The premise here is that a fire starts in the office and initially ignites paper stacks and books and eventually office furniture. A fast fire growth rate with a 250 kW/m² fire will be entered into the FDS model. It will be assumed that the office is unoccupied at the time and the office door is left open. The objective here is to study the effects of the smoke leaving the office and thus causing an untenable condition in the corridor which provides a one way only exit. Delayed movement from occupants in this faculty office corridor can result in detrimental harm. If smoke and or fire reach a level so as to block off occupant escape through smoke visibility or any of the other untenable factors, then they may be harmed or worse.
Figure 37 shows the initial set up of Design Fire 3. As described previously, the intent with this scenario was to visualize the impacts to occupants in the other offices evacuating the corridor.

The resulting heat release data graph is shown in Figure 38. The pattern closely follows the data from Kim and Lilley test data.

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**Figure 37, Design Fire 3 Initial FDS model setup.**

**Figure 38, FDS HRR for Design Fire 3, Note: Inset HRR from Hyeong-Jin Kim and David G. Lilley, Jan 2000, Heat Release Rates of Burning Items in Fires, AIAA 2000-0722**
Temperature and heat flux do not get to an untenable level before the end of the model simulation time (see Figure 39).

Figure 39, Top: maximum temperature begins at 175 seconds. Bottom: Maximum heat flux begins at 133 seconds.
The FDS analysis shows that carbon monoxide levels do increase enough during the simulation to cause harm from limited exposure.

![Figure 40](image1.png)

*Figure 40, CO levels reach a maximum of 0.05% at about 143 seconds through the office and main second floor corridors.*

As represented in Figure 41, lack of visibility becomes significant at 40 seconds into the simulation. Visibility reduces to less than 5 meters at this time and may cause panic due to the difficulty of occupants to get through it. The visibility problem is also flowing into the main corridor in this simulation.

![Figure 41](image2.png)

*Figure 41, Visibility becomes untenable at approximately 39 seconds. The occupant of the office corridor should have evacuated before this time.*
Figure 42 shows a significant margin of time between how fast occupants begin to move from the other offices in the corridor and out of the building. Because the scenario involves the faculty office door being propped open, the smoke from the furniture fire quickly starts to move into the corridor. Faculty occupants in the other offices at the time must react and move quickly to avoid being trapped by too much smoke near the office. The pre-evacuation time estimated could quite possibly prevent occupants from getting away from this area before they are harmed. The smoke density could begin to block people from moving out into the main corridor and to an exit.

![Design Fire #3 (Faculty Office): ASET vs RSET](image)

**Figure 42. ASET vs RSET Design Fire 3**
Design Fire 4: Atrium Lobby with Smoke Barrier Failure

Design fire 4 is a fire scenario that happens in the atrium lobby of the building similar to Design Fire 1 but with a significant difference. The key characteristics are as follows:

- Fire Source – Furniture in lobby
- Fire Growth – Based on heat release rate (HRR) data from Kim and Lilley (Figure 44)
- Maximum HRR – 2.5MW
- Soot Yield – 0.198 g/g (polyurethane flexible foam, SFPE Handbook, Table A.39)

Design fire assumptions:

- Lobby is unoccupied.
- Lobby smoke detector initiates fire alarm.
- Smoke Barriers on third floor fail to activate.

Figure 43 shows the initial FDS model setup for Design Fire 4 which is similar to Design Fire 1 with the difference being that the smoke management system on the third floor fails. This means that the smoke barriers in corridor of the third floor do not close, and the smoke door does not close in the compartment at the top of the main stairwell. In this scenario, it is expected that the smoke will rise to the third floor.
The heat ramp is the same FDS input used for Design Fire 1 (see Figure 44). The resulting HRR is very similar.

Maximum temperature and heat flux happen at approximately 295 seconds and do not reach an untenable condition throughout the simulation (see Figure 45 and 46). Occupants are estimated to have evacuated the building in under 90 seconds before the temperature and heat flux get to its maximum.
Carbon monoxide maximum concentration happens at 354 seconds at about 0.02% (see Figure 47). Occupants will have evacuated the building before this becomes an untenable condition.
Figure 48 shows that visibility levels start dropping down to less 10 meters at about 63 seconds from the start of the simulated fire. This happens in areas of the main lobby and on the second floor corridor near the lobby area. In the most optimum scenario, occupants may have already left that area before this condition occurs. However, if there is a large delay in occupant movement due to panic or clustering in certain areas, there is a potential risk of harm to occupants before they can get clear from the area.

Figure 48, Time of initial untenable condition occurring due to diminished visibility on second floor corridor.

Figure 48 shows that untenable conditions occur before occupants can begin to move towards a building exit and before they can evacuate the building. This is because the visibility on the second floor corridor near the lobby area starts to diminish below 10 meters at about 63 seconds into the simulation. Occupants could be out of that immediate area before those conditions occur. However, because occupant movement is assumed to be at an optimum speed, then there is potential risk of danger.

Figure 49 shows that untenability conditions (due to smoke visibility) can occur before occupants can fully evacuate the building. These are similar to the results of Design Fire #1 in which visibility becomes diminished below the threshold before all occupants begin to move towards the exits of the building. The additional potential hazard in this scenario is that the
occupants on the third floor are now susceptible to untenable conditions before evacuation because of the failure of the smoke barriers from closing.

Summary of Results:

The results vary for each type of Design Fire as can be seen in Figure 50. Design Fires 1 and 4 in which there is a sofa fire in the main lobby of the building seem to reflect a potential risk. A fire in the lobby will produce smoke that is quickly directed onto the second floor corridor. This is because the ceiling of the lobby is at the same level of the second floor corridor so the smoke reaches the ceiling and starts moving laterally in all directions. And any smoke that might drift onto the first floor corridor will immediately flow through to the second floor through open stairwell and second floor corridor light wells. When looking at the movement of smoke in the FDS simulation program, one might assume that occupants have left the areas where smoke visibility becomes untenable, but the occupant movement speed is based on the assumption that there is no queuing when people are leaving the classrooms and that they move at the fastest speeds. The Design Fire 4 scenario in which the smoke barriers on third
floor fail to close pose an even higher risk of harm to occupants as the smoke from the fire quickly rises to the third floor.

The FDS results for Design Fire 2 show that there should be plenty of time for occupants to evacuate the building before conditions become untenable. Most of the effects of the fire are contained in the classroom for a long period of time. When the smoke layer in the room drops low enough, it starts to move into the corridor and immediately rises to the second floor corridor until visibility is diminished to under 10 meters at just over 350 seconds. The smoke detector activates at about 17 seconds. Using the estimated time of building evacuation of approximately 72 seconds, then one can assume that all occupants have a large safety gap in terms of time. This would be the case even if the occupant evacuation were slower than estimated.

The results of Design Fire 3 show that there is enough time for occupants to evacuate the office corridor, but they have to begin movement as soon as possible and move as fast as possible. The simulation shows that a fast-growing fire event with the office door propped open will produce and move smoke into the corridor quickly. This smoke is shown to build quickly in the corridor area blocking access to the main building corridor and the exit to the east end stairwell. The smoke also starts to move quickly westward in the main corridor.

![RSET vs ASET](image)

Figure 50, Summary of ASET vs RSET for all Design Fires.
Recommendations:

The following recommendations include details for specific Design Fire scenarios. However, care must be taken regarding decision making to resolve problems areas based on simulated models. A holistic approach must be applied. For example, the Fire Protection engineer or Authority Having Jurisdiction (AHJ) should be careful not to resolve a problem in one Design Fire scenario only to cause a problem in another Design Fire scenario.

Relative to Each Design Fire:

The following is a list of recommendations for each Design Fire scenario:

1) Design Fire 1 (Atrium Lobby):
   a. Remove furniture from lobby area.
   b. Replace furniture with noncombustible materials.
   c. Add horizontal sprinkler heads above furniture.

2) Design Fire 2 (1st Floor Classroom):
   a. Eliminate as much combustible materials as possible.
   b. Perform regular inspections for cleanliness through all areas of the building.

3) Design Fire 3 (2nd Floor, East End Office):
   a. Provide awareness training to office occupants of risks in the area.
   b. Install smoke exhaust system specifically for that area.

4) Design Fire 4 (Atrium Lobby with 3rd Floor Smoke Barrier Failure):
   a. Similar recommendations as Design Fire 1.
   b. Ensure inspection and maintenance plans are performed on smoke barrier systems.
Emergency Management Planning:

Emergency management planning should be a key element to supporting occupant evacuation. It may not be practical to try to include students in the planning, but all faculty and building staff can be trained to have specific roles and responsibilities during an emergency event. The student population of the building could be a combination of first year through PhD candidate level students. Some will be well familiar with the building, others may not at all. For example, if the fire alarm activates during the first week for a freshmen student in the building, they may not be familiar at all what to do. However, faculty can help guide students out with minimal training.

The estimate used for Pre-evacuation times are based on empirical data. Steps should be taken to reduce this potential time frame as much as possible. This is probably best done through both training and enhancement of the fire alarm system.

Conclusions:

The overall assessment of Engineering IV (building 192) is that while the building was compliant with all applicable building and safety codes regarding fire protection, adjustments need to be made to reduce risk of occupant harm during a fire event. This analysis looked at the both the prescriptive aspects and performance aspects of the fire protection components and systems of the building. The objective of this report was to use these analyses to estimate whether occupants could get out of the building in a reasonable time and safe manner during a fire emergency event. While there is no way to predict the exact time or type of fire that may occur, this report helps provide an estimate of what the outcome could be.

From the prescriptive analysis perspective, the various building fire protection components were designed and constructed in accordance with the appropriate fire protection safety and building design codes. The egress provided the correct number of exit accesses and distances to those accesses so that people trying to escape the building could do so in a safe manner. There were enough emergency access exits per NFPA 101 (LSC) on the second and third floors which lead to external stairways. There were other aspects such as LED exit signs and the appropriate panic door hardware installed throughout. The installed sprinkler system throughout the building was designed and constructed in accordance with the appropriate code and appropriate purpose of the building. The fire main supply water flow and pressure had been originally tested and proved to meet the requirement of the building. The fire alarm notification system was also designed and constructed in accordance the appropriate fire safety codes. The fire alarm system is connected to other critical building systems such as the
elevators and HVAC as required. Lastly, the International Building Code (IBC) requires a smoke control system for atrium designs that connect three or more floors. This system is in place in Engineering IV in the form of smoke barriers that would close off the third floor from the first two floors of the building when signaled by the fire alarm control panel.

From a performance perspective, it was shown that there may be risk in some Design Fire scenarios of occupants not being able to evacuate certain areas of the building or the entire building before hazardous fire conditions occurred. For example, the atrium feature of the building includes the main lobby and corridors of the second and third floors. This feature provides some advantages that include natural lighting and air conditioning. However, this analysis showed that fires in the common area of the first floor can cause smoke to spread quickly to the higher floors and into emergency exit pathways. Another area of risk was identified in the faculty office Design Fire scenario. The corridor of the faculty offices on the first and second floors contain dead end areas and may cause a problem during evacuation if an office fire were to occur.

A full risk management program should be developed to identify the probabilities of the various Design Fire scenarios. In addition, mitigation techniques can be developed and analyzed to make decisions on what actions to take and how to prioritize investment.
References:

8. NFPA 72, National Fire Alarm and Signaling Code, 2019 Edition
Appendix B – Fire Alarm System Components
NFS-640
Intelligent Addressable
Fire Alarm System

General
The NFS-640 intelligent Fire Alarm Control Panel is part of the ONYX® Series of Fire Alarm Controls from NOTIFIER.

As a stand-alone small-to-large system, or as a large network, the ONYX® Series of products meets virtually every application requirement.

Designed with modularity and for ease of system planning, the NFS-640 can be configured with just a few devices for small building applications, or for a large campus or high-rise application. Simply add additional peripheral equipment to suit the application.

Features
• One, expandable to two, isolated intelligent Signaling Line Circuit (SLC) Style 4, 6 or 7.
• Up to 159 detectors (any mix of ion, photo, thermal, or multisensor) and 159 modules (N.O. manual stations, two-wire smoke, notification, or relay) per SLC; 318 devices per loop/636 per FACP or network node.
• Standard 80-character display, 640-character large display, or display-less (a node on a network).
• Network option – 103 nodes supported (NFS-640, NCA Network Annunciator, or NCS Network Control Station) using wire or fiber-optic connections.
• 6.0 amp switch mode power supply with four Class A/B built-in Notification Appliance Circuits (NAC). Selectable System Sensor strobe synchronization.
• Built-in Alarm, Trouble, and Supervisory relays.
• Up to 64 output circuits per FACP or network node; circuits configurable online.
• VeriFire® Tools offline program option. Sort Maintenance Reports by compensation value (dirty detector), peak alarm value, or address.
• Autoprogramming and Walk Test reports.
• Optional universal 636-point DACT.
• 80-character remote annunciators (up to 32).
• EIA-485 annunciators, including custom graphics.
• Printer interface (80-column and 40-column printers).
• History file with 800-event capacity in nonvolatile memory, plus separate 200-event alarm-only file.
• Alarm Verification selection per point, with tally.
• Autoprogramming and Walk Test reports.
• Positive Alarm Sequence (PAS) Presignal.
• Silence inhibit and Auto Silence timer options.
• March time / temporal / California two-stage coding / strobe synchronization.
• Field-programmable on panel or on PC, with VeriFire® Tools program check, compare, simulate.
• Full QWERTY keypad.
• Charger for up to 90 hours of standby power.
• Non-alarm points for lower priority functions.
• Remote ACK/Signal Silence/System Reset/Drill via monitor modules.
• Automatic time control functions, with holiday exceptions.
• Surface Mount Technology (SMT) electronics.
• Extensive, built-in transient protection.

NFS-640 shown in CAB-B4 with NCA 640-character display.
• Powerful Boolean logic equations.

NCA 640-CHARACTER DISPLAY FEATURES:
• Backlit, 640-character display.
• Supports SCS Series smoke control system in both HVAC or FSCS modes (not UL-Listed for FSCS).
• Printer and CRT EIA-232 ports.
• EIA-485 annunciator and terminal mode ports.
• Alarm, Trouble, Supervisory, and Security relays.

FLASHSCAN® INTELLIGENT FEATURES:
• Poll 318 devices in less than two seconds.
• Activate up to 159 outputs in less than five seconds.
• Multicolor LEDs blink device address during Walk Test.
• Fully digital, high-precision protocol (U.S. Patent 5,539,389).
• Manual sensitivity adjustment — nine levels.
• Pre-alarm intelligent sensing — nine levels.
• Day/Night automatic sensitivity adjustment.
• Sensitivity windows:
  – Ion – 0.5 to 2.5%/foot obscuration.
  – Photo – 0.5 to 2.35%/foot obscuration.
  – Laser (VIEW®) – 0.02 to 2.0%/foot obscuration.
  – Acclimate Plus™ – 0.5 to 4.0%/foot obscuration.
  – HARSH™ – 0.5 to 2.35%/foot obscuration.
• Drift compensation (U.S. Patent 5,764,142).
• Degraded mode — in the unlikely event that the CPU-640 microprocessor fails, FlashScan® detectors revert to degraded operation and can activate the CPU-640 NAC circuits and alarm relay. Each of the four built-in panel circuits includes a Disable/Enable switch for this feature.
- Multi-detector algorithm involves nearby detectors in alarm decision (U.S. Patent 5,627,515).
- Automatic detector sensitivity testing.
- Maintenance alert (two levels).
- Self-optimizing pre-alarm.

**VIEW® (VERY INTELLIGENT EARLY WARNING) SMOKE DETECTION TECHNOLOGY:**
- Revolutionary spot laser design.
- Advanced intelligent sensing algorithms differentiate between smoke and non-smoke signals (U.S. Patent 5,831,524).
- Addressable operation pinpoints the fire location.
- No moving parts to fail or filters to change.
- Early warning performance comparable to the best aspiration systems at a fraction of the lifetime cost.

**ACCLIMATE PLUS™ LOW-PROFILE INTELLIGENT MULTI-SENSOR:**
- Detector automatically adjusts sensitivity levels without operator intervention or programming. Sensitivity increases with heat.
- Microprocessor-based technology; combination photo and thermal technology.
- FlashScan® or classic mode compatible with NFS-640.
- Low-temperature warning signal at 40°F ± 5°F (4.44°C ± 2.77°C).

**HARSH™ HOSTILE-AREA SMOKE HEAD:**
- Provides early warning of smoke detection in environment where traditional smoke detectors are not practical.
- The detector's filters remove particulates down to 30 microns in size.
- Intake fan draws air into photo chamber, while airborne particles and water mist are removed.

- Requires auxiliary 24 VDC from system or remote power supply.

**RELEASING FEATURES:**
- Ten independent hazards.
- Sophisticated cross-zone (three options).
- Delay timer and Discharge timers (adjustable).
- Abort (four options).
- Low-pressure CO₂ listed.

**VOICE AND TELEPHONE FEATURES:**
- Solid state message generation.
- Hard-wired voice control module options.
- Firefighter telephone option.
- 30- to 120-watt high-efficiency amplifiers (AA Series).
- Backup tone generator and amplifier option.
- Multichannel voice transponder (XPIQ).

**HIGH-EFFICIENCY OFFLINE SWITCHING 3.0 AMP POWER SUPPLY (6.0 A IN ALARM):**
- 120 or 220/240 VAC.
- Displays battery current/voltage on panel (with display).

**FlashScan® Exclusive World-Leading Detector Protocol**
At the heart of the NFS-640 is a set of detection devices and device protocol — FlashScan® (U.S. Patent 5,539,389). FlashScan® is an all-digital protocol that gives superior precision and high noise immunity.

In addition to providing quick identification of an active input device, this protocol can also activate many output devices in a fraction of the time required by competitive protocols. This high

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**Sample System Options**

**NFS-640** shown in CAB-C4 with KDM-2 and voice alarm system

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SpectrAlert®
Selectable Output P1224MC Horn/Strobes, S1224MC Strobes, and H12/24 Horns

General
System Sensor® SpectrAlert® Selectable Output Horns, Strobes, and Horn/Strobes offer enhanced features that include the widest range of candela options available and the capability to recognize and self-adjust for either 12- or 24-volt operation. With an overall feature set that combines performance, installation ease, flexibility, and a consistent, aesthetically pleasing appearance, the SpectrAlert Selectable Output devices provide both the innovation and efficiency synonymous with the SpectrAlert name.

Performance. SpectrAlert selectable output wall-mount horns, strobes, and horn/strobes offer key performance features long associated with the SpectrAlert name. The selectable-candela strobes and horn/strobes offer average current draws that are not only lower than conventional fixed-candela SpectrAlert products, but also lower than similar selectable-candela products. By consuming less current, the ability to connect even more devices per loop is possible, resulting in a lower installed cost.

Installation. SpectrAlert selectable output horns, strobes, and horn/strobes offer the same installation-friendly features synonymous with the SpectrAlert name, such as the option of two- and four-wire operation; the ability to use standard-sized backboxes with no encroachment into the box; and universal mounting incorporating the labor-saving QuickClick™ feature. Such labor-saving features make wire connections simple and fast, further reducing installed cost.

Flexibility. SpectrAlert selectable output strobes and horn/strobes offer the broadest range of candela options. In addition, the selectable output strobes and horn/strobes can operate on either 12 V or 24 V, with no setting required; the device recognizes and self-adjusts to the correct current automatically. Temporal 3 or Continuous tone options continue to be available, in either an Electromechanical or 3 kHz pattern.

Aesthetics. SpectrAlert selectable output horns, strobes, and horn/strobes incorporate the same stylish, low-profile design of the conventional SpectrAlert products, for a consistent and aesthetically pleasing appearance across the entire product line.

Features
• Operate on either 12 V or 24 V.
• Widest range of candela options:
  • 12 V: 15 and 15/75 candela.
  • 24 V: 15, 15/75, 30, 75, 110 candela.
• Easy candela selection.
• Lower current draw.
• Easy DIP switch selection for horn options.
• Easy mounting with QuickClick.
• Synchronizable with MDL Sync-Circuit™ module.
• Meets UL 1971, NFPA 72, and ADA signaling requirements.

NOTE: All strobe and horn/strobe models incorporate a new patented voltage booster design that has a more consistent flash bulb voltage over the range of candela selections. The benefit to the customer is a high quality strobe device.

Engineering Specifications
SpectrAlert horns, strobes and horn/strobes shall be capable of mounting to a standard 4.0” x 4.0” x 1.5” (10.16 x 10.16 x 3.81 cm) backbox or a single-gang 2.0” x 4.0” x 1.875” (5.08 x 10.16 x 4.763 cm) backbox using the universal mounting plate included with each SpectrAlert product. Also, SpectrAlert products, when used in conjunction with the accessory Sync-Circuit Module, shall be powered from a non-coded power supply and shall operate on 12 or 24 volts. 12-volt rated devices shall have an operating voltage range of 9 – 17.5 volts. 24-volt rated devices shall have an operating voltage range of 17 – 33 volts. SpectrAlert products shall have an operating temperature of 32° to 120°F (0°C to 49°C) and operate from a regulated DC or full-wave-rectified, unfiltered power supply.

STROBE
Strobe shall be a System Sensor SpectrAlert Model _______ listed to UL 1971 and be approved for fire protective service. The strobe shall be wired as a primary signaling notification appliance and comply with the Americans with Disabilities Act requirements for visible signaling appliances, flashing at 1 Hz over the strobe’s entire operating voltage range. The strobe light shall consist of a xenon flash tube and associated lens/reflectors system.

HORN/STROBE COMBINATION
Horn/Strobe shall be a System Sensor SpectrAlert Model listed to UL 1971 and UL 464 and shall be approved for fire protective service. Horn/strobe shall be wired as a primary signaling notification appliance and comply with the Americans with Disabilities Act requirements for visible signaling appliances, flashing at 1 Hz over the strobe’s entire operating voltage range. The strobe light shall consist of a xenon flash tube and associated lens/reflectors system. The horn shall have two tone options, two audibility options (at 24 volts) and the option to switch between a Temporal 3 pattern and a Non-Temporal Continuous pattern.
NBG-12LX
Addressable Manual Pull Station

General
The Notifier NBG-12LX is a state-of-the-art, dual-action (i.e., requires two motions to activate the station) pull station that includes an addressable interface for any Notifier intelligent control panel except FireWarden series panels, and the NSP-25 panel. Because the NBG-12LX is addressable, the control panel can display the exact location of the activated manual station. This leads fire personnel quickly to the location of the alarm.

Features
- Maintenance personnel can open station for inspection and address setting without causing an alarm condition.
- Built-in bicolor LED, which is visible through the handle of the station, flashes in normal operation and latches steady red when in alarm.
- Handle latches in down position and the word “ACTIVATED” appears to clearly indicate the station has been operated.
- Captive screw terminals wire-ready for easy connection to SLC loop (accepts up to 12 AWG/3.25 mm² wire).
- Can be surface mounted (with SB-10 or SB-I/O) or semi-flush mounted. Semi-flush mount to a standard single-gang, double-gang, or 4” (10.16 cm) square electrical box.
- Smooth dual-action design.
- Meets ADAAG controls and operating mechanisms guidelines (Section 4.1.3[13]); meets ADA requirement for 5 lb. maximum activation force.
- Highly visible.
- Attractive shape and textured finish.
- Key reset.
- Includes Braille text on station handle.
- Optional trim ring (BG12TR).
- Meets UL 38, Standard for Manually Actuated Signaling Boxes.
- Up to 99 NBG-12LX stations per loop on CLIP protocol loops.
- Up to 159 NBG-12LX stations per loop on FlashScan® protocol loops.
- Dual-color LED blinks green to indicate normal on FlashScan® systems.

Construction
Shell, door, and handle are molded of durable polycarbonate material with a textured finish.

Specifications
- Shipping Weight: 9.6 oz. (272.15 g)
- Normal operating voltage: 24 VDC.
- Maximum SLC loop voltage: 28.0 VDC.
- Maximum SLC standby current: 375 μA.
- Maximum SLC alarm current: 5 mA.
- Temperature Range: 32°F to 120°F (0°C to 49°C)
- Relative Humidity: 10% to 93% (noncondensing)
- For use indoors in a dry location

Operation
Pushing in, then pulling down on the handle causes it to latch in the down/activated position. Once latched, the word “ACTIVATED” (in bright yellow) appears at the top of the handle, while a portion of the handle protrudes from the bottom of the station. To reset the station, simply unlock the station with the key and pull the door open. This action resets the handle; closing the door automatically resets the switch.

Architectural/Engineering Specifications
Manual Fire Alarm Stations shall be non-coded, with a key-operated reset lock in order that they may be tested, and so designed that after actual Emergency Operation, they cannot be restored to normal except by use of a key. An operated station shall automatically condition itself so as to be visually detected as activated. Manual stations shall be constructed of red-colored polycarbonate material with clearly visible operating instructions provided on the cover. The word FIRE shall appear on the front of the stations in white letters, 1.00 inches (2.54 cm) or larger. Stations shall be suitable for surface mounting on matching backbox SB-10 or SB-I/O, or semi-flush mounting on a standard single-gang, double-gang, or...
4" (10.16 cm) square electrical box, and shall be installed within the limits defined by the Americans with Disabilities Act (ADA) or per national/local requirements. Manual Stations shall be Underwriters Laboratories listed.

Manual stations shall connect with two wires to one of the control panel SLC loops. The manual station shall, on command from the control panel, send data to the panel representing the state of the manual switch. Manual stations shall provide address setting by use of rotary decimal switches.

The loop poll LED shall be clearly visible through the front of the station. The LED shall flash while in the normal condition, and stay steadily illuminated when in alarm.

**Product Line Information**

**NBG-12LX:** Dual-action addressable pull station. Includes key locking feature. (Listed for Canadian and non-Canadian applications.)

**NBG-12LXSP:** Spanish/English labelled version.

**NBG-12LXP:** Portuguese labelled version.

**SB-10:** Surface backbox; metal.

**SB-I/O:** Surface backbox; plastic.

**BG12TR:** Optional trim ring.

**17021:** Keys, set of two.

**NY-Plate:** New York City trim plate.

**Agency Listings and Approvals**

In some cases, certain modules or applications may not be listed by certain approval agencies, or listing may be in process. Consult factory for latest listing status.

- **UL/ULC Listed:** S692 (listed for Canadian and non-Canadian applications).
- **MEA:** 67-02-E.
- **CSFM:** 7150-0028:0199.
- **FDNY:** COA #6085 (NFS2-640), COA #6098 (NFS2-3030).
- **BSMI:** CI313066760047.
- **U.S. Coast Guard.**
- **Lloyd’s Register.**
- **FM Approved.**

**Patented:** U.S. Patent No. D428,351; 6,380,846; 6,314,772; 6,632,108.
Appendix C – Fire Alarm Panel Wiring Diagram
## Table 5.1.1.2 Summary of Sprinkler System Inspection, Testing, and Maintenance

<table>
<thead>
<tr>
<th>Item</th>
<th>Frequency</th>
<th>Reference</th>
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<tr>
<td><strong>Inspection</strong></td>
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<tr>
<td>Control valves</td>
<td></td>
<td>Chapter 13</td>
</tr>
<tr>
<td>Fire department connections</td>
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<td>Chapter 13</td>
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<tr>
<td>Gauges (wet and deluge systems)</td>
<td>Quarterly</td>
<td>Chapter 13</td>
</tr>
<tr>
<td>Gauges (dry and preaction systems)</td>
<td>Monthly/quarterly</td>
<td>Chapter 13</td>
</tr>
<tr>
<td>Hanger/braces/supports</td>
<td>Annually</td>
<td>5.2.3</td>
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<tr>
<td>Heat tracing</td>
<td>Per manufacturer’s requirements</td>
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<td>Hydraulic design information sign</td>
<td>Annually</td>
<td>5.2.5</td>
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<td>Information signs</td>
<td>Annually</td>
<td>5.2.7, 5.2.8, 5.2.9</td>
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<td>Internal piping condition</td>
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<td>Chapter 14</td>
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<tr>
<td>Pipe and fittings</td>
<td>Annually</td>
<td>5.2.2</td>
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<tr>
<td>Sprinklers</td>
<td>Annually</td>
<td>5.2.1</td>
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<td>Sprinklers (spare)</td>
<td>Annually</td>
<td>5.2.1.4</td>
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<tr>
<td>Supervisory signal devices (except valve supervisory switches)</td>
<td>Quarterly</td>
<td>5.2.4</td>
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<td>System valves</td>
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<td>Chapter 13</td>
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<td>Valve supervisory signal devices</td>
<td>Quarterly</td>
<td>5.2.4</td>
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<tr>
<td>Waterflow devices</td>
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<td>5.2.4</td>
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<tr>
<td><strong>Test</strong></td>
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<td>Antifreeze solution</td>
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<td>Control valves</td>
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<td>Chapter 13</td>
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<tr>
<td>Gauges</td>
<td>5 years</td>
<td>Chapter 13</td>
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<td>Main drain</td>
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<td>Chapter 13</td>
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<td>Sprinklers</td>
<td>At 50 years and every 10 years thereafter</td>
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<td>Sprinklers (fast-response)</td>
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<td>Sprinklers (harsh environments)</td>
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<td>Supervisory signal devices (except valve supervisory switches)</td>
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<td>Waterflow alarm devices (vane and pressure switch type)</td>
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<td>Low-point drains (dry pipe and preaction systems)</td>
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<td>Sprinklers and automatic spray nozzles protecting commercial cooking equipment and ventilation systems</td>
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<td>Obstruction</td>
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NFPA 25, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems. 2017
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<th>Sequence of Operation</th>
<th>ELEVATOR</th>
<th>LOBBY SMOKE DETECTOR</th>
<th>AREA SMOKE DETECTOR</th>
<th>PULL STATION</th>
<th>ANNUNCIATE ON FACP</th>
<th>ANNUNCIATE AT REMOTE ANNUNCIATOR</th>
<th>SOUND THE GENERAL ALARM</th>
<th>ACTIVATE ALL ROLL DOWN DOORS AND FIRE SHUTTERS ELEVATORS</th>
<th>SHUT DOWN ASSOCIATED AIR (HVAC) UNIT</th>
<th>ANNUNCIATE AT REMOTE 24 HOURS ATTENDED LOCATION</th>
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Appendix E – Sequence of Operations