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F.P.E. 596 CULMINATING PROJECT: WARREN J. BAKER CENTER FOR SCIENCE BUILDING REVIEW

SPRING 2017

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STATEMENT OF DISCLAIMER

REPORT KEYWORDS:

FDS, NFPA 101, Smoke Control System, Performance Based Design, RESET vs. ASET.

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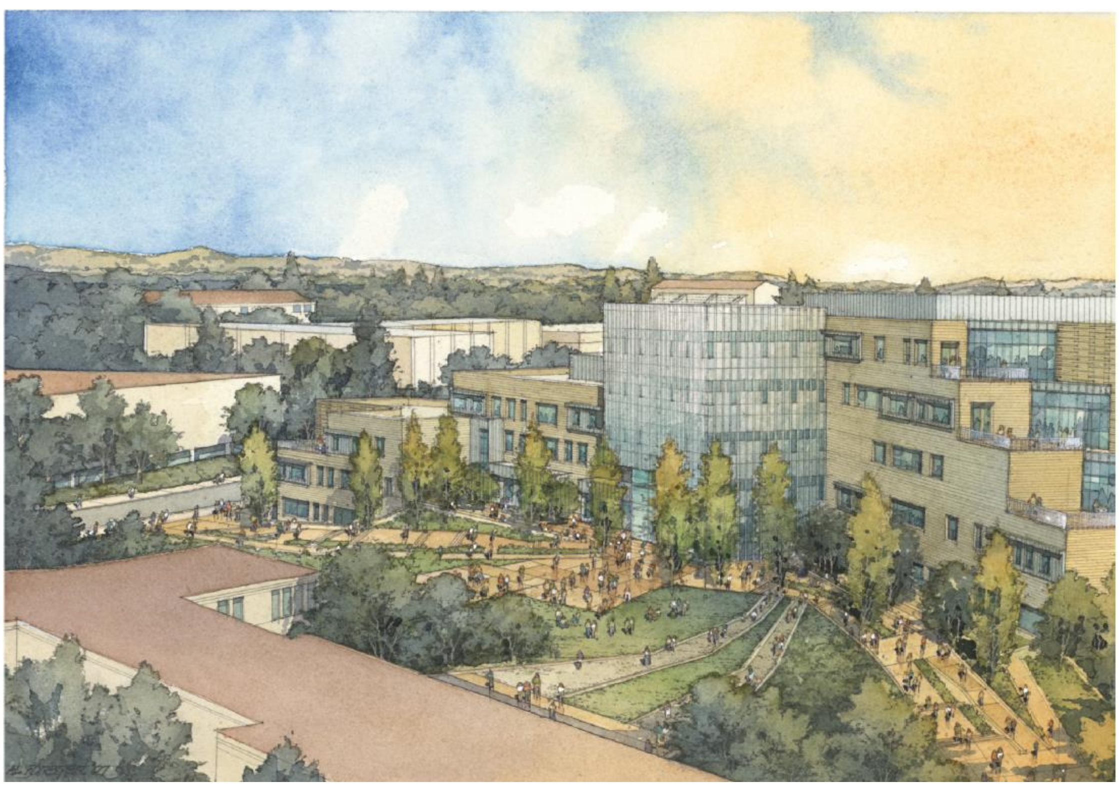
Special thanks to my family, which grew from three to five, over the course of this endeavor. There would have been no way that I could have balanced my responsibilities as a father, student, and engineer without their patience, love and assistance.

Thanks to Professor Mowrer, Professor Pascual, Professor Rich, Professor Simonian, and Professor Lautenberger for instruction, direction and flexibility.



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Executive Summary

This report is a focused review and discussion of the life safety and fire protection design of Cal Poly Building 180: The Warren J. Baker Center for Science in partial fulfillment for the requirements of a Master's of Science degree in Fire Protection Engineering at Cal Poly, San Luis Obispo. The report focuses on discussion areas specific to the curriculum of the Cal Poly Fire Protection Master's program, including analysis of egress, structural fire protection, detection, alarm and automatic protection designs in comparison to current and effective codes and standards. This report also includes a, performance based, tenability analysis for the central atrium and the building egress using computer-modeling software (FDS, PyroSim and Pathfinder)

Comparison to current codes shows that there are some building features that do not meet current code, including an inadequate number of exit doors for assembly use areas, inadequate floor egress capacity, and excessive dead end and common path travel distance distances. Rooms 304 and 306 on the third level are considered assembly use, since they are expected to have more than 50 occupants, but are only provided with a single exit instead of the required two. Rooms 304 and 306, also have a common path length of 67.5 ft., which exceeds the maximum common path limits allowed for assembly use. Occupant loading on the third level is estimated to be 683 occupants, however, the calculated egress capacity of this floor, per the LSC, is 627 occupants. Lastly, a 57.8 ft. long dead end corridor is located on the second level adjacent Room 239 and 260, which exceed these the 50-ft. allowable from the IBC and LSC.

In the performance based approach section, a design fire was selected and modeled, using FDS and PyroSim. The available safe egress time (ASET) was determined based on tenability limits suggested from the SFPE handbook. The ASET is then compared with the predicted, required safe egress time (RSET), which was developed using available data and modeling from Pathfinder. Using data from the SFPE handbook and the Pathfinder model, the RSET time is estimated at 12 minutes. The FDS model indicated that tenability is lost on the 6th level at approximately 101 seconds (1.7 minutes), due to lack of visibility. The model also indicated that excessive heat flux is expected on the egress path from exit stair 3, as early as 180 seconds (3 minutes) into the simulation. Tenability limits for air temperature and asphyxiant gases were not exceeded during the 12-minute FDS simulation.

To meet current codes, it is recommended that occupants on the third level are limited to 627 persons, and occupants in room 304 and 306 are limited to less than 50 persons. By limiting occupants, adequate egress capacity is provided, and rooms 304 and 306 are reclassified as business use. Business use areas, have less stringent common path and exit number requirements which are satisfied with existing construction. A new wall or closet is recommended in the dead-end corridor to effectively reduce the distance to acceptable levels.

To provide tenability for the central atrium, a mechanical exhaust system is recommended to provide adequate visibility, 6ft. feet above the egress paths. Additionally, less combustible, or noncombustible furnishing should be used to ensure that acceptable levels of heat flux are maintained for the duration of egress. The use of non-combustible or less combustible furnishing could also help to maintain acceptable levels of visibility utilizing the existing smoke control system. Modeling should be completed to determine the most effective and economical approach.

OVERVIEW

Overview

REPORT SCOPE

This report was developed as a part of a culminating project in partial completion of the Fire Protection Engineering Master's Program at Cal Poly, San Luis Obispo. The scope of the report is focused on specific areas of the building design in reference to currently accepted codes and standards and some discussion of performance based tenability analysis. The topics include the building's structural fire protection design, the life safety design for egress, and tenability, and the building's automatic fire protection, and fire alarm design. These areas of discussion were selected as part of the core curriculum for the Fire Protection Engineering program.

BUILDING HIGHLIGHTS

This building is a fully sprinklered, six story, steel moment frame building, which has been constructed on a sloping grade. This building is primarily classrooms, teaching and project laboratories, and office spaces with supporting spaces throughout for the instruction of university level students. The building also features a central atrium and several exterior balconies. Figure 1, below, shows a view of the south face of the building, with the camera facing northeast (left image), and facing northwest (right image). The northeast facing photo is taken from approximately the same elevation as the first level, and the northwest facing photo is taken from approximately the same elevation as the third level.

Figure 1 - South side of the building facing northeast (Left), and northwest (Right)

OVERVIEW

CODES AND REFERENCES

The building's structural fire protection and life safety design was developed to meet requirements from the 2013 Edition of the California Code of Regulations Title 24, Part 2, Volume 1 of 2, also known as the *California Building Code* (CBC). The CBC is based on the 2012 Edition of the International building code (IBC).

The building's fire detection and alarm system was primarily designed using the 2007 version of the California Code of Regulations Title 24, Part 3*, The California Electrical Code* (CEC), Part 9, *The California Fire Code* (CFC), and on the 2007 versions of NFPA 72, *The National Fire Alarm Signaling Code*. The CFC is based on the 2006 International Fire Code (IFC) and the CEC is based on the 2005 edition of NFPA 70, *National Electrical Code*.

The building's automatic sprinkler protection design was developed to meet requirements from the 2007 Edition of the CBC and NFPA 13, *Standard for the Installation of Sprinklers System,* 2007 Edition

This report will utilize the 2015 edition of NFPA 101 (LSC), the 2016 edition of the NFPA 72 handbook, the 2014 edition of NFPA 70 handbook, the 2016 edition of the NFPA 13 handbook, and the 2014 edition of NFPA 25, *Standard for the inspection, Testing and Maintenance of Water-Based Fire Protection Systems* for review . The SFPE Handbook of Fire Protection Engineering, 4th and 5th Edition (SFPE-4/5), and the NFPA Fire Protection Handbook 20th Edition (NFPA) were used for background information and data. Specific requirements will be identified along with their appropriate reference when appropriate.

The February 21, 2014 Architectural Record Drawing Set, CAD drawing files, Cal Poly Facilities Planning Space Data Sheets and College Simplified Drawings were used for the review of B180. Appendix B includes data from these documents.

The August 23, 2013 Fire Alarm As-Built drawing set, CAD drawing files, Building Specification Books 1 and 2, and the product listing cut sheets were used for the review of B180.

The September 29, 2011 Fire Suppression Submission, Shop Drawings and Hydraulic Calculations were used for this review. Appendix G Figures are images from the drawing set.

These documents are considered internal to Cal Poly University and shall not be disclosed to unauthorized personnel.

Structural Fire Protection

Utilizing non-combustible and fire resistive components for a building's structure can go a long way to limit fire spread and building damage during a fire. The IBC, CBC and LSC provide guidance and requirements that limit building size, or require specific building types based on building use, which helps to reduce fire damage to the building.

CONSTRUCTION CLASSIFICATION AND DESIGN

The building is six stories tall with a normally unoccupied penthouse that reaches 108 ft. The building can be broken into three zones, the West Wing, the Central Atrium and the East Wing (See Figure 2 below.) The highest occupied floor is 64 ft. from the lowest level of fire department access (for that level), so per the definition in CBC, the building is not considered a high-rise building and the previsions in IBC Section 403 for high-rise buildings would not apply.

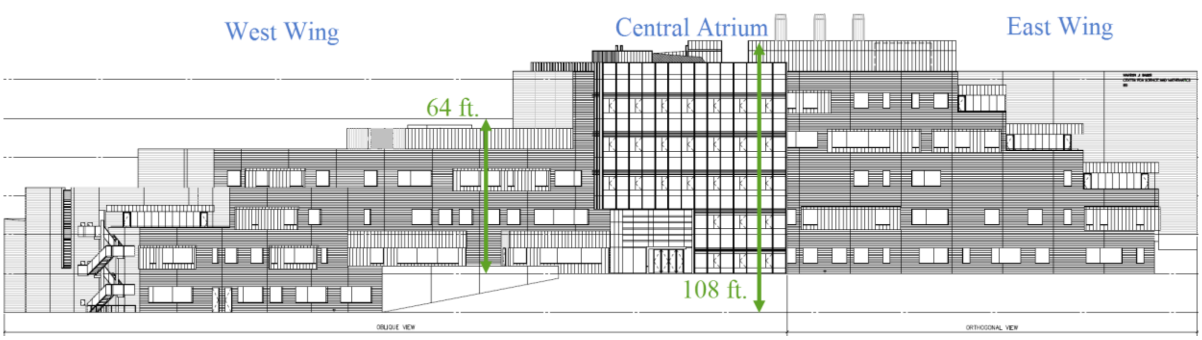

Figure 2 - Building South Elevation View

The building has been design as a Type 1B-FR building per the CBC/IBC, with 2-hour rated structural frame, 2-hour exterior and interior bearing walls, 2-hour fire rated floor assembly, and 1-hour rated roof assembly. The primary structure is steel frame, with several different types of beams and columns used (See Figure 3 below). The nonbearing interior walls are not provided with a fire rating; however, the nonbearing exterior walls are specified as having a 1- hour fire rating.

STRUCTURAL FIRE PROTECTION

Figure 3 - South side of the building facing west during construction

Previsions for separated occupancies were used, per CBC Section 508.3.3, which provides a 1-hour fire rated wall between the business use areas and the assembly, hazardous storage, and electrical use areas. A 1- hour fire rated wall between the mechanical rooms and electrical and hazardous use areas are also provided.

The building's eastern wall is built 38 ft. from the Math and Science Building (Building 25), which provides 19 ft. of fire separation distance. Fire separation distance is defined by the IBC, as the distance measured to an imaginary line between two buildings, to the closest interior lot line, or to the centerline of a street, an alley or public way.

MAIN STRUCTURE FIRE RESISTANCE

IBC Section 602.2 indicates that Type I and II buildings must be constructed with noncombustible materials per Table 601. IBC Table 601 indicates that a Type IB building is required to provide a 2-hour rated structural frame, 2-hour rated exterior and interior load bearing walls, 2-hour rated floor assemblies, 1-hour rated roof assembly, and does not require a fire rating for nonbearing interior walls and partitions. IBC Table 602 also indicates that the required fire resistance for exterior nonbearing walls should be increased to 1-hour fire rated for IB buildings with group Assembly or Business use.

LSC 13.1.6 indicates that assembly occupancy requires Type I (442), II (332) or II (222) for a five story or greater sprinklered building. This building would fall into a Type II (222) building per Commentary Table 8.1 in the LSC since the building plans indicate an IBC (CBC) IA construction. Per Table A.8.2.1.2, Type II (222) indicates that exterior walls supporting a floor, interior, bearing walls supporting a floor, columns and beams supporting a floor all have a 2-hr fire rating. All exterior walls, interior, bearing walls, beams and columns that are supporting only the roof have a 1-hr fire rating. This table also indicates that the

floors will have a 2-hr fire rating and the ceiling assemblies will have a 1-hr fire rating. All other nonbearing exterior and interior walls have a 0-hr fire rating.

Although the building design indicates that there is no limit in the percentage of openings, protected or unprotected, the CBC Table 705.8 of the IBC indicates that this is not acceptable. The IBC indicates that only 75% of the wall is permitted to have unprotected openings for sprinklered buildings with between 15 ft. and 20 ft. of fire space separation. Figure 4 below illustrates the elevation view of the east side of the building which is close to the Building 25. It is estimated that the percent openings are much less than 75% of the overall exterior of this face of the building, so the design acceptable per the IBC. All other faces of the building are provided with at least 20 ft. of fire separation, so they would have unlimited allowable unprotected openings.

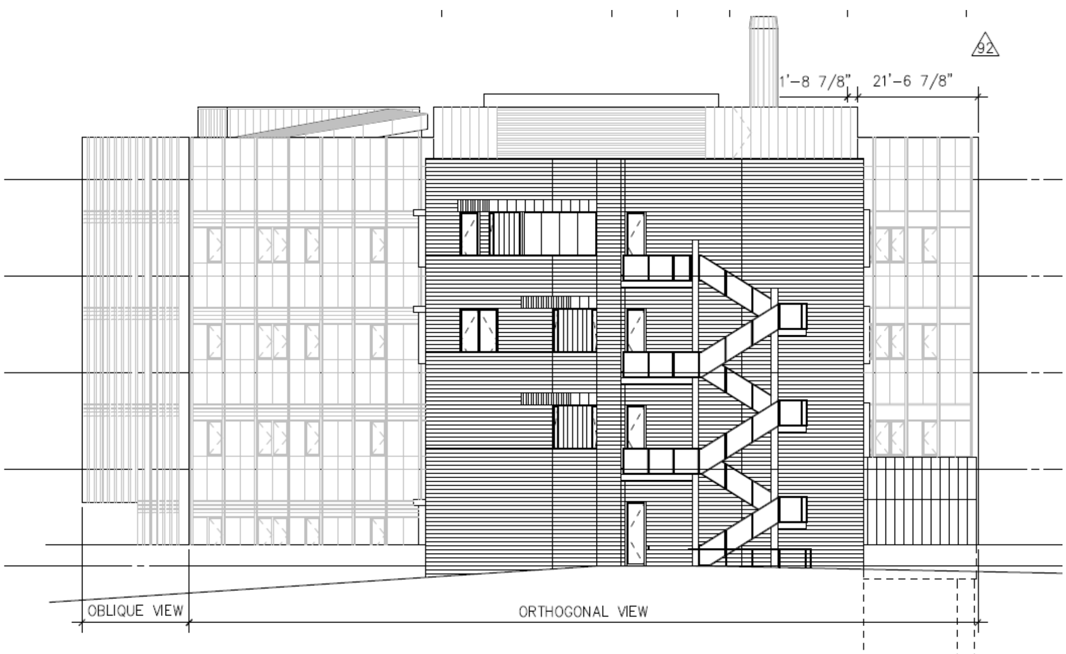

Figure 4 - East Elevation

The area per story has been provided below in Table 1, excluding all accessory occupancies. The allowable floor area can be calculated using Equation 5-3 from the IBC, listed below as Equation 1, however for this building, calculation of the allowable floor area is not necessary per Table 506.2. Both A-3 and B use occupancies are allowed to have an unlimited floor area for Type IB buildings.

STRUCTURAL FIRE PROTECTION

Table 1- Area per level

Level	Occupancy Area [sq. ft.]	Group A-3 Area	Group B Area	Group H-3 Area
Level 1	15594	10162	335	0
Level 2	32064	0	30020	985
Level 3	30946	943	28418	0
Level 4	25037	712	22976	0
Level 5	15828	739	13435	0
Level 6	15074	192	13097	0
Total	134,543	12,748	108,281	985

$$A_a = \left[A_t + \left(NS\ x\ I_f\right)\right]$$

A_a = Allowable area (sq. ft.)

A_t = Tabular allowable area factor (NS, S13R or SM value) in accordance with Table 506.2

NS = Tabular allowable area factor in accordance with 506.2 for a non sprinklered building.

I_f = Area factor increase due to frontage (percent) as calculated in accordance with Section 506.3

Equation 1- IBC Equation 5-3 for Mixed-Occupancy, Multistory Buildings.

FLOOR CONSTRUCTION AND ASSOCIATED MEMBERS

The floors for the building are primarily constructed of reinforced concrete slabs over a steel frame. There are several different types of steel beams and joists used to support the floor assembly, and the floors have been provided with SFRM to attain the require 2-hour fire rating. UL design D902 was used to estimate the required SFRM that would be required for the floor assembles. The building plans indicate that there are two composite steel deck schedules that are used, and the main steel deck is provided with 3-1/4in. of lightweight concrete, and is assumed to have unrestrained steel beams. The thickness of concrete meets the requirements per the UL design to provide a 2-hour fire barrier, and indicates that a minimum of 1 in. of SFRM would be required to provide a 2-hour fire rating for a fluted steel deck.

WALLS AND PARTITIONS

The separated use separation requirement from the CBC is similar to the guidance in Section 508.4.2 of the IBC. This IBC section also indicates that in each story, the building area shall be such that the sum of the ratios of the actual building area of each separated occupancy divided by the allowable building area of each of the separated shall not exceed 1. This condition is also met, since the areas for group assembly and business are unlimited, and since the area of hazardous waste on the second level is well under the allowable area of 60,000 sq. ft. per IBC Table 506.2.

STRUCTURAL FIRE PROTECTION

In addition to use separation, exits and other building opening need consideration per the LSC. Exit access corridors typically need to have specified fire rated partitions, but since this building is being treated as an existing building, fire rated construction in exit access corridors is not required per 7.1.3.1 (1), and there are no requirements for fire rating in access corridors per 13.3.6 and 39.3.6. LSC 7.1.3.2.1 (3a) indicates that exits should have a minimum 1-hr fire rating when the exit connects four or more stories. A.7.1.3.2.1 (3) indicates that existing buildings that have walls in good repair and consisting of gypsum wallboard, or masonry units can usually provide satisfactory protection for the purposes of 1-hr fire rating. This building has been built with 2-hr fire rated exit enclosures for the two internal stairs (Stair 3 and 4) per CBC, so they are more than adequate per the LSC requirements.

Elevator shafts and vertical shafts are required to have 2-hr rated walls and 90-min rated doors per Table 8.3.4.2, which is provided in this building per CBC. The existing fire rating has been indicated on the attached plans in Appendix A. No additional areas of fire-rated construction are required.

UL design U419 has been used to design all 1- hour rated and 2-hour rated walls with steel frame. UL design U906 was used for the 2-hour rated CMU exterior walls. For all designs, different layers and thickness of gypsum wallboard are used to attain the required fire rating. Horizontal rated portions/ceilings utilize UL design U438 and design detail has been included below as Figure 5.

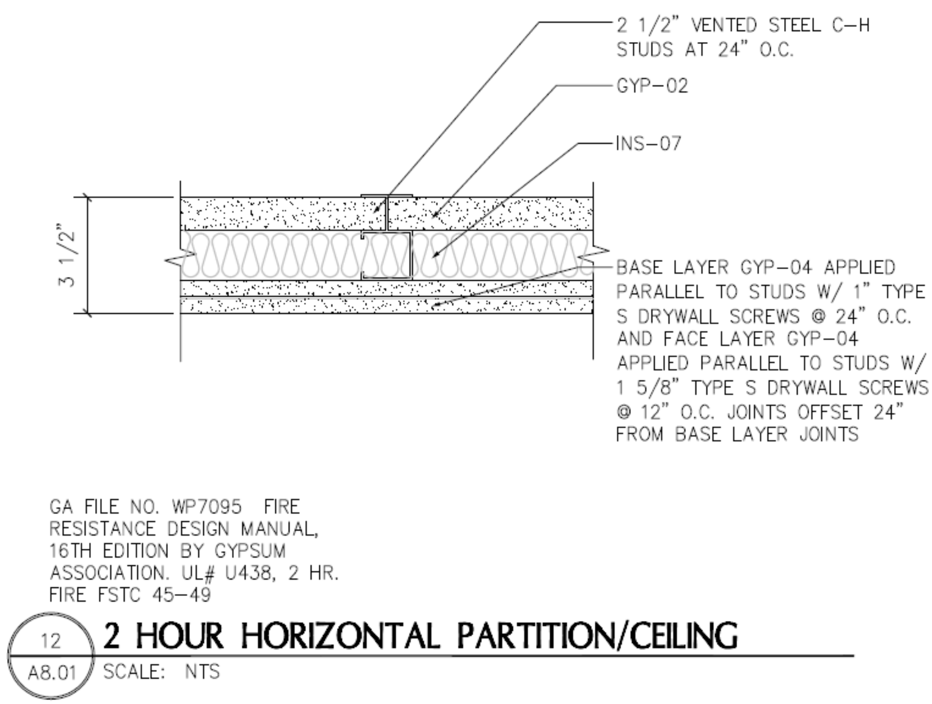

Figure 5 - 2- hour rated horizontal partition

STRUCTURAL FIRE PROTECTION

ROOF CONSTRUCTION AND ASSOCIATED MEMBERS

The roof assembly also has several different designs, including a composite steel deck, and 3 in. steel deck with foam insulation and wood sheathing. All designs include steel beams, provided with SFRM on the underside to meet the required 1-hr fire rating.

DOORS AND PENETRATIONS

Per the plan's door schedule, doors for exit corridors are provided with a 90-min fire rating. The H-2 use rooms are provided with a 60-minute fire rating. All electrical rooms and telecom rooms are provided with doors with a 45-min fire rating, and the storage use rooms are provided with 20-min rated doors.

All penetrations are provided with the same fire rating as the wall they penetrate per the plans and the specifications, and are required to meet a specific UL listing.

ATRIUMS

An atrium is formed by vertical openings on the north and south side of central area, starting on the second level. The Atrium connects the second level to the sixth level. The north opening utilizes a set of open stairs and the south opening is open to above. This area is provided with increased sprinkler protection per the CBC and has been separated from the east and west classroom wings with a 2-hour fire rated barrier and automatic doors. A 1-hour fire rated smoke control area separates the atrium from the second and third level business areas, so that it only connects three levels of business occupancy. The design of the atrium meets the requirements the 2015 edition of the IBC, which requires automatic sprinklers, smoke control and a 1-hour fire barrier per Section 404. This area also meets the separation requirements of Section 8.6.7 of the LSC.

A second smaller atrium is formed above the lobby of the first level which is open to the second level. A 1-hour rated glazing is provided on the second level. Similar to the central atrium, this arrangement is acceptable per the IBC and LSC since this area is protected by an adequate sprinkler system and meets all of the conditions required.

INTERIOR FINISH

LSC Table A.10.2.2 indicates the wall and ceiling interior finish classifications limitations for exits, exit access corridors and other spaces. The LSC table breaks down the interior finish requirements for all occupancies based on new or existing construction. The table breaks the requirements for assembly use again based on whether there is less than or greater than 300 occupants. Section 404.8 of the IBC provides additional information regarding the interior finish of the Atrium. A summary is presented below in Table 2. The first level would fall into the greater than 300 occupants, existing assembly area requirement and the third floor would be less than 300 occupants. The rest of the floors would fall into the existing business occupancy.

Table 2 - Interior Finish Requirements

Level	Exits	Exit Access Corridors	Other Spaces
Level 1	A	A or B	A or B
Level 3	A	A or B	A, B, or C
All other levels	A or B	A or B	A, B, or C
Atrium	B	B	B

Class A interior finishes have a flame spread index between 0 and 25. Class B interior finishes can have a flame spread index up to 75 and Class C finishes can have a flame spread index up to 200. Class A, B and C all allow a smoke developed index up to 450. Since the building is adequately sprinklered, the exits on level one and three can also use Class B interior finishes and all other areas on all levels can use up to C. The ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, determines the class rating of the material.

SUMMARY

This building's structural design meets all the current codes and standards to help limit damages expected from a fire. The design for the central atrium, was developed per the CBC, but still meets the intent of the IBC and LSC. The interior finishes specified are also acceptable, but as time progresses, changes can occur that can result in unacceptable finish uses. Any changes to the building finishes or design should be reviewed to ensure that the structural fire protection continues to meet current codes.

One of the important factors in determining the code requirements for structural fire protection is driven by the occupancy of the structure. The next section in this report reviews the occupancy selection for this building.

Occupancy Review

This section discusses the occupancy classification for the building, based on the use of the spaces, and the appropriate code requirements from the LSC and the IBC. Code requirements for special structures such as atriums, and communicating spaces are also discussed as they pertain to life safety design.

OCCUPANCY CLASSIFICATION

Sections 6.1.11.1 and A6.1.11.1 of the LSC indicates that college and university instructional buildings, classrooms under 50 people and instructional laboratories should be considered a business occupancy. The LSC indicates that we should reference Section 39 for occupancy specific requirements. For this reason, the majority of this building is classified as business occupancy.

This building also utilizes large lecture halls, several larger classrooms and labs that are expected to exceed 50 students. These rooms are classified as assembly occupancy, per LSC Section 6.1.2.

The third, fourth, fifth and sixth level also have small terrace balconies. These areas are not specifically discussed in the LSC, but it is conservatively assumed that they should be treated as an assembly occupancy when their occupant load exceeds 50 people with an assembly use since is possible that they can be occupied by many students at one time. These areas are considered separate from the floor occupancy since the exterior walls have a 1-hour fire rating.

This building has been designed as a separated occupancy per the CBC, however since exit paths pass from the separated occupancy into the other occupancy, they must be treated as a mixed occupancy per LSC 6.1.14.1.2. Per the LSC, the first and third levels are considered mixed, assembly and business occupancies and the second, fourth, fifth and sixth levels are business occupancies.

Each level utilizes a 2-hr fire rated floor assembly (previously discussed in the construction section), which is acceptable per LSC Table 6.1.14.4.1 (a) and (b) to maintain separation. This building also uses a 1-hr rated smoke partition in the main atrium for separation, which is acceptable per LSC section 6.1.14.4.6. All levels have incidental areas of storage that are being considered part of the predominate occupancy per LSC 6.1.14.1.3 and A.6.1.14.1.3 (3). The mechanical area on the first level, larger storage area on the second level and all electrical rooms have been separated from the level occupancy by a 1-hr rated wall. This level of separation is acceptable per LSC Table 6.1.14.4.1 (a) and (b), with the 1-hr reduction of fire protection requirement for the use of a sprinkler system.

It is worth noting that LSC section 6.1.3 defines an educational occupancy as an area used for the educational purposes through the 12th grade by six or more persons for four of more hours per day, for more than 12 hours per week. If this building were to be reclassified as an educational occupancy, due to the presence of younger students during the summer months, the building would need to be modified to meet the requirements in occupancy specific sections, Chapter 14/15, of the LSC.

OCCUPANCY REVIEW

SPECIAL STRUCTURES

The LSC has special previsions for high-rise buildings, which it defines by the same criteria as the IBC/CBC, as an occupiable story that is greater than 75 ft. above the lowest level of fire department access. LSC section A.3.3.36.7 supplies additional information, specifically for buildings built on a slope with multiple levels of fire department access, that indicates that judgment should be used to determine the lowest level of access. For this reason, LSC requirements for a high rise were not applied.

ATRIUMS

As discussed in the construction portion of the report, the large central atrium is provided with at least 1-hr fire rated walls to other occupancies, and only connects three levels of business use. This design also meets the requirements of LSC 8.6.7 (4), since the building has an approved, supervised, automatic sprinkler system.

The second smaller atrium is also acceptable per LSC 8.6.7 (4) since this area is protected by an adequate sprinkler system and meets all the conditions required by LSC 8.6.6 for a communicating space. This sprinkler system is assumed to meet the requirements of LSC 9.7, which will be discussed later in the report (LSC Section 9.7 specifies the use of NFPA 13 for sprinkler design and NFPA 72 for the sprinkler alarm system design).

OCCUPANCY USE

Figures B1-B6 in Appendix B, illustrate the different occupancy uses for the different areas of each floor. The areas are coded using the information in Table 3 below.

Table 3- Space Use Designations

Occupancy/Space Designation	Color Code
Assembly (>50 Occupants)	
Laboratories	
Class Room (< 50 Students)	
Business (Office)	
Storage	
Mechanical Room	
Electrical Room	
Restroom	
Elevator and Lobbies	
Exit Corridors	
Exit Stairs	

OCCUPANCY REVIEW

All the occupied areas, with their designated occupant load, has been calculated by floor, for each floor in in Appendix B, Table 2B, and summarized in Table 4 below. The occupancy loading for most spaces has been defined in Table 7.3.1.2 of the LSC. Per A.7.3.3, standard rounding has been used for the egress calculations. The original occupant loads from the life safety plans have been included in the table. Differences in the occupancy load by floor is due to small differences in the life safety plan's room dimensions, and some areas that are being used in ways that were not initially anticipated. The same load factors for use were used in this report as in the original life safety analysis.

Table 4 - Occupant Load Summary

Level	Occupancy Area	Occupant Load	Original Occupant Load
Level 1	15594	512	638
Level 2	32064	536	619
Level 3	30946	683	640
Level 4	25037	447	422
Level 5	15828	270	263
Level 6	15074	250	251
Total	134543	2641	2833

The storage occupancy load factor (500 sq. ft. per person) has been assigned to electrical rooms and mechanical rooms, since these rooms, like a storage area, are not constantly occupied and typically have some amount of stored equipment and stock. A load factor of 50 sq. ft. per person has been assigned to all bathrooms since this closely approximates the number of stalls in a bathroom and provides a conservative estimate for occupation.

The area directly outside lecture room 101, on the first level of the building, has been enlarged and labeled as a lobby. It is possible that this will be waiting space for the lecture hall; however, it would not meet the requirements for a waiting space per LSC 13.1.7.2 (1) and (2), since this space encroaches on the clear width of the main exit and the means of egress to the main exit from the other lecture halls (114,107,113, and 112). For these reasons, the increased loading for a waiting space was not added to the first level, and this level should not be used for queuing the lecture hall. This area was included in the original life safety plan egress analysis, which added an additional 97 occupants to the first floor.

The classroom wing hallways in the second through sixth levels have not been included in the occupancy loading area since the primary occupancy use is laboratories and/or assembly. Both uses are net usage and do not include walls, shafts and corridors per the guidance in section A.7.3.1.2 of the LSC Handbook. The lobby area and the corridors on the first floor have been excluded for the same reason, as noted above. The atria space on the second through the sixth floor was included in the occupancy area since this area is

primarily a business use, which is a gross load factor. The seventh level (roof) of the building is not included in any of the occupancy analysis since this area is not occupied.

SUMMARY

Using the definitions in the IBC and the LSC, this building is considered a business occupancy. Two floors are considered a mixed occupancy of assembly and business use. There are also areas on each floor that are considered separated occupancies that use appropriate fire rated separations per the IBC and LSC. Occupant loading for each use area is based on the use indicated on the room details from the Cal Poly Plans Website, and occupant load factors in the IBC. A major determining factor for the building occupancy is based on the fact that this building is used for college aged students, but areas of this campus are also used during the summer months to facilitate high school aged student education. If this building is also used for high school aged student education, then additional requirements may be needed to facilitate an educational occupancy.

The next step in developing the life safety design for a building, once the building use, occupancy and occupant load is determined, is to examine the required egress component locations, number, and minimum size to facilitate the safe egress of the expected occupant load. The next section reviews and discusses the egress design and code requirements.

Egress

The LSC has specific requirements for the number and capacity of paths of egress, and their arrangement to ensure that travel distances do not strand or confuse occupants. This section discusses the code requirements for the design of the means of egress as they apply to the life safety design. Special egress features such as areas of refuge and horizontal exits are also discussed.

EXIT NUMBER AND CAPACITY

Since this building has areas of mixed occupancy, the more stringent requirement needs to be satisfied per LSC 6.1.14.3.2. Table 5 summarizes the number of exits required, the exits that are provided and the total exit capacity for each floor. More details on individual exits is included in Appendix C, Table C1 and C2. LSC 13.2.4.2 was used for the required number of exits per floor on the first and third floor since it is more stringent than the requirement from 39.2.4.1, and 39.2.4.1 (2) which is used for the business floors. The total number of exits provided is adequate.

LSC Section 7.3 and 7.3.3.2 was used to determine the capacity of the means of egress per 13.2.3.1(1) and 39.2.3. LSC Table 7.3.3.1 was used to determine the capacity of the egress doors and stairs. All the exit stairs, with the exception of exit stair 3, has a clear width of 47 in. so equation 7.3.3.1 from the LSC was used, where, C, is the capacity in persons, and, Wn , is the nominal width of the stair. This equation is included as Equation 2 below. The standard 0.3 inch per person was used for Stair 3 which has a reported clear width of 44 in. The plan detail reports both the handrail-to-handrail width and the clear width. The clear width is 1 in. less than the handrail-to-handrail width, and it is not clear why this difference is reported. The clear width measurement will be used for this analysis per the LSC. (See Appendix D Figures D4-D7 for all stair details).

$$C = 146.7 + \left(\frac{W_n - 44}{0.218}\right)$$

Equation 2- Exit Capacity adjustment for stairs over 44in.

Table 5 - Exit Number and Capacity

Level	Exits Required	Exits Provided	Exit Capacity
Level 1	3	3	1620
Level 2	3	6	2480
Level 3	3	4	627
Level 4	2	3	467
Level 5	2	2	307
Level 6	2	2	307
Total	15	20	5928

EGRESS

Looking at only the required and available exit capacity, all but the third level has adequate egress capacity. There is a discrepancy between the life safety plans and the stair details in the architectural plan set and finished door schedule, where the life safety plans incorrectly assign a clear width of 48 in. for all stairs. For this reason, and some differences in the in the definition of occupant loading for space use, this floor has inadequate exit capacity. If the stair is 48 in. clear, then the egress capacity for the floor would match the original life safety design occupant load of 640. Since the addition, or expansion of stairs to a completed building would be unreasonable, an occupancy limit would need to be applied to the 3rd level to provide adequate egress capacity.

Additionally, per LSC 13.2.3.6.1, 13.2.3.6.2 and 13.2.3.6.3, every assembly occupancy shall be provided with a main entrance/exit that accommodates one-half of the total occupant load at the level of exit discharge (LED). Per 3.3.85, the first level is the LED since it the lowest story from which not less than 50% of the required number of exits and not less than 50% of the required egress capacity from such a story discharge directly outside at the finished ground level. The three 72 in. wide doors are expected to accommodate 1080 occupant which is almost 200% of the first level occupant load.

LSC 13.2.3.6.5 allows that if a main exit is through a lobby or foyer, then the aggregate of all exits from the lobby shall be permitted to provide the required capacity of the main exit, and indicates that occupant will likely use all doors in a lobby since they are familiar with the area. Using the main entrance/exit doors and the exit through the stairwell in the lobby, the aggregate exit capacity would be 1260 people. The addition of the exit through the stairwell in the lobby is unnecessary since over 50% of the occupant load can be accommodated with the main entrance/exit doors, but because the exit door is in the lobby area, the door will be excluded from the available exit capacity for the exits not considered part of the main exit.

The remaining exit, not part of the main exits, is the exterior exit door at the end of the hallway adjacent the fire pump room (Exit 1.2). The life safety plans indicate that the interior door, adjacent to the restrooms in the hallway, is an exit door, however, per LSC 7.2.6.1 and 7.1.3.2.1 (1), to be able to considered an exit, the hallway beyond the door would need to be considered an exit passageway. To be considered an exit passageway, the walls would need to be provided with a 1-hr fire rating. For this reason, the east interior door was not considered a means of egress, but because this door has a clear width of 72 in., this width was used to determine the exterior exit door's avaible egress capacity. This exit door is large enough provide the remaining 50% of available egress to the assembly occupants which satisfies, LSC section 13.2.3.6.2.

Lecture Halls 101 and 114 fall under the assembly occupancy with fixed seating and Rm 101 has stadium style seating. Rm 101 has 44 in. aisle, with steps that have 6in tall risers and 57 in. long treads which meets the requirements of LSC 13.2.5.5, for aisle clearance and LSC 13.2.5.6.4/5/6 for aisle stairs and ramps. LSC 13.2.3.2 and Table 13.2.3.2 were used to verify that the doors of Rm 101 are sized properly. See Appendix D.

It is not indicated on the plans, but there should be aisle marking on the aisle stairs in Rm 101 per LSC 13.2.5.6.10

EGRESS

Exit doors for the first and third floor and for Room 101 are provided with panic hardware per LSC 13.2.2.2.3 and 7.2.1.7 since they serve an occupant load of 100 or more. The entire building is provided with an alarm system, so the requirements in LSC Section 13.3.4, to provide an alarm system for assembly occupancies with an occupant load over 300, is satisfied.

All the classrooms and offices utilize a minimum of 36 in. clear width doors, which should facilitate 120 occupants. The use of a single 36 in. door for these rooms is acceptable per LSC 39.2.4.3. All assembly rooms have two exit doors except for Rooms 304 and 306, which each only have one 36 in. door. Per LSC 13.2.4.2, two separate means of exit are required for these spaces.

EXIT ARRANGEMENT

LSC 7.5.1.3.1 through 7.5.1.3.7 provides guidance on the required remoteness of the exits for this building. The general requirement is half of the diagonal distance of the room or floor. All the rooms meet this requirement on all floors. The exit arrangement on all the floors is acceptable if we consider only the minimum number of required exits to get adequate exit capacity. Some of the exits are much closer than half the diagonal distance, but if we treat those as supplemental, the overall arrangement is acceptable. See Appendix A, Figures A1-A2 for some of the measured distances. The exit measurements are limited to dissimilar room types.

HORIZONTAL EXIT

The central atrium area of the building, has 2-hour rated walls which meet the requirement for a horizontal exit per LSC 7.2.4. The fire rating extends from the ground to the roof for three levels on the west side and five levels on the east side. The doors have a 90-minute fire rating. There has not been any substitution of exits in place of the horizontal exits, however they have been included in the original LSC life safety plan for calculation of egress distances.

AREA OF REFUGE

All exit stairs have been indicated on the life safety plans as areas of refuge. The stairs have a clear width of at least 44 in., so they would be acceptable per LSC 7.2.12.2.32 (2) as an existing area of refuge; however, per LSC 7.2.12.2.2, Stair #3 cannot be considered an area of refuge since this stair discharges back into the building.

EXIT TRAVEL DISTANCES AND DEAD ENDS

LSC 39.2.6 indicates that the distance limits for an existing sprinklered business occupancy is 100 ft., 50ft., and 300 ft. for common path limit, dead-end limit and travel distance, respectively. For the business occupancy levels (2, 4, 5 and 6) the longest common path distance is 99 ft. 2in. and 152 ft. 1in. total distance from Room 422/522/622 to Exit Stair No. 1. There is a 57 ft. 9 in. dead end in the east corridor of level 2 that has had a door installed with appropriate signage to minimize use of the dead end for egress travel. All other dead ends are significantly less.

LSC 13.2.5.13 and 13.2.6.2 indicates that the distance limits for an existing sprinklered assembly occupancy is 20 ft. and 250 ft. for dead end limit and total distance limit respectively. LSC 13.2.5.1.2 indicates that the common path limit is 75 ft. for less than or equal to 50 people and 20 ft. for over 50 people. The longest total distance is 206 ft. 8 in. on the third level, room 330A to exit stair No. 1. There are no appreciable dead ends on the first and third level. The longest common path distance in the assembly areas is 67 ft. 7 in. on the first level, from room 110 to the split between the main lobby exit doors and the east exit door. This distance is acceptable since there are less than 50 occupants expected to use this path. The next longest common path is 67.5 ft. from the student work spaces on the third level, Rooms 304 and 306 to the split point in the atrium. This common path is unacceptable since the occupant load for these spaces is expected to exceed 50 occupants.

LSC 7.12.1 indicates that the common path of travel for mechanical rooms should be limited to 150 ft. in sprinklered existing buildings if no fuel-fired equipment is present. The code also indicates that the path must readily identifiable. The common path should be limited to 50 ft. if fuel-fired equipment is used. The common path of travel from the main mechanical room is over 50 ft. It should be confirmed that fuel-fired equipment is not in use.

Although not included in the occupancy loading analysis, the upper roof was considered for egress adequacy. Per 7.12.2 a single exit is acceptable since the roof is used exclusively for mechanical equipment, however it limits the common path of travel per 7.12.1. All common paths of travel in this area are in excess of the allowable 150 ft. for existing facilities. A second exit would be required to reduce the common path of travel distances.

EXIT SIGN LOCATIONS

Exits signs should be installed at every exit, with the exception of exit doors that are obviously and clearly identifiable as exist per LSC 7.10.1.2.1. The exit sign should be readily visible from all directions of exit egress. Figure 6 shows an example from the LSC Section 7.10.

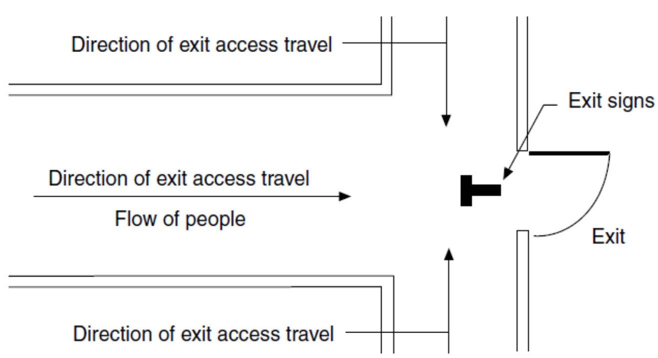

Figure 6- Example of Exit Signage

EGRESS

When the direction of exit is not obvious, directional components should be marked per 7.10.1.2.2 and 7.10.2. In the exit corridor, such as in one of the classroom wings, signs should be placed so that no sign is in excess of 100 ft. from the corridor entrance per 7.10.1.5.2. In general, all signs should be illuminated per 7.10.5.1.

In addition to exit signs, LSC 13.2.10.3 indicates that evacuation diagrams should be provided for the assembly occupancy floors.

See Appendix A for the recommended exit sign locations. The exit signs are marked with a red elliptical symbol. Although not indicated, to reduce clutter in the drawing, exit signs should be placed in every room above the exit door.

SUMMARY

The arrangement and number of exits for each level is acceptable, but a second exit is required for Rooms 304 and 306 since they are considered assembly use. These rooms also exceed the common path limit of 20 ft. for assembly use of over 50 occupants. Inadequate egress capacity is provided for the 3rd level, based on the exit stair details in the architectural plans. There is a discrepancy between the original life safety design and the architectural plans for the exit stairs, so additional investigation is needed to confirm.

Initiation of egress is often triggered by the notification devices of the fire alarm system. Alarm coverage for the entire building is paramount to ensure that all occupants are notified to exit. The next section of the report discusses the fire alarm system details.

Fire Alarm System Overview

The fire alarm system is a crucial part of the life safety design for the building to ensure that the occupants are notified of any unsafe conditions. This section of the report will discuss the overall design of the fire alarm system, the main components, and the expected sequence of events that should occur following the detection of a fire.

SYSTEM CHARACTERISTICS

Section 13.3.4 of the LSC requires that existing assembly occupancies, with an occupant load exceeding 300, are required to be provided with an approved fire alarm system in accordance with LSC section 9.6.1. LSC section 39.3.4.1 also indicates that existing business occupancies are required to have a fire alarm system in accordance with section 9.6 when the building is more than three stories in height or more than 100 occupants. LSC section 9.6.1 indicates that fire alarm systems shall be maintained, installed and tested in accordance with NFPA 72 and NFPA 70. Total smoke detection coverage is not included in the alarm requirements.

NFPA 72 defines the fire detection and alarm system as a protected premises fire alarm system and a proprietary supervising station alarm system per A.3.3.103.4. The system utilizes one-way in-building fire emergency voice/alarm communication system (EVACS) and a two-way, fire fighter wired telephone system. The system is designed to communicate all supervisory, trouble and alarm signals to the Cal Poly Dispatch Center.

The initiating device circuits (IDC), notification appliance circuits (NAC), and signaling line circuits (SLC) are specified to have, 2-wire, Class B pathways (formally Style A, Style Y and Style 4.0 for the IDC, NAC, and SLC respectively), and the fire fighter telephone circuits are specified to have, 2-wire, Class A (formally Style Z) pathways. The pathway classes are defined based on the circuit behavior following an open line. Figures 7 and 8 show the differences between Class A and B.

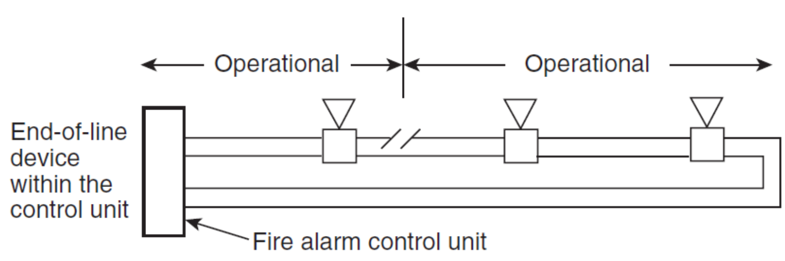

Figure 7 – 2-wire class A circuit (formerly Style Z) Fire Fighters Pathway

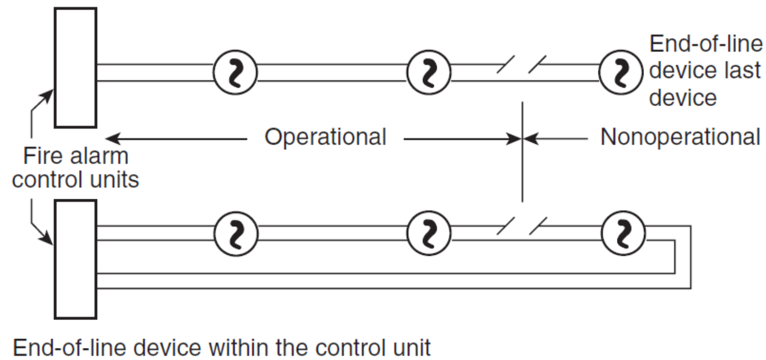

Figure 8 – 2-wire Class B circuit (analogous to former Style A, Y and 4.0)

Per NFPA 72, 2007 Edition, Appendix C the following characteristics apply to the previously used Style designations:

- Style A and Y: A fault occurs in the circuit downstream of the first device (shown as hash marks in the above figures) and the device between the fire alarm control unit (FAC) activated. The FAC should indicate a trouble signal where the fault occurs and alarm where the device was activated.
- Style Z: A fault occurs in the circuit in the middle of the circuit (shown as hash marks in the above figures), and a device on either side of the fault is activated. The circuit is reset and ground is applied to either side of the fault. The FAC should indicate audible and visual trouble signal where the ground was applied and alarm where the device was activated.
- Style 4.0: This is a parallel circuit in which multiplex interface devices transmit signal and operating power over the conductors. The interface devices should be operable up to a point of a single break and should send trouble signal for all the valuations shown on the signaling table including the loss of carrier.

Per NFPA 72, 2016 Edition 12.3.1, a Class A pathway, which closely resembles a Class A circuit, should perform as follows:

- It includes a redundant path.
- Operational capability continues past a single open, and the single open fault shall result in the annunciation of a trouble signal
- Conditions that affect the intended operation of the path are annunciated as a trouble signal.
- Operational capability is maintained during the application of a single ground fault.
- A single ground condition shall result in the annunciation of a trouble signal.

Per NFPA 72, 2016 Edition 12.3.2, a Class B pathway, which closely resembles a Class A circuit, should perform as follows:

- It does include a redundant path.

- Operational capability stops at a single open.
- Conditions that affect the intended operation of the path are annunciated as a trouble signal.
- Operational capability is maintained during the application of a single ground fault
- A single ground condition shall result in the annunciation of a trouble signal.

The IDC, NAC and SLC pathways have a pathway survivability Level 1 since the building is sprinkler protected and all cables, interconnecting conductors or other physical pathways are installed in metal raceways. The fire fighter telephone pathways have a survivability level 2, which consists of 2-hr rated circuit integrity cable and enclosures.

FIRE ALARM PANEL

This alarm system design utilizes a single fire alarm control panel located in the main electrical room on the first floor. A FM Approved, UL Listed, addressable fire alarm panel from Honeywell/Notifier, Model NFS2-640 is specified for use. This room is provided with smoke detection per NFPA 72, section 10.4.4, which requires smoke detection at the location of control units in normally unoccupied locations. This alarm design utilizes, 64 dual relay/monitor modules, 12 relay modules, and one six-relay control module to transmits signals from the imitating devices to the control module.

DISPOSITION OF SIGNALS

The fire alarm system has specific requirements for all types of signals per NFPA 72. Section 23.8.5 provides guidance for the local alarms in the facility, and Section 26.4.6.6 provides guidance for the signals that are to be sent to the proprietary supervising station. Figure 9, below, is a copy of the sequence of operations from the as-built plan set of the alarm drawings. This sequence of operations matrix details the system response to alarm, supervisory and trouble signals. A larger version is also available in Appendix E.

FIRE ALARM SYSTEM OVERVIEW

EVENT	SUPERVISORY CONDITION AT FACU	TROUBLE CONDITION AT FACU	ALARM CONDITION AT FACU	ACTIVATE FIRE ALARM AUDIO/VISUAL DEVICES AND VOICE ALARM COMMUNICATION	DISPLAY TEXT ON LCD ANNUNCIATOR	ACTIVATE SHUNT TRIP RELAY	SHUTDOWN AIR HANDLER UNIT	ACTIVATE ELEVATOR RECALL	SHUTDOWN INDIVIDUAL ASSOCIATED DAMPERS	DEACTIVATE MAGNETIC DOOR HOLDERS	ACTIVATE SUPERVISORY SIGNAL TO RECEIVING STATION (CAMPUS POLICE)	ACTIVATE TROUBLE SIGNAL TO RECEIVING STATION (CAMPUS POLICE)	ACTIVATE ALARM DIALER SIGNAL TO RECEIVING STATION (CAMPUS POLICE)	BYPASS ALL ALARM OUTPUTS (NOTIFICATION, SHUNTS, RELAY OUTPUTS) FOR TESTIN	OPEN ATRUIM DOORS WITH MOTORIZED DOOR OPERATORS	ACTIVATE ATRIUM PASSIVE SMOKE EVACUATION SYSTEM
FIRE ALARM CONTROL UNIT																
PANEL SUPERVISORY CONDITION (TEST BYBASS) ON ACM-24 AT	X				X						X			X		
PANEL TROUBLE CONDITION (AC POWER FAIL, LOW BATTERY, OPEN CIRCUIT, GROUND FAULT, ETC.)		X			X							X				
PANEL ALARM CONDITION			X	X	X		X			X			X			
MANUAL PULL STATION ACTIVATION			X	X	X					X			X			
SPOT SMOKE DETECTOR ACTIVATION			X	X	X					X			X			
DUCT SMOKE DETECTOR ACTIVATION			X	X	X				X	X			X			
AIR HANDLING UNIT DUCT SMOKE DETECTOR ACTIVATION			X	X	X		X						X			
SPRINKLER TAMPER SWITCH	X				X						X		X			
SPRINKLER WATER FLOW ACTIVATION			X	X	X					X			X			
FIRE PUMP RUNNING			X	X	X					X			X			
FIRE PUMP LOSS OF PH ASE	X				X						X					
FIRE PUMP PHASE REVERSAL	X				X						X		X			
HEAT DETECTOR ACTIVATION (ELEVATOR EQUIPMENT)			X	X	X	X				X			X			
ELEVATOR LOBBY/ EMR SMOKE / ELEVATOR HOISTWAYS			X	X	X			X		X			X			
SHUNT TRIP POWER SUPERVISION	X				X						X					
GENERAL ALARM (ANYWHERE WITHIN THE BUILDING)			X	X	X		X			X			X			
ATRIUM SMOKE CONTORL SYSTEM ALARM			X	X	X					X			X		X	X
BEAM SMOKE DETECTION WITHIN ATRIUM			X	X	X					X			X		X	X
PULL STATION WITHIN ATRIUM			X	X	X					X			X		X	X
SPRINKLER WATER FLOW WITHIN ATRIUM			X	X	X					X			X		X	X

Figure 9- Sequence of Alarm System Operation

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INITIATING DEVICE TYPES

This alarm system utilizes several different types of initiating devices throughout the building. The system primarily relies on the use of duct-type photoelectric smoke detectors for alarm activation. See Figure 10 for an example of the duct detector utilized.

Figure 10 - Notifier/System Sensor DNR Photoelectric Duct Smoke Detector

FIRE ALARM SYSTEM OVERVIEW

Below is a list of all initiating devices used:

- 64, Notifier/System Sensor DNR, photoelectric duct smoke detectors
- 31, Notifier/System Sensor NBG-12LX, manual pull Stations
- 23, Xtralis OSE-SPW, beam type smoke detector transmitter
- 15, Xtralis OSI-90, beam type smoke detector receiver
- 18, Notifier/System Sensor FSP-851, photoelectric smoke detector

This building is also fully sprinklered with Tyco TY-3231 quick response sprinklers below the dropped ceilings. The sprinklers act a heat detectors in the room that allow water to flow once fused. The risers are provided with waterflow alarms on each floor, and a fire pump run alarm, that is connected to the fire alarm system which will trigger a full fire alarm. All initiating devices have been identified on each floor on the fire alarm as-built plan in Appendix E.

INITIATING DEVICE ARRANGEMENT

As indicated above, this alarm design primarily utilizes duct smoke detectors for smoke detection in the building, which does not constitute as total coverage of the building per NFPA 72 section 17.5.3.1. However, NFPA 72 section 17.5.3.1 indicates that total coverage only applies when required by other codes, standards and other laws. Since this building is classified as a business and assembly occupancy per the LSC, the system design should meet the requirements in LSC sections 38.3.4.2 for business and 13.3.4.2 for assembly. Both sections allow alarm system initiation to be by manual means installed in accordance with section 9.6.2.1 (1), by approved automatic fire detection system in accordance with section 9.6.2.1(2), or by an approved automatic sprinkler system in accordance with section 9.6.2.1(3). LSC section 13.3.4.2.1 (2) indicates that when automatic sprinkler protection is provided, then the initiation of the alarm system shall also be activated by waterflow, even if manual means of initiation has been provided.

The alarm system design provides manual fire alarm boxes located within 60 in. of all exit doorways and within 200 ft. of each other satisfying LSC section 9.6.2.1. The LSC handbook commentary specifically discusses the use of manual alarm system initiation only in business occupancies and indicates that the code assumes that the building personnel are alert and competent and will initiate the alarm on the first sign of smoke. The alarm design also utilizes waterflow devices for alarm activation which satisfies, sections 13.3.4.2.1 and 38.3.4.2 for both occupancy uses.

Additional smoke detection, including the beam type detectors in the atrium areas and spot type detectors near the horizontal exits have also been provided. It is assumed that these have been provided for additional fire life safety objectives, and to meet the CBC. Per NFPA 72 section 17.5.3.3.1, for buildings with nonrequired coverage, alarm systems installed in this instance should still be installed to meet the requirements of the code, apart from prescriptive spacing. If, the additional detection is provided with the aim of total smoke detection in the building, then additional protection is required to meet NFPA 72. Specifically, NFPA 72 section 17.7.4.3 indicates, that duct detectors should not be used as a substitute for open area detectors, due to the potential insufficient airflows for smoke detection.

The beam type smoke detectors (Figure 11 below) are installed per the manufacturer's recommendations. The transmitters are installed at an appropriate angle from the receiver and they do not exceed the maximum number of transmitters per receiver.

Figure 11 – Xtralis OSI0 Beam Imager

SMOKE CONTROL SYSTEM

A passive smoke control system has been design for the five-level central atrium area that has been developed based on the CBC, Section 909. The atrium is separated from the other occupancies on the first two levels by a 1-hour rated wall, and mixed with the business occupancies on the upper levels. The central atrium area of the building is also separated from the wings of the building by a 2-hour rated wall.

Section 404.5 of the IBC requires that any vertical opening over two stories (the definition of an atrium), shall have a smoke control system installed in accordance with Section 909. Section 909.4 requires that a rational analysis is developed that provides a design that maintains tenability for all occupants for not less than 20 minutes or 1.5 times the calculated egress time, whichever is greater. The IBC indicates that the analysis shall include at least consideration of stack effect, temperature effect of the fire, wind effect, climate effects on the building and occupants, building leakage, and interaction between the control system and the proposed fire scenario.

This smoke control system was designed to meet the criteria for a passive exhaust method per Section 909.8.1 of the IBC. This section requires the smoke layer height to be maintained 6 ft. above any walking surface that is part of the egress path. Section 8.6.7 of the LSC has very similar requirements to the IBC for the atrium space, requiring the smoke layer maintained at least 6 ft., above the highest unprotected opening for existing, previously approved atriums where an engineering analysis has been performed.

Section 404.6 of the IBC indicates that the atrium space should be separated from other occupancies with at least a 1-hour fire rated barrier. This atrium design uses exception 3 in Section 404.6 that allows mixing

of up to three floors if the spaces are included in the design of the smoke protection. LSC Section 8.6.7.1 has the same 1-hour fire separation requirement, but makes exception for existing previously approved atriums (a), and allows any number of levels to be open to the atrium provided an engineering analysis has been completed (b).

An engineering analysis was developed by ARUP, that developed an adequate smoke control design at time of construction. The design utilizes two, 100 sq. ft. exhaust vents at the top of each of the atrium vertical openings, which are designed to open following fire alarm activation. Doors that lead into the atrium space on each level, will be automatically released, to maintain a smoke barrier in the space, and the main entrance doors on the second level will be automatically opened. The sequence of events for the alarm design is displayed in Figure 9, above. Actions related specifically to smoke control system have been indicated with red blocks, and actions shared by the atrium smoke control design and the building smoke control design are indicated with purple blocks.

Smoke spread in other areas of the building is limited using HVAC duct smoke detection, and interlocking of associated smoke dampers and air handling units for shutdown shut down. The intent of this action is to control the spread of smoke in the building. Actions related specifically to the HVAC and building smoke control have been indicated with a blue block on the sequence of operations matrix, Figure 9, above.

NOTIFICATION DEVICES

Notification Devices

NFPA 72 does not specifically require the installation of notification devices for buildings. It instead, refers to the LSC, the AHJ or other governing codes or standards. LSC section 38.3.4.3 (1) indicates that offices should have alarms in accordance with LSC section 9.6.3. LSC section 13.3.4.3 indicates that the alarm must activate an audible alarm in a constantly attended receiving station within the building. Sections 13.3.4.3, 13.3.4.3.2, and 13.3.4.3.3 indicate that both the positive and presingnal alarm sequence shall per permitted, and that a voice announcements shall be initiated by the person in the constantly attended receiving station. LSC 9.6.3.5 indicates that buildings should be provided by visible and audible signals in accordance with NFPA 72.

NFPA 72 defines a presignal feature as an alarm sequence that sends the initial fire alarm signals to sound only in department offices, control rooms, fire brigade stations, or other constantly attended locations. The signal can also be transmitted to a supervision station. After the initial fire alarm, human action is required to activates the general alarm, or there is a feature of the control system that delays the general alarm by more than a minute. Based on the operations matrix for this alarm system (Figure 9), a presignal alarm sequence is not indicated for use.

NFPA 72 defines a Positive Alarm Sequence as an alarm sequence that provides a timed delay of a general alarm, up to three minutes, to allow for investigation. Figure 12 below, from NFPA 72 indicates a positive alarm sequence. A positive alarm sequence is not indicated for use on the building's sequence of alarm system operation.

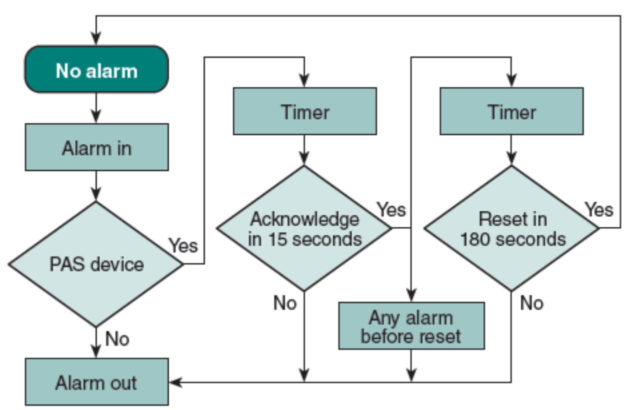


Figure 12 - Positive Alarm Sequence (PAS), Exhibit 23.1 NFPA 72

NOTIFICATION DEVICES

DEVICE MODELS

The alarm system design utilizes four different types of wall mounted notification devices in the system design. The following devices are included in the design, which are all included in the Notifier/System Sensor SpectrAlert Device Family shown in Figure13:

- 165, Notifier/System Sensor SPSW, speaker strobes
- 73, Notifier/System Sensor SE, strobe only
- 7, Notifier/System Sensor SPWK, outdoor speaker
- 6, Notifier/System Sensor SPW, speaker only

Figure 13 - SpectrAlert Device Family from Notifier/System Sensor

Although not specifically a notification device, 12 fire fighter phone jacks are included in the system design for commination with the central station and fire department. See Appendix E for fire alarm system layout and the locations of all the notification devices.

AUDIBLE DEVICE ARRANGEMENT

NFPA 72 section 18.4.10 indicates that within acoustically distinguishable spaces (ADS), where voice intelligibility is required, voice communication systems shall be intelligible. NFPA 72 section 18.4.10.1 indicates that buildings are required to be broken into ADSs, however, the concept of ADS was not included in NFPA 72 until 2010, so ADS were not defined for this building. This report will assume that all areas, with the exception of the rooms listed in NFPA 72 A.18.4.10.2.1, will be required to have voice intelligibility to be an effective ECS system.

NOTIFICATION DEVICES

At least one speaker is provided in each of the classrooms and labs, and in the halls. Speakers are also provided on the balcony areas. All the speakers are provided with a power rating, and are typically rated for 2W in the classrooms and wider halls, and reduced power for smaller spaces. Table 6 indicates the expected sound level output from each of the speakers relative to their rating. See Appendix E for the location of all audible devices.

Table 6 - Speaker Sound Output

Sound Output				
UL Reverberant (dBA @ 10 ft.)	2W	1W	½ W	¼ W
Wall-Mount SP Series	86	83	80	77

Since speakers are provided in all the ADSs, it is possible that the design meets Voice/Alarm requirements of NFPA 72, but the system would need to be tested for intelligibility and audibility.

VISUAL DEVICE ARRANGEMENT

Combination speaker/strobe and strobe only notification devices are provided through the entire building, which can be seen on the alarm drawings in Appendix A. Alarm plan's general notes indicate that all wall mounted visual devices will be mounted 80 in. above finished floor to the bottom of the floor lens, in accordance with NFPA 72 18.5.5.1.

The selected strobes meet the 1 Hz minimum flash rate per NFPA 72 18.5.3.1, but the manufacture did not publish the pulse duration. Varying candela rating are used to provide adequate coverage for each space. The appropriate candela rating has been used to satisfy NFPA Table 18.5.5.4.1 (a), indicated below in Table 7.

Table 7 - NFPA 72 Table 18.5.5.4.1(a) for visible appliances

TABLE 18.5.5.4.1(a) *Room Spacing for Wall-Mounted Visible Appliances*

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

NA: Not allowable.

PROPOSED SPEAKER LAYOUT

NFPA 72 Supplement 2 indicates that a good place to start with the design of the sound system is 1 watt per 750 ft^2 to 1000 ft^2. This starting point should be adjusted to account for the acoustic environment of the speaker. Special attention should be taken to ensure that the signal is not distorted or decayed, due to reverberation or echo, and should maintain an acceptable signal to noise ration. Supplement 2 indicates that a good target point for signal to noise ratio is 10 dB. Additionally, NFPA 72 A.24.4.2.2.2 indicates that ceiling mounted speakers should be utilized and spaced at a maximum spacing of twice the ceiling height (20 ft. spacing for the upper floors) for moderately high spaces (8 ft. to 12 ft.). If wall speakers are used, or if ceiling speakers exceed twice the ceiling height, a computer modeling program should be used to ensure audibility and intelligibility. Since the labs and classrooms will have hard surfaces (e.g., tile floors, metal tables, etc), the rooms may by acoustically challenging, and require more stringent spacing to avoid reverberation. The main atrium, lobby atrium and assembly lecture halls will also need additional attention due to their high ceilings.

ALARM POWER REQUIREMENTS

Alarm Power Requirements

SECONDARY POWER SUPPLY REQUIREMENTS

NFPA 10.6.7.2.1.2, indicates that the secondary power supply for in-building emergency voice/alarm communications service shall be capable of operating the system under quiescent load for a minimum of 24 hours and then shall be capable of operating the system during a fire or other emergency condition for a period of 15 minutes at maximum connected load. NFPA 72 10.6.7.2.1.1 also indicates that the battery calculation shall also include a 20 percent safety margin above the calculated amp-hour capacity required.

SECONDARY POWER SUPPLY CALCULATIONS

The fire alarm plans have undergone six different revisions to get to the as-built plan set, and the bill of materials, one-line alarm drawing, and plans all show signs of revision. The voltage drop calculations, and battery calculations, have not been updated with the revisions, and contain several errors. Also, the bill of materials, one-line drawing and alarm plans do not agree. The published versions of voltage drop and battery calculations plans and one-line drawing are included in the Annex sections.

All voltage drop calculations, and battery calculations, that cover revised areas, need to be reevaluated based on the existing condition. Since there is disagreement between the drawings, a site survey should be completed and have the drawings confirmed and updated.

Voltage drop calculations and battery calculations were completed for the 5th floor 3rd circuit since it had the greatest published voltage drop, and was a circuit that was revised. Voltage drop calculations can be seen in Table 8 and 9 below. The circuit was found to be acceptable, and it is likely that the remaining circuits will be acceptable as well, since they started with less voltage drop than the 5th and 3rd flood circuit. Distances were estimated to the new appliances, and since the voltage dropped to within 1.01V from the minimum voltage, additional information should be found and updated calculations should be completed.

Battery calculations were completed for the FACP. The FACP is loaded with all the appliances from all the floors, with the exception of the notification devices on the 2nd floor west and the upper floors. The 48.18 amp-hours battery that was calculated is below the 55 amp-hour specified; however, the remaining batteries for the remote power supplies should be recalculated to ensure they are still sized properly for the actual devices installed.

Table 8 - Voltage Drop Calculations for the 5th Floor 3rd circuit.

Panel/ Circuit #	Notifier RNPA, PS3- Circuit 5V3								
Area Covered	5th Floor East								
Nominal System Voltage		24							
Minimum Device Voltage		20							
Total Circuit Current	1.881		Wire Guage	Ohm's Per 1000 ft					
Distance from source to 1st dev		15	14	3.07					
Wire Gauge for balance of circu			14	3.07					
Device Number	Distance from Previous device	Voltage At Device	Drop from Source	Percent Drop	Current in amps	Device Model #		Device Type	Candela Rating
5V301	15	23.83	0.173	0.72%	0.066	System Sensor	SPSW	HRN/SB	15
5V302	15	23.66	0.340	1.42%	0.066	System Sensor	SPSW	HRN/SB	15
5V303	15	23.50	0.501	2.09%	0.066	System Sensor	SPSW	HRN/SB	15
5V304	25	23.24	0.760	3.17%	0.181	System Sensor	SPSW	HRN/SB	95
5V305	8	23.17	0.834	3.47%	0.094	System Sensor	SPSW	HRN/SB	30
5V306	15	23.04	0.963	4.01%	0.066	System Sensor	SPSW	HRN/SB	15
5V307	60	22.54	1.458	6.07%	0.202	System Sensor	SPSW	HRN/SB	110
5V307A	30	22.33	1.668	6.95%	0.077	System Sensor	SPSW	HRN/SB	15/75
5V307B	41	22.06	1.935	8.06%	0.077	System Sensor	SPSW	HRN/SB	15/75
5V308	70	21.64	2.359	9.83%	0.202	System Sensor	SPSW	HRN/SB	110
5V309	45	21.42	2.576	10.73%	0.202	System Sensor	SPSW	HRN/SB	110
5V310	10	21.39	2.611	10.88%	0.066	System Sensor	SPSW	HRN/SB	15
5V311	20	21.33	2.675	11.14%	0.066	System Sensor	SPSW	HRN/SB	15
5V312	30	21.24	2.758	11.49%	0.094	System Sensor	SPSW	HRN/SB	30
5V313	80	21.07	2.933	12.22%	0.202	System Sensor	SPSW	HRN/SB	110
5V313A	50	21.02	2.980	12.42%	0.077	System Sensor	SPSW	HRN/SB	15/75
5V313B	25	21.01	2.992	12.47%	0.077	System Sensor	SPSW	HRN/SB	15/75
Total	554	End of Line Voltage		21.01	1.881				
Point to Point Method									
CIRCUIT IS WITHIN LIMITS									
Totals		Volatge Drop							
Current	Distance								
1.881	554	**2.992**							
End of line Voltage		**21.01**							
Percent Drop		**12.47%**							

ALARM POWER REQUIREMENTS

Table 9 - Calculated Required Battery Capacity for FACP and 2nd Floor East

ITEM	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QTY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QTY		TOTAL ALARM CURRENT PER ITEM
FACP	Fire Alarm Control Unit	0.2850	X	1	=	0.2850	0.285	X	1	=	0.285
UDACT	Univeral Dialer	0.4000	X	1	=	0.4000	0.1	X	1	=	0.1
FDU-80	Remote Annunciator	0.0643	X	2	=	0.1286	0.0643	X	2	=	0.1286
APS-6	Power Supply Amp	0.0000	X	1	=	0.0000	0.025	X	1	=	0.025
OSE-SPV	Beam Smoke Emitter	0.0035	X	17	=	0.0595	0.0035	X	17	=	0.0595
OSI-90	Beam Smoke Imager	0.0310	X	12	=	0.3720	0.031	X	12	=	0.372
PULL	Manual Pull	0.0004	X	31	=	0.0124	0.0004	X	31	=	0.0124
RM	Relay Module	0.0017	X	14	=	0.0238	0.0022	X	14	=	0.0308
FSP-851	Smoke Detector	0.0003	X	35	=	0.0105	0.0003	X	35	=	0.0105
FDM-1	Dual Monitor Module	0.0008	X	13	=	0.0104	0.0064	X	13	=	0.0832
SPWK	Speaker Only	0.0000	X	3	=	0.0000	0.0008	X	3	=	0.0024
SW	Strobe Only 15CD	0.0000	X	14	=	0.0000	0.066	X	14	=	0.924
SW	Strobe Only 30CD	0.0000	X	7	=	0.0000	0.094	X	7	=	0.658
SW	Strobe Only 75CD	0.0000	X	1	=	0.0000	0.158	X	1	=	0.158
FJ	Fire Fighter Phone Jack	0.0075	X	12	=	0.0900	0.0075	X	12	=	0.09
XP6-R	Six Relay Control Module	0.0015	X	1	=	0.0015	0.032	X	1	=	0.032
XP10-M	10-Input Monitor Module	0.0035	X	1	=	0.0035	0.055	X	1	=	0.055
SPSW	Speaker/Strobe 15CD	0.0000	X	8	=	0.0000	0.071	X	8	=	0.568
SPSW	Speaker/Strobe 30CD	0.0000	X	13	=	0.0000	0.096	X	13	=	1.248
SPSW	Speaker/Strobe 75CD	0.0000	X	4	=	0.0000	0.153	X	4	=	0.612
SPSW	Speaker/Strobe 95CD	0.0000	X	4	=	0.0000	0.176	X	4	=	0.704
SPSW	Speaker/Strobe 115CD	0.0000	X	12	=	0.0000	0.205	X	12	=	2.46
FMM-1	Monitor Module	0.0037	X	19	=	0.0703	0.0037	X	19	=	0.0703
FDRM-1	Dual Relay/Monitor Module	0.0013	X	62	=	0.0806	0.024	X	62	=	1.488
DNR	Duct Smoke Dector	0.0003	X	62	=	0.0186	0.0003	X	62	=	0.0186
					TOTAL SYSTEM STANDBY CURRENT (AMPS)	1.5667				TOTAL SYSTEM ALARM CURRENT (AMPS)	10.1953

REQUIRED STANBY TIME (HRS)		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY	REQUIRED ALALRM TIME (HOURS)		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HRS)
24	X	1.5667	=	37.6008	0.25	X	10.1953	=	2.548825

REQUIRED STANDBY CAPACITY (AMP-HRS)		REQUIRED ALARM CAPACITY (AMP-HRS)		TOTAL CAPACITY (AMP-HRS)		SAFETY FACTOR 20%		ADJUSTED BATTERY CAPACITY (AMP-HRS)
37.6008	+	2.548825	=	40.149625	X	1.2	=	48.17955

Inspection, Testing and Maintenance

INSPECTION

NFPA 72 section 14.3.1 indicates the visual inspections shall be performed in accordance with the scheduled in Table 14.3.1, and NFPA 72 Section 14.3.3 indicates that extended interval shall not exceed 18 months.

TESTING

NFPA 72 section 14.4 details the requirements for the testing of the alarm system. NFPA 72 Table 14.4.3.2 details the testing interval for all alarm system components, and NFPA A.14.4.2 indicates that reacceptance testing should be completed when changes are made to the system. NFPA 14.4.2.5 indicates that a 10 percent functional test shall be performed when changes are made to the system executive software.

MAINTENANCE

The code does not provide extensive information on alarm system maintenance beyond the information in NFPA sections 14.3 and 14.4, however is directs the system owner to maintain the equipment per the manufacturer's guidance.

RECORDS

NFPA 72 Section 14.6.1 indicates that records of the completion of the acceptance test, a set of the as-built installation drawings, operation and maintenance manuals and a sequence of operation shall be created and maintained for the life of the system. The maintenance and testing records should be retained until the next test and for 1 year thereafter.

SUMMARY

The fire alarm system has been installed in accordance with NFPA 72, per the requirements of the LSC and IBC. This system uses both manual means of activation as well as automatic means, utilizing smoke detection and sprinkler flow. A EVAC notification system has been utilized, and the alarm system has been included in the smoke control design for the atrium.

Intertwined with the fire detection design is the automatic sprinkler protection. Besides helping to control and minimize fire damage, automatic sprinklers act as heat detectors, that when fused, allow sprinkler water to flow. This waterflow activates the waterflow alarm that is tied into the buildings fire alarm design. The automatic sprinkler protection design is discussed in the next section.

Automatic Sprinkler Protection Design

The building automatic sprinkler protection is the first active line of defense for fighting fires, and minimizing fire damage. The sprinklers act to control and potentially extinguish fires so that the fire department can respond. They are a critical component of the building's life safety design. This section discusses, the protection requirements for the different areas of the building, and the details of the fire protection design.

PROTECTION CLASSIFICATION

This facility is a University Building that is used for instruction of math and the sciences. The majority of the building spaces are classrooms, lecture halls and offices. These rooms should be protected as light hazard per NFPA 13 Section 5.2 and Section A.5.2 (5), (12) and (13). The building also utilizes several research and instructional laboratories. NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals* 2015 Edition, Section 4.2.2.1, indicates that instructional laboratory units shall be classified as Class C or D laboratory units. NFPA 13 Section 22.8.1 (2) indicates that Class C and D Laboratories shall be protected as Ordinary Hazard group 1 (OH-1) occupancies. NFPA 13 Section A.5.3.1(11) also indicates that all mechanical rooms should be protected as OH-1.

This facility has been designed using the density/area method (discussed further later in the report). NFPA 13 Section 11.2.3.1.1 (1) indicates that Figure 11.2.3.1.1 (Figure 14, below) should be used for the determination of the required density.

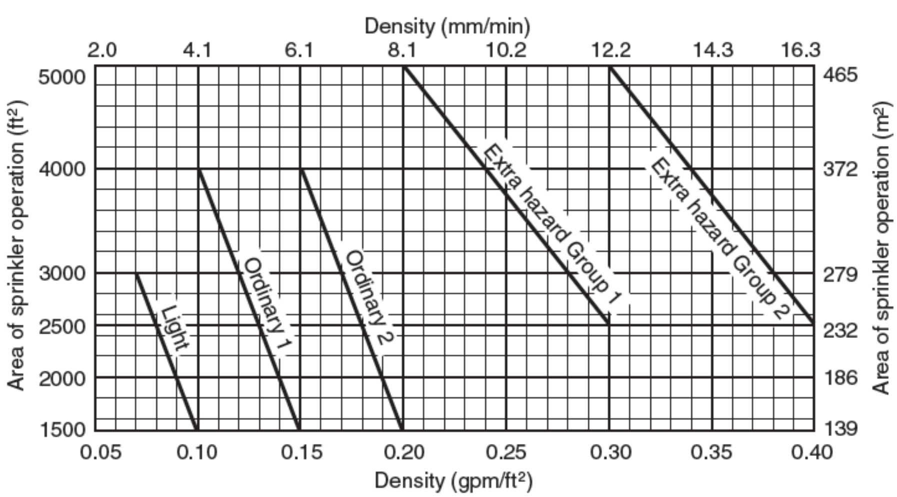


FIGURE 11.2.3.1.1 *Density/Area Curves.*

Figure 14 - NFPA Figure 11.2.3.1.1 Required Density/Area Curves

AUTOMATIC SPRINKLER PROTECTION DESIGN

A few rooms in the facility are designated for storage that are incidental to the rest of the predominate occupancy. These rooms should be protected per the guidance in NFPA 13 Chapter 13 and Table 13.2.1, *Discharge Criteria for Miscellaneous Storage up to 12 ft. (3.7 m) in Height* and discussed in the design section of the report. The NFPA Table is included in Appendix G, as Figure G1 .

ATRIUMS

Two atriums are formed by vertical openings on the north and south side of the central second level that connects to the sixth level. These vertical openings cannot be considered communicating spaces because they connect more than three contiguous stories per LSC section 8.6.6 (1), and cannot be considered large openings per NFPA 13 Section 8.15.4.4 because they are less than 1,000 sq. ft. in area on all levels (2nd floor to 6th floor). For these reasons, these spaces should be treated as vertical openings. Design requirements for vertical openings are indicated in Section 8.15.4 of NFPA 13, and discussed further in the design section of this report.

MAIN WATER SUPPLY

The Cal Poly water supply is characterized by a gravity fed system that is connected to a fire booster pump in the building. The building is connected by an underground, 8 in. P.V.C. (C900 Class 200) pipe, that has been cut into the existing water main directly east of Fire Hydrant #63, see Figure 15 below. A Wilkins Model 350ADA 8 in. double backflow assembly with outside screw and yoke valves (OS&Y) has been installed upstream of the fire pump on the exterior of the building.

The fire pump is a Peerless electric driven fire pump that is rated for 750 gpm at 133 psi.

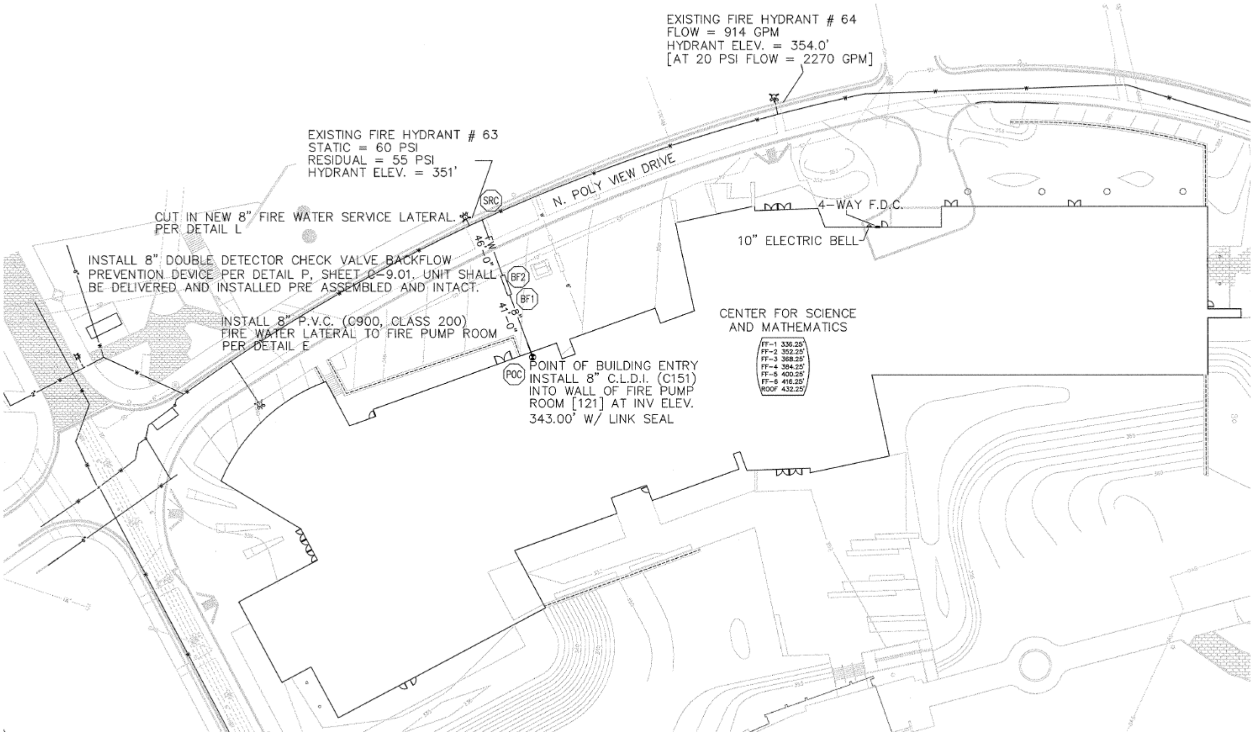


Figure 15 - Water Supply Underground

SUPPLY DETAILS

The school main was tested by flowing from hydrant #64 and taking residual pressure readings from hydrant #63. The test conducted on 8/19/2011 by Fluid Resource Management resulting in a static system pressure of 60 psi and a residual pressure of 55 psi flowing 914 gpm. The effective point of the flow test is hydrant #63. Figure 16, details the school water supply and the design curve of the pump. The adjusted supply curve below is an estimate of the public water supply effective at the suction side of the fire pump. The supply was reduced by adding a fixed pressure loss of 7 psi based on the Wilkins friction loss design curve for the backflow preventer, Figure 17, which is approximately the same pressure loss at all the pump flow points. 3 psi was added to the water supply since the effective point of the test was 8 ft. higher than the point of connection. A 10% reduction in static and residual pressure was added for comparison to the site plans, however NFPA 13 Handbook Section A.23.2.1.1 commentary indicates that a more appropriate method is to determine the safety factor based on the characteristics of the specific water supply.

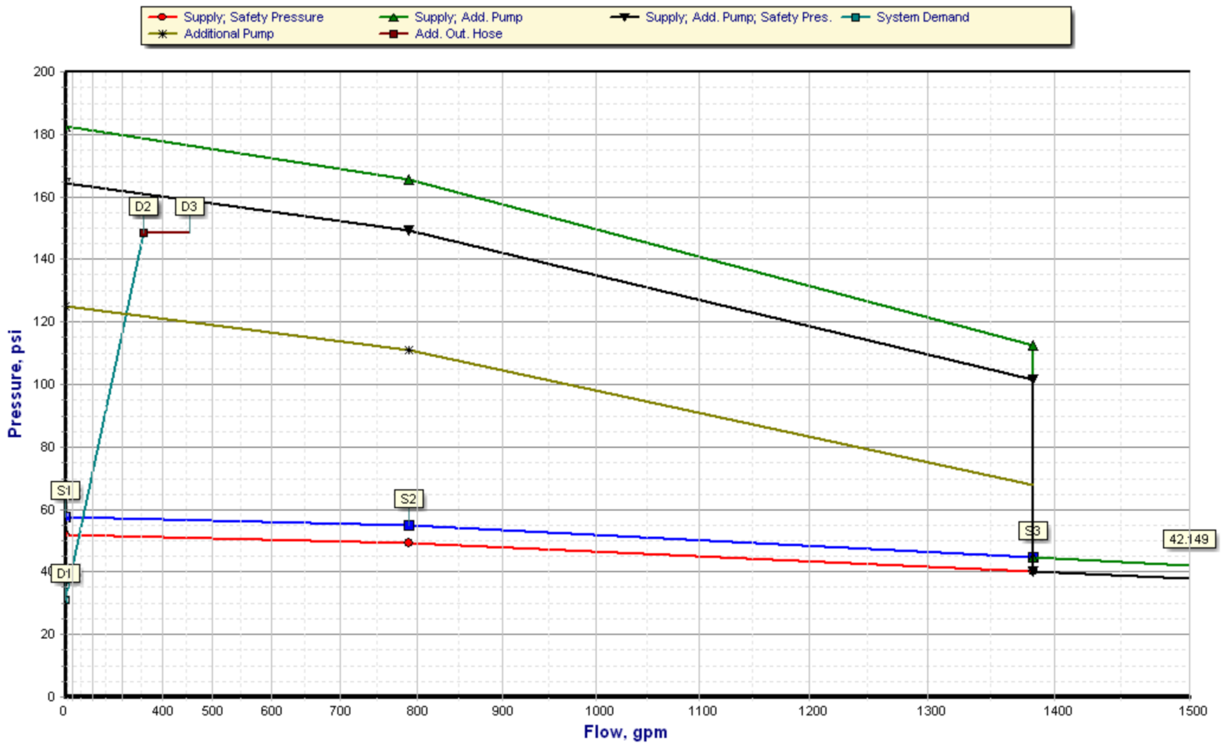


Figure 16 – Demand and Supply Curves

The blue line with the blue square is the adjusted supply curve at the pump suction, the olive line with a star is the pump design curve, and the green line with the upward pointing triangle is the combined supply curve. The Red line with the circle and the black line with the downward pointing triangle are the supply curves with a 10% safety margin. The teal line, with the D1 and D2 labels, is the demand curve line for the computer model of Remote Area 6-4, effective at the discharge of the pump. Additional discussion of the computer model generated is included later in this section.

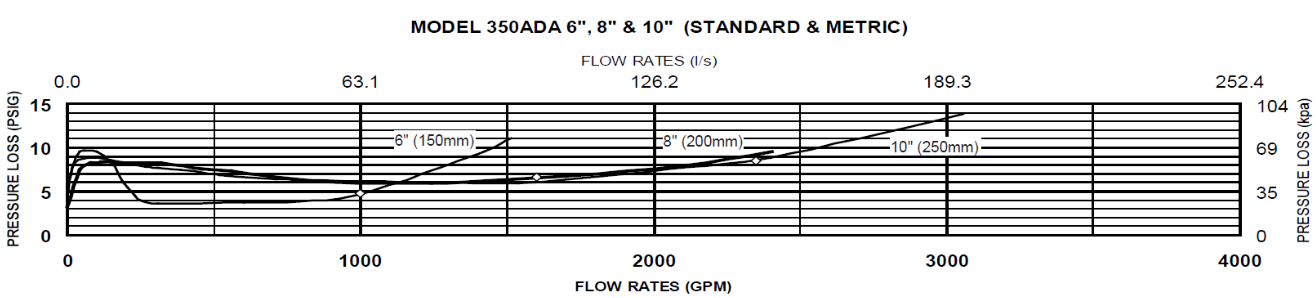


Figure 17 - Backflow Friction Loss Curve

FIRE DEPARTMENT CONNECTION (FDC)

This site is provided with one FDC, which is piped to the second floor using 6 in. pipe to the north side of the building. The connection utilizes four 2-½ in. hose connections in accordance with NFPA 13 Section 6.7.1.

DESIGN

The site utilizes TYCO, K = 5.6 sprinklers from the TY-FRB family. Ordinary temperature (165 °F), quick response, recessed, pendent sprinkler heads, SIN TY3231, are used in the classrooms, labs, offices and lecture halls. Intermediate temperature (200 °F), quick response, upright sprinkler heads, SIN TY3131, are used in the stairwells and in the larger mechanical rooms. A single intermediate temperature, quick response, sidewall sprinkler, SIN TY3331, is used in the first-floor design.

The pump utilizes a steel, schedule 40, 6 in. feed main piping that is piped to Stairwell #3 to serve as the main riser for the 2nd – 6th floors and to the other stairwells as hose standpipes (See Appendix G for piping details to the main riser and stairwell standpipes). The first-floor riser is piped off the 6 in. feed main piping in the pump room. A steel, schedule 10, 3 in. riser is used with a steel, schedule 10, 3 in. crossmain for the central area of the first floor and steel, schedule 10, 2½ in. mains for the other areas of the floor. Steel, schedule 40, 1 in. branchlines are used with heads on various spacing to avoid ceiling obstructions. The average coverage area per head is 165 sq. ft. for the light hazard areas and approximately 130 sq. ft. spacing in the OH-1 mechanical area. Figure 18, below, illustrates the drop used for the recessed pendent sprinklers used in the light hazard spaces. The sprinklers drop can vary from six inches to over 20 feet. Sprinklers are not provided above the dropped ceiling, since the space above is not considered a combustible space.

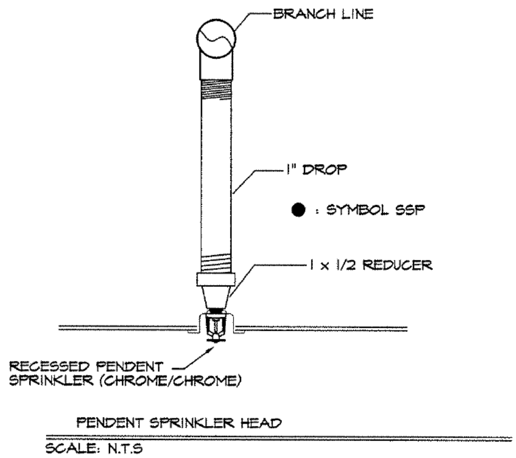
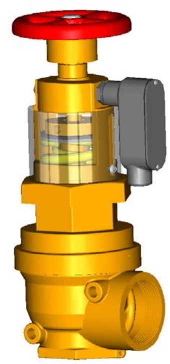


Figure 18 - Sprinkler Drop Example

The second through sixth floor systems have similar characteristics with a steel, schedule 40, 6 in. vertical feed main in stairwell #3, steel, schedule 10, 2½ in. risers and mains and steel, and schedule 40, 1in. branchlines. See Appendix G for details on piping locations.

The first-floor riser uses a 3 in., Elkhart Brass Field Adjustable Pressure Reducing Valves (URFA), illustrated below in Figure 19. This valve regulates the pressure downstream of the valve. This valve also acts as the check valves for the first floor. The remaining floors utilize a 2½ in. butterfly vale, and check valve. All the risers are equipped with a TYCO MOD-513 flow switch and a 1¼ Test-N-Drain with pressure relief valve.



(URFA-20-2.5 MODEL SHOWN)

Figure 19 - Elkheart Brass URFA valve.

Copper tubing is used for sprinkler piping in the stairwells on the first floor. A di-electric union was used between the steel and copper pipe to avoid galvanic corrosion.

As indicated in the occupancy section, there are two vertical openings that require special sprinkler protection per NFPA 13, 2016 edition. NFPA 13 8.15.4.1 indicates that draft stops and sprinklers on 6 ft. spacing should be installed along the perimeter of the vertical openings. Sprinklers are provided in the proximity of the vertical openings, but are spaced at greater than 6 ft. spacing. Based on the current design, these openings are considered unprotected vertical openings. This design is acceptable for this building since the atrium, and smoke control design is based on unprotected vertical openings.

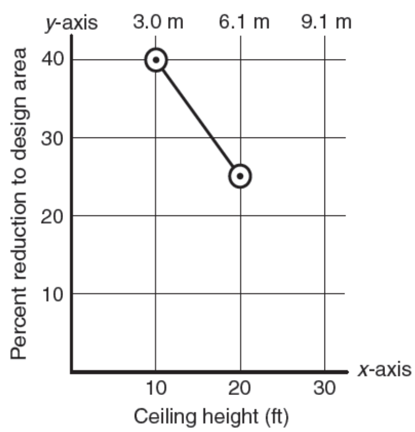
REMOTE AREA DESIGN

This building was hydraulically designed using the design/area approach. Several remote areas have been identified and summarized in Table 10, below (See Appendix G for locations off all remote design areas). All light hazard areas include 100 gpm of inside hose stream, and all OH-1 areas have an additional 150 gpm of outside hose for a total of 250 gpm hose, per Table 11.2.3.1.2 in NFPA 13.

Table 10 - Hydraulic Design Areas

Design Area	Occupancy	Hazard Group	Density / Area [(GPM/SQ. FT.)/SF. QT.]	Coverage Area [SQ. FT.]	BOR Demand [GPM @ PSI]	Demand at Pump [GPM @ PSI] Incl. Hose
1-1	Lecture Hall	Light Hazard	0.10/1520	168	251@126.6	351@130
1-2	Lecture Hall	Light Hazard	0.10/1575	163	328@162.2	428@168
3-1	Lab	OH-1	0.15/967*	130	253@102.6	403@122
3-2	Lab	OH-1	0.15/1135*	130	234@107.3	384@126
6-1	Lab	OH-1	0.15/940*	130	233@95.5	383@135
6-2	Corridor	Light Hazard	0.10/5 HDS	225	113@34.5	213@72
6-3	Lab	OH-1	0.15/920*	130	273@108.4	423@149
6-4	Office/Lobby	Light Hazard	0.10/1567	210	347@116.9	447@161

Design areas with an asterisk have been reduced due to the use of quick response sprinkles per NFPA 13 section 11.2.3.2.3.1 and Figure 11.2.3.2.3.1. This figure is illustrated as Figure 20, below. Remote areas 3-1, 3-2, 6-1 and 6-3 have a 10½ ft. ceiling height, which results in 39.25% reduction allowable.



Note: $y = \frac{-3x}{2} + 55$ for U.S. Customary Units

Note: $y = -4.8x + 54.6$ for S.I. Units

For ceiling height ≥10 ft and ≤20 ft, $y = \frac{-3x}{2} + 55$

For ceiling height <10 ft, $y = 40$

For ceiling height >20, $y = 0$

For SI units, 1 ft = 0.31 m.

FIGURE 11.2.3.2.3.1 *Design Area Reduction for Quick-Response Sprinklers.*

Figure 20 - Quick Response Sprinkler Reduction

Remote area 6-3 has the most demanding sprinkler design when hydraulically calculated out to the discharge of the fire pump. Remote Area 6-2 reflects the most demanding corridor section, with a base of riser (BOR) of 113 GPM at 34.5 psi. The design area of five sprinklers was used per NFPA 13, Section A.8.1.

The sprinkler designers did not indicate if the general storage areas were accounted for in their design. An investigation should be conducted to find out what commodities are being stored in the storage rooms, and in what configuration to ensure that adequate protection is provided in the storage areas. Since the room sizes of the storage areas would be small and since the sprinkler design has a significant safety cushion, it is likely that the areas will be adequately protected. If not, it could be possible to increase the sprinkler head sizes in the storage areas to provide a higher level of protection.

A higher temperature heads were used in the fire pump room and main electrical room but a hydraulic analysis was not performed for these areas that require a OH-1 level protection to ensure they are properly protected. Based on the proximity of the main mechanical room and the water density that is available on the first floor in the lecture halls, it is likely that more than adequate protection is avaible for the entire room.

HAND CALCULATION SUMMARY

A sample friction loss calculation was performed for design area 1-1 (See attached hand calculations in Appendix H). This system is slightly different from the typical hand calculation model, because the system utilizes head drops rather than a riser nipple and an elevated branchline with sprinklers on sprigs. To approximate the system two simplifications were made. The first was to model the system as heads on a dropped branchline, rather than heads dropped from an elevated branchline and main, and the second was to give all the branchlines the same drop distance. The most remote branch line in the system has a different drop length but it is not expected to have a significant impact on the model, since an equal elevation change occurs when the drops from the sprinkler and the change in election of the crossmain is considered.

The hand calculations used the Hazen-Williams formula to determine the friction loss in the pipe per ft. The equation is listed as Equation 23.4.2.1.1 in NFPA 13, and included below as equation 3:

$$p = \frac{4.25 * Q^{1.85}}{C^{1.85} * d^{4.87}}$$

Where:

p = friction loss in pipe [psi/ft.]

Q = flow [gpm]

C = friction loss coefficient of pipe

d = inner diameter of pipe

Equation 3- The Hazen-Williams formula.

A C-factor of 120 was used for all pipes and the internal diameter of the Schedule 40 1 in. pipe and Schedule 10 2½ in. and 3 in. pipe was used. The flowing fixed friction losses, in Table 11, were used for the system, including a 61 psi drop for the pressure reducing valve at the base of riser #1.

Table 11- Fittings Equivalent Length

Fitting Symbol	Fitting	1 in. [ft.]	2½ in. [ft.]	3 in. [ft.]
T	90° Flow Thru Tee	5	10	15
H	45° Elbow	1	3	3
E	90° Standard Elbow	2	6	7

The resultant base of riser demand for design area 1-1 was 248.4 gpm at 131.1 psi.

COMPUTER SIMULATION MODEL AND COMPARISON

The sprinkler designers used design analysis software from Hyratec Inc. for their hydraulic analysis. This system uses a nodal approach to the hydraulic analysis which is slightly different than the manual calculation method. This method is preferable to the hand calculation method for this building, because the remainder of the design areas have a sprinkler layouts that would be particularly difficult for hand calculations due to varying sprinkler heights, and coverage areas. The computer model also uses slightly different pipe lengths and fittings loss figures.

A second computer simulation was completed using SprinkCalc III, for hydraulic demand area 6-4, since it was determined to be the most demanding hydraulic area. The diagram of the model can be seen below in Figure 21. The model resulted in a demand of 456 gpm @ 149 psi, effective at the discharge of the fire pump. The results are 2% greater and 7.2% less for flow and pressure, respectively, than the hydraulic model generated by the contractor. The model also predicted a 10.2 psi safety margin compared to the 13.6 psi safety margin that the contractor model predicted. Additional details for the computer model are included in Appendix H.

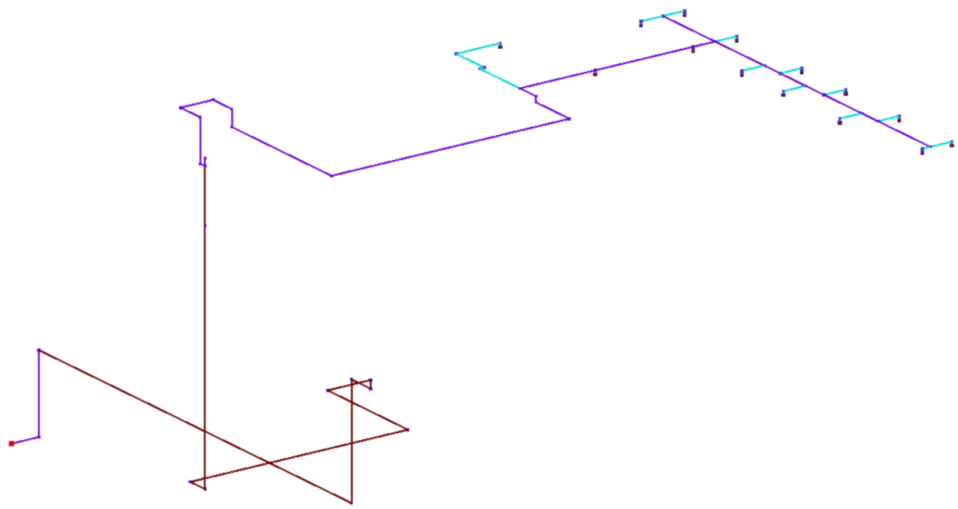


Figure 21 - SprinkCalc Hydraulic Model

The differences in flow and pressure between the two models is expected to be due to small differences in pipe length and less fittings in this report's computer simulated model than in the contractor computer model.

The hand calculations for the design areas on the first level (The second demanding design area) resulted in much closer results to the contractor computer model. There was a difference of 0.88% and 3.49% design area 1-1 between the hand calculations and the computer simulation for flow and pressure, respectively. Differences in the pressure value is likely due to the simplifying assumption that there is one drop for the entire branchline, rather than a drop per head. This resulted in a greater flow in the single drop, which has likely contributed to the higher pressure drop result.

Inspection Testing and Maintenance

CODE COMPLIANCE

NPFA 13 Section 21.7 indicates that all sprinkler systems should be inspected, tested and maintained per the guidance in NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based, Fire Protection Systems*. The NFPA 13, 2016 Handbook indicates that since there may be multiple editions of NFPA 25 that that an owner must comply, and since this building was built to the 2007 NFPA 13 code, they should follow the 2002 edition of NFPA 25, at a minimum per Section 27.1 and Section 2.2. However, since this review is based on the 2016 edition of NFPA 13, and since the majority of code requirements are typically retroactive, the 2014 edition of NFPA will be used. Table A.27.1 from NFPA 13 has been included in Appendix D, which included some maintenance schedules that are required by NFPA 13.

INSPECTION, TESTING AND MAINTENANCE INTERVALS

NFPA 25 provides inspection, testing and maintenance for all aspects of the sprinkler system. Chapter 5 details the inspection intervals for sprinklers and Chapter 8 details the interval for electric fire pumps. The full inspection, testing and maintenance tables for sprinklers and fire pumps are included in Appendix D, a highlighted summary is provided in Table 12 below.

Table 12 - Highlight of some inspection intervals

Frequency	Component	Action	Reference (NFPA 25)
Weekly	Fire Pump System	Inspect	8.2.2
	Electric Fire Pump*	No-Flow Test	8.3.1.2
	Control Valves (Sealed)	Inspect	NFPA 13 A.27.1
Monthly	Fire Department Connection	Inspect	NFPA 13 A.27.1
	Control Valves (locked/tamper)	Inspect	NFPA 13 A.27.1
Quarterly	Waterflow Alarm Devices	Inspect	5.2.5
	Valve Supervisory devices	Inspect	5.2.5
	Gauges	Inspect	5.2.4.1
	Hydraulic Nameplate	Inspect	5.2.6
	Mechanical Waterflow Devices	Test	5.3.3.1
	Pressure Reducing Valve	Test	Manufacturer
Annually	Sprinklers	Inspect	5.2.1
	Spare Sprinklers	Inspect	5.2.1.4
	Electric Fire Pump	Full-Flow Test	8.3.3
	Fire Pump Components	Maintenance	8.5
	Control Valves	Testing	13.3.3.1
	Control Valves	Maintenance	13.3.4
	Backflow Assemblies	Test	13.6.2
	Main Drain	Test	13.2.5,13.2.5.1,13.3.3.4

INSPECTION TESTING AND MAINTENANCE

A weekly fire pump testing interval was used rather than the more typical monthly testing interval for electric fire pumps. This interval was used per NFPA 25, 8.3.1.2.1 (4), since the university water supply is not expected to be able to provide sufficient pressure to be of material value without the pump.

SUMMARY

The sprinkler protection for the building was designed and installed per NFPA 13, and is expected to provide adequate sprinkler protection based on the information available. Since the building is now occupied, routine inspections of the building contents should be completed to ensure that items stored in the building can still be adequately protected. A separate hydraulic model and hand calculations were developed to verify the sprinkler analysis completed at the time of construction, which was found to be valid.

PRESCRIPTIVE ANALYSIS SUMMARY

The majority of the building design still meets current codes and standards. The buildings structural design meets the requirements in the IBC and LSC, and incorporates separations to limit the damages from fires. The occupancy classification of the building has been appropriately classified per the IBC and LSC. The fire alarm system has been installed appropriately, and meets the requirements from the LSC and IBC, and the fire protection system has been installed to meet requirements of NFPA 13.

The only areas of issue are regarding the egress design of the building. There is inadequate egress capacity, and unacceptable common path distances on the third level, and unacceptable dead end distances on the first level. There are also two assembly use rooms on the third level that require two means of egress from the room, but are only provided with one.

Performance Based Analysis

The LSC allows for a performance-based approach for the life safety design of the building. Section 5.1 details the requirement of the application, documentation, and verification of the method, and 5.2 details the performance objectives of the design. This section suggest four different objective methods for which Method 1 is applied for this report. LSC A.5.2.2, Method 1 states:

"The design team can set detailed performance criteria that ensures that occupants are not incapacitated by the fire effects."

In other words, the objective and requirement of this method is to ensure that all the occupants are evacuated from the building spaces prior to an untenable environment. The application of this method would require both the modeling of the fire growth, smoke spread with a focus on the toxic gas levels and the occupant egress paths and progress over time. Occupant characteristics would need to be considered to develop appropriate egress time estimations. This method, while more intensive that the other methods, would allow for the most flexible building design. This method is expected to be more applicable to this building since the characteristics of the occupants are known, or at least easily obtained, and it is not likely to change significantly over time.

Other methods that solely focuses on smoke level, rather than occupant characteristics, would likely result in more costly and restrictive construction and would be more applicable to varying occupant characteristics, or less favorable characteristics that require extended egress times, such as a high percentage of infirm or disabled occupants.

A similar performance based approach, discussed earlier in this report, has already been developed during building construction, for the central atrium smoke control design. This design followed requirements in section 909 of the CBC/IBC and used available information prior to the building's construction. This performance based analysis will use some of the requirements for tenability that are indicated in the IBC, but will focus on requirements in the LSC, and suggested levels of tenability in the SFPE Handbook. Fire models and occupant characteristics, discussed in the next sections, will be based on existing building and available information.

Fire Scenario

DESIGN FIRES

As discussed in earlier, this building is comprised of mainly classrooms, instructional laboratories and offices, which fall under Business occupancy use. There are a few lecture halls that fall into the assembly occupancy use per the IBC and LSC. Mr. Richard Campbell with the National Fire Protection Association (NFPA) Fire Analysis and Research Division generated a report that studied structure fires from 2001-2007 in the US. His report, *Structure Fires in Educational Properties,* published in *September* 2013, analyzed 700 structure fires, specifically in college classroom buildings and adult education centers. The report indicated that 51% of the fires resulted from cooking equipment, 10 % from arson, 8% from heating equipment, 5% from smoking materials and 5% from electrical distribution and lighting equipment. Figure 22, below is a chart of Mr. Campbell's findings, with the remaining causes not mentioned in his report marked as other.

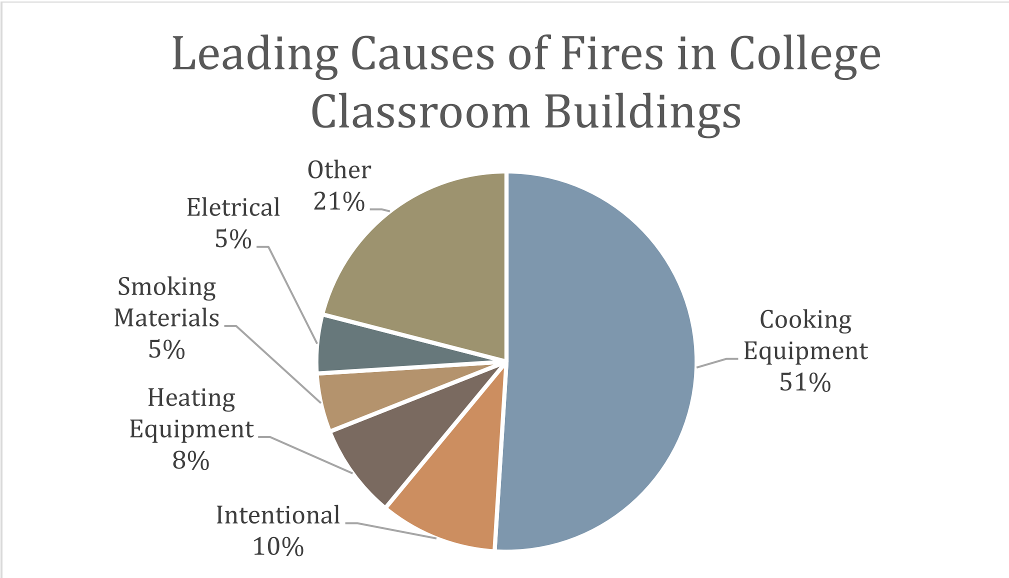


Figure 22 - Leading Casus of Fires in College Classrooms

Mr. Campbell's report also indicated that the cooking equipment fires accounted for only 2% of the property damage, whereas the intentionally set fires contributed to 10% of the direct property damage. The report also indicated that of the 700 fires, 31% originated in a kitchen, 7% in a bathroom, 6% in a Hallway, 3% in a Hallway, Office, or unclassified area. All other areas had 2% or less average area of occurrence.

FIRE SCENARIO

Looking at the report, cooking fires in a kitchen is by far the most common cause and location for a fire, but this building has not been specified with a dedicated cooking area. For this reason, and because it represented a higher portion of the total property damage, arson is expected to be the most likely cause for a fire in this building. Reviewing the fire point of origin information, the bathroom, laboratory, or hallway has the highest number of occurrence, once the kitchen is eliminated.

An arson related bathroom fire would be an acceptable fire scenario selection, however, a fire in this area is expected to be relatively minor due to the noncombustible nature of a bathroom, and the 2-hour rated walls provided. Additionally, this area is provided with a duct smoke detector above, and automatic sprinkler detection at the ceiling. A fire in this area is not expected to challenge the tenability of the building without additional contributing factors, such as smoke detection and sprinkler impairment.

An arson related fire in a laboratory would also be an acceptable fire scenario, and is one that should be investigated. The model could utilize full scale fire testing of wood furniture and the plastic and upholstered student chairs for modeling the heat release rate (HRR) curve for the fire. Details on materials would also need to be considered to evaluate for fire spread, but due to the presence of automatic sprinkler protection, an out of control fire is not expected for this fire scenario. For this reason, and due to the lack of specific modeling data available, this fire scenario was not used for this report.

The selected fire scenario, is an arson related fire started in the hallway of the central atrium, that involves the upholstered couches (See Figure 23 below). This scenario is in an area that is not provided with sprinkler protection, and is expected to present a challenge to the building's tenability due to the atrium's naturally ventilated smoke control system.

Figure 23 - Performance Based Analysis Fire Location

FIRE SCENARIO

The three cushion couches are manufactured by Coalesse Design Studio and utilize a TB 117, polyurethane foam cushion and polyester fabric. These couches do not indicate that they adhere to the requirements of TB133. The couches are 7.7 ft. long, 2.9 ft. wide, and 2.4 ft. tall. The frame of the couch is assumed wood frame. The expected fire development is following the ignition of one of the couches, that at least one of the adjacent couches will able become involved in the fire, adding to less tenability. FDS has been used to model the selected scenario, and discussed later in this report.

As noted earlier, the Cal Poly Campus is potentially used during the summer for high school aged students. Campbell's report also investigated 4,060 structure fires in nursery through high school, which found that 49% of fires resulted from intentionally set fires. This information seems to further justify the reasoning that arson would be an appropriate cause for the fire scenario.

Evacuation (RSET)

OCCUPANT CHARACTERISTICS

The performance based assessment to determine the required safe egress time (REST) can be broken into several time groups that include fire detection time, alarm time, pre-movement time and movement time See Figure 24, below). Detection and alarm time can be influenced by the installation of sprinklers, and alarm devices. Movement time can be estimated using hydraulic analysis, but must make specific assumptions of the building occupant characteristics to help develop the movement model. Pre-movement times are also difficult to determine since it is an attempt to predict the amount of time a human being will take to react to a fire scenario.

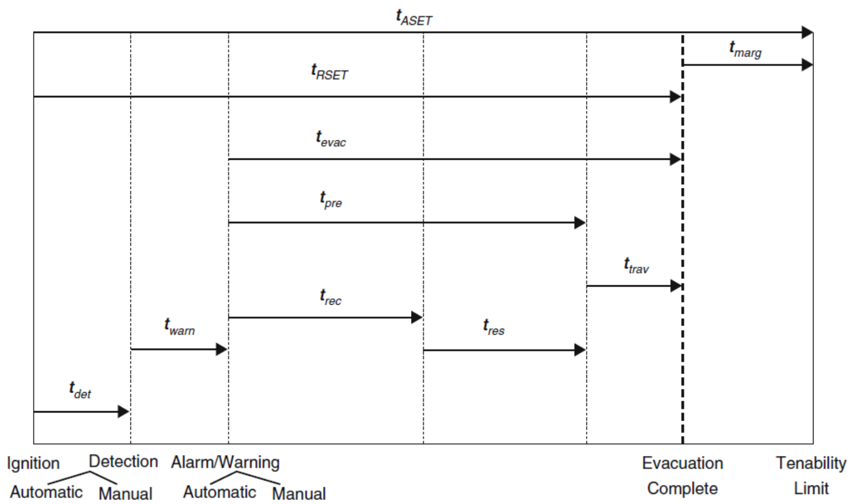


Figure 24 - RSET vs. ASET

Ms. Guylène Proulx further defines the pre-movement time in her SFPE Chapter (SFPE-4 Chapter 3-12) into the recognition time and response time, where the recognition time is explained as follows:

> "The interval between the time at which the alarm signal is perceived and the time at which the occupant interprets the signal as indicating a fire/emergency event. This time includes the investigation and milling, for example to determine the situation."

The Response time is described as:

> "the interval between recognition time and the time at which the first move is made to evacuate the building. This time includes activities such as firefighting , warning others, gathering family members and pets, dressing, retrieving personal belongings, call the fire department and so on."

EVACUATION (RSET)

Mr. John Bryan did extensive research over the last 40 years and complied data on many of the fire events to study the actions that people took during actual fire events. These events are discussed in detail in his SFPE chapter (SFPE-4 Chapter 3-11). This data can be used to compare derived movement times and help to develop pre-movement times, however the first step in developing the pre-movement scenario is to identify the occupant characteristics and determine its impact on egress.

Some of the more salient occupant characteristics that would likely affect this building are as follows:

Age/Experience: College Factual.com has indicated that 94.8% of the students at Cal Poly are ages 18-24. Since most of the occupants are younger, they could be expected to be react quicker due to peak health and alertness, and almost all are expected to be ambulatory. This occupant characteristic should reduce the movement time and could reduce some of the response time, but, since these students are younger, is it possible that they do not have life experiences that could help to reduce the recognition time of the fire. The lack of experience with emergency situations could have a very strong impact on the pre-movement time due to uncertainty. Lastly, since they are students have been trained since kindergarten to listen to instruction from teachers, they might not react until given guidance from the professor.

Physical Capabilities: Again, since this building is expected to have young occupants, it is expected that the clear majority of the students will be ambulatory, since they could get themselves to class. This physical ability would have a direct reduction in the movement time.

Familiarity: Since most students are in these classrooms at least twice a week, it is expected that they will be at least familiar with the floor that they attend and the entrance or exit that they have used. It is likely that they will utilize the closest means of ingress/egress. This behavior should help to reduce the movement time since they will be familiar with at least one egress route. In addition, due to this familiarity, it is more likely that they will be willing to move towards that egress, thus reducing the response time.

If the professors have completed fire drills and, are aware of the fastest and safest egress route from their classroom, then the the movement time and response time could further be reduced. The training of teachers would be an excellent tool for reducing the pre-movement and movement times.

Density: Since this building has primarily offices and labs, the overall destiny is rather low compared to other occupancies such as stadiums and halls. The reduced density should allow for the maximum egress flow out of the building, reducing the movement time.

Commitment: Students and teachers do not have an innate commitment to the lecture or items in the classroom (other than their personal items). This occupant characteristic is in contrast to a family in an apartment building, where there might be children, pets and family heirlooms or in a movie theater where people might not want to get up and miss a part of the movie that they paid for. The lack of commitment to the task should help to reduce the response time and movement time.

Alertness: It is expected that most students will be fully alert and awake during their lecture or lab work and will be able to respond and react quicker than if they were asleep. This characteristic should help to reduce both the recognition and response time.

False Alarms: Although false alarms are more a building characteristic, regular false alarms could contribute to the pre-movement time, by influencing the occupant. If false alarms are common in a building, it is likely that the occupants could become complacent to the fire alarm and simply ignore the alarm. This complacent occupant behavior could require an additional alert of some type (smoke/fire/secondary information) to illicit a response, delaying the pre-movement time significantly.

Groups: Since the classrooms will likely respond at a similar time, decent sized groups would be expected, and it is probable that all the students in single area would leave at the same time. If there are stragglers, along the group's path, that are not sure how to proceed, they might be encouraged to move with the group. It could also be argued that the response time could be delayed if there is a preemptive effort to assemble the group prior to movement.

PRE-MOVEMENT TIMES

Since this building is sprinkler protected and is equipped with smoke detection, the detection and alarm times for a fire are expected to be very short. NFPA requires a 90-second alarm activation with sprinkler flow, and this building utilizes smoke detection throughout, so detection and alarm times are not expected to be long.

Table 3-11.14 from Mr. John Bryan's chapter in the SFPE Handbook (SFPE-4 Chapter 3-11) indicates that the highest percentage of people first notified others in a fire event, and then left the building. For our occupancy and occupants, I think that this occupant behavior would fit, and expect the alert, able students to announce the plan to evacuate and move. Based on the above occupancy factors, it would be reasonable to compare the pre-movement times to the estimated times for mid-rise office times that are presented by Ms. Guylène Proulx's SFPE chapter (SFPE-4 Chapter 3-12), Table 3-12.2. The physical characteristics of the test building is expected to be similar, since the spaces in an office building are similar to professor offices and smaller classrooms. In addition, since these times were from an unannounced drill, and they had good alarm performance, it is reasonable to relate these response times to our NFPA alarm system. It is also assumed that the occupants in the test have a similar level of alertness, commitment and familiarity with the building as the students in the classroom. Both mid-rise office evacuations had office wardens, which would parallel the role of the professor in our scenario.

The mean delay time was 0.6 min. and 1.1 min. for a warm and cold day respectively. The third quartile and max times for the tests was 0.8 min. and 1.4 min. and <4min and <5min for the two test respectively. One differences in occupant characteristics could be the overall density of the building. The Lab and Lecture Halls will have more students than that of an office building. It is expected that the increased density in some areas could increase the movement time, but it is expected to have less of an effect on the pre-movement time.

EVACUATION (RSET)

EXIT TIME HAND CALCULATION AND DISCUSSION

The movement time calculation utilizes the basic hydraulic model for an estimation of travel time out of the building. This model uses several specific assumptions to be able to apply the model and has certain limitations. The following is a list of assumptions used:

1. All occupants start to move at the same instant. Studies of past fires have shown that there is a range in responses by individuals in both the response and recognition so the actual time will likely be longer than the calculated result.
2. The Occupants use the ideal exit distribution and equally distribute to the exit stairs. This occupant distribution is the most optimistic approach for egress movement and will underestimate the result.
3. All the occupants move at the same speed in the same direction without any interruptions, impairments or disabilities. This assumption is an optimistic approach for egress movement and will underestimate the result. In actual scenarios, it is expected that people will move at different speeds at different times and may choose to change directions as the situation demands.
4. The prime controlling factor in the model is assumed be the exit door discharging from the stairway exit for the interior stairs. Since the doorways at the bottom of the stairwells effectively chokes the stairwell flow, queuing is expected behind the door and the door is expected to see its maximum specific flow.
5. The maximum specific flow and density through the door is expected to the same for all occupants. Again, this assumption is a simplifying generalization and will not be accurate for all people. The values for flow and density approximates range of the anticipated flow through the doors and stairs.
6. All occupants will be at the point of floor egress at the start of the moment time. This point is an assumption of efficient evacuation, and it is expected that the time needed to get to the point of egress would be smaller than the movement time.

Effective width reductions have been used per Table 3-13.1 and Figure 3-15.5 from the SFPE handbook, 4th edition. The exit stairs have 1.5 in. diameter handrails that extend 1.5 in. out from the wall; however, the standard six inches. reduction from each side results in a less effective width. Since all the stairs have been defined by their clear width, rather than the nominal stair width, six inch was added to the reported clear width and then reduced by the 12-in. effective reduction for size. The stairs have 11 in. tread depth with riser heights that vary, but do not exceed seven inches. Floor height is 16 ft. with a landing in the middle. A riser height of 7 in. was used in the calculation as a conservative estimate. Equation 4 was used to determine the calculated flow. Since the landings of the stairwells for Stairs 1, 4 and 5 are irregular in shape an estimate was made based on the information provided from the stair details (Appendix C). Table 13 summarizes the exit stair and doors for each level.

Table 13 - Flow Seeds for Specified Exits

Exit	Clear Width [in.]	Effective Width [ft.]	Specific Flow, F_s [persons/min/ft.]	Calculated Flow, F_c [persons/min]	Between floors distance [ft.]
D1	36	2.0	24	48.0	-
D3	36	2.0	24	48.0	-
D4	36	2.0	24	48.0	-
D5	36	2.0	24	48.0	-
S1	47	3.4	14.05	48.0	54.1
S3	44	3.2	15.16	48.0	47.6
S4	47	3.4	14.05	48.0	46.2
S5	47	3.4	14.05	48.0	61.31
1.1	216	17.0	24	235.0	-
1.2	96	7.0	24	168.0	-
2.1	144	11.0	24	235.0	-
2.2	144	11.0	24	235.0	-
2.3	72	5.0	24	120.0	-
2.4	72	5.0	24	120.0	-

$$F_c = F_s W_e$$

Equation 4- Calculated Flow Speed

The first step in the movement time estimation is to calculate the time that it would take for the occupants to exit the floor into the stairwells. As stated earlier, it is assumed that all occupants will immediately be waiting at the floor egress point entrance, so no time will be added to get to the egress point for the individual run of the movement time estimation.

The egress capability of the stair alone is greater than the door, so only the door will need to be considered for the first step, and the maximum specific flow for the door will be used per Table 3-13.5 SFPE since there is assumed that there is que at the door. As a first order approximation, each floor will be considered individually. Table 14 summarizes the results from this first order approximation.

Table 14 - Individual floor egress times

	Time to exit floor [min]	Time to reach ground floor [min]	Additional time to Complete Egress [min]	Total Time for Egress [min]
Level 1	0.98	0.00	0	0.98
Level 2	0.74	1.02	1.33	3.09

Level 3	3.56	2.99	6.96	13.51
Level 4	3.19	3.23	6.30	12.72
Level 5	2.81	2.88	2.81	8.51
Level 6	2.61	3.84	2.61	9.06

Table 14 also indicates that the first and second level will already be evacuated, or very close to evacuated by the time that the third level has entered the stairs, so these floors will not be considered in the exit analysis further. Only Stairs 1 and 3 connect all the upper levels and Stair #3 would be the limiting stairway due to its smaller effective width.

The second step would be to calculate the transitional flow from the door into the stairs. Equation 5 is used to determine the specific flow of the stairs.

$$F_{s(stair)} = \frac{F_{s(door)} W_{e(door)}}{W_{e(stair)}}$$

Equation 5 - Transitional Flow Equation

With a specific flow of 15.16 persons/min. /ft., Equation 6 can be used to solve for the density in the stairway, where a= 2.86 and k=212 per Table 3-13.2 SFPE.

$$F_s = (1 - aD) * kD$$

Equation 6 - Specific Flow Equation

The calculated starting density for Stair #3 is 0.100. The density can then be used to determine the speed in the stairs, using Equation 7.

$$S = k - akD$$

Equation 7 - Linear Speed Equation

The speed in the first movement step would be 151.4 ft. /min. With a floor-to-floor travel distance of 47.6 ft. the time to travel to the next floor would be 0.31 min. At 0.31 minutes 15 people would have entered Stair 3 at levels three through 6, with the calculated flow of 48.0 people/min, for a total of 60 people in the stairway.

We then would need to merge the incoming flow from the doorways with the flow in the stairwell using Equation 3 modifying it for two flows into Equation 8.

$$F_{s(out-stair)} = \frac{\left(F_{s\,(in-door} * W_{e\,(in-door)}\right) + \left(F_{s\,(in-stair)} * W_{e\,(in-stair)}\right)}{W_{e\,(out-stair)}}$$

Equation 8 - Merging Flow Equation

The resulting stair specific flow would be 30.16 persons/min/ft., however, this specific flow rate is in excess of the maximum flow rate for stairs per Table 3-13.5, so the stair flowrate will be reduced to the maximum, 18.5 persons persons/min./ft. This specific flow gives us a calculated flow rate of 37 people/min. Using Equation 4 again to determine density (0.168 people/ft.) and then speed (110.1 ft./min.) in the stairwell. At this new speed, the rate of decent will be 0.43 minutes per floor.

The next step is to empty the remaining occupants from their floors that are waiting at the exit door, one level at a time starting with the sixth level. With 15 occupants from each floor in the stairwell each floor has a different number of occupants waiting to enter, due to the different number of occupants and exits on each floor. The number of occupants that are assumed to use Exit stair 3 is based on the exit number ratio that was developed by the life safety engineer. Exit Stair 3 accounts for 50% off occupants on the fifth and sixth level and 31.5% on the fourth level and 25.5% on the third level. The remaining occupants waiting to get into Exit Stair 3 at 0.31 minutes would be 110, 116, 148, and 172 on the sixth, fifth, fourth and third level respectively.

Using Equation 9, below, we can track the egress time to evacuate the third through the sixth level. Table 15 summarizes the times when each floor is evacuated to the lower floor.

$$t_p = \frac{People}{F_c} + travel\ time\ between\ floors$$

Equation 9 - Travel Time Equation

Table 15 - Hand Calculations Evacuation Time via Exit Stair 3

Level	Evacuation Time [min]
Level 6	3.71
Level 5	7.28
Level 4	11.71
Level 3	16.79

Since Exit Stair 3 does not exit directly outside, there would be some extra time needed for the occupants to move from the stair exit to the south atrium door. If they are traveling at the same speed as in the stairwell, then it is expected to add 0.63 minutes for a total movement time of 17.4 minutes.

Several limitations are present in this model, that were noted in the assumption or in the analysis portion, but the biggest drawbacks of the hydraulic modeling method is the assignment of single values to represent a range of individual occupants characteristics and the inability of the model to predict human decision. The model assumes that the occupants will egress in an orderly fashion, by the numbers, and patiently wait in line to enter the exit, but this seems to be overly optimistic. This hand calculation represents is considered to be the most 'economical' model. It is likely that the occupants will enter the stairwell simultaneously, and when a backup is created, it is possible that some occupants will leave the area to find another means of egress. The result of this unpredictable behavior is likely to extend the length of the egress, but is difficult to model. Newer computer models are available that attempt to mitigate some of the drawbacks of the assumptions of the model, including assigning individual movement speeds to different types of individuals that better matches the blend of occupant characteristics.

EGRESS COMPUTER MODELING

A Pathfinder model was developed using the architectural plans and occupant load distribution based on the room use and area per room. As indicated earlier in this report, there are some differences in loading for each floor from the original life safety plan, due to differences in room area and current use. The Pathfinder model, Figures 25 and 26 below, covers only the 2nd though the 6th level. Some exits on the 2nd level, such as the back door exit to room 261, have been closed to force occupants to follow the direction of the exit signage in particular rooms and halls.

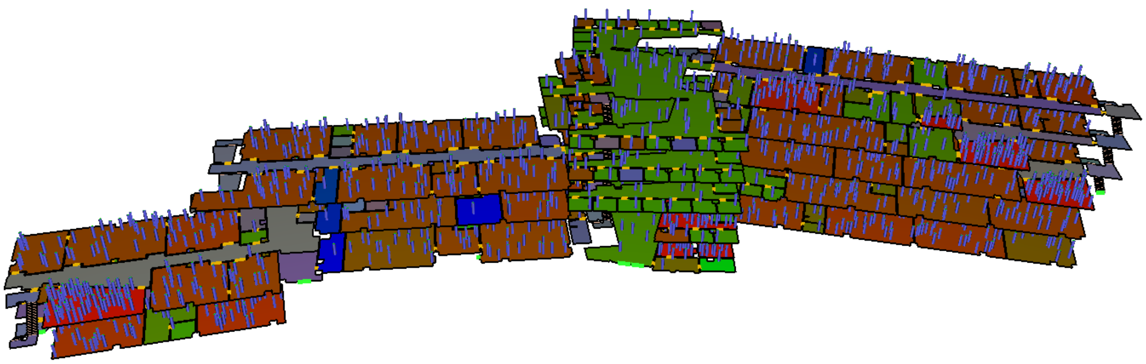


Figure 25 - Pathfinder Model, Facing North

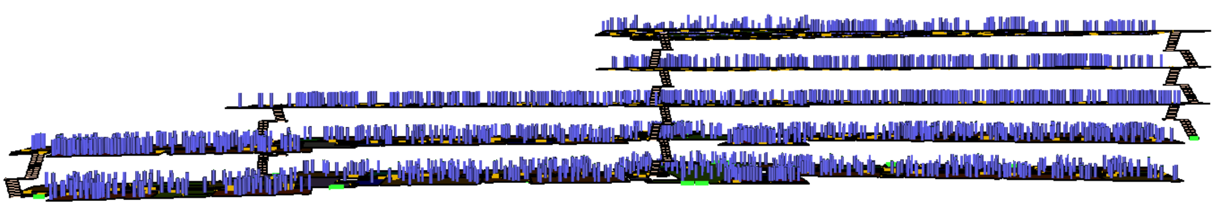


Figure 26 - Pathfinder Model South Elevation, Facing North.

The original life safety design, and the atrium smoke control study completed by ARUP, utilizes the horizontal exits that separate the west and east wing from the central atrium in addition to Exit Stair 3 as means of exit for the building. This method does not account for occupants that might be traveling from the wings into the atrium space attempting to egress. This methodology is arguably acceptable, since the doors are expected to close once the alarm sounds; however, the exit signage is still expected to attract occupants to the interior stair (Exit Stair 3), so the Pathfinder model for this report allows for occupant travel into the atrium from the wings for egress.

College Factual, a college statistics website studied 20,149 Cal Poly San Luis Obispo Students, and found that 94.8 % were ages 18-24 years old. The remaining 5.2% were 25 years old and over. CSU Mentor,

another college statics website, indicated the average student age at Cal Poly is 20 years old and that the student population is approximately 47% female. Wong and Cheung conducted videotaped evacuation, which included 44 college students aged 20-24 years old, approximately 34% female. The average walking speed observed on a horizontal surface was 4.3 ft. /s. [1.3 m/s], along a 55-ft. long corridor [SFPE-5 Table 64.15]. The observed average walking speed from this study is used in the Pathfinder model based on the similarities to this building occupancy. An average of the traditional walking speed, 4.1 ft./s. in a walkway and 3.6 ft./s. on stairs [SFPE-4, 3-12], was used for the remaining median aged occupants.

Data on disabled students at Cal Poly was not readily available so information from Chapter 3-12 of the SFPE handbook was used to estimate the percentage of disabled students, and their walking speeds. Ms. Guylène Proulx indicates, in her SFPE chapter, that the 2005 American Community Survey from the U.S. Census Bureau estimated that 14.9 % of Americans, five years and older, had some level of disability. Table 3-12.4 of the SFPE handbook indicates that the mean speed for all disabled occupants in testing, was 3.28 ft./s. with a standard deviation of 1.38 ft./s. An occupant distribution of 14.9% disabled, with walking speed of 1.9 ft./s. was used in this model. This speed accounts for 84% (one standard deviation from the mean) of the recorded walking speeds on a horizontal surface in Table 3-12.4 [SFPE-4].

Since the FDS Fire model uses a fire scenario that is located at the south end of the central atrium, a second Pathfinder scenario was completed with south atrium doors removed as an avenue for egress. Table 16 summarizes the time needed to evacuate each floor of the central atrium for both models. Total egress travel of the central atrium, and the building, was predicted at 10.5 minutes (~632 seconds) for both Pathfinder models. The 10.5 minute travel time is based on the time when the last occupant reaches the north atrium exit, Exit 2.1. The times indicated in Table 16 are when the last occupant for each floor enters Exit Stair 3.

Table 16- Pathfinder Model Evacuation Time via Exit Stair 3

Evacuation Time per Level [min]		
Level	Both Doors Open	South Doors Closed
Level 6	6.67	6.5
Level 5	5.67	5.75
Level 4	3.3	3.21
Level 3	2.47	2.61

The removal of the south atrium doors for egress resulted in additional queuing in the Pathfinder model at Exit Stair 3. Once the crowds became large enough, several occupants left the area, and moved to another exit. The overall result was slightly less egress times on all the upper levels except level five. This occupant behavior is based on the default occupant behavior in the Pathfinder model. Further investigation will be needed for verification of this occupant behavior, and to determine if this this behavior is appropriate.

EVACUATION (RSET)

The FDS model, discussed in the next section, indicated a detection time of 22.5 seconds (0.4 minutes). Including the pre-movement time of 1.1 minutes, discussed above, the RSET for both Pathfinder models is 12 minutes.

Tenability Analysis

VISIBILITY

The SFPE handbook discusses the findings of several fire events, and proposes a tenability limit for visibility of 32.2 ft. for large enclosures, and 16.4 ft. for small enclosures. For our building, the tenability limit of 32.2 ft. is expected to be applicable for the atrium space. These suggested visibility limits are derived using the concept of fractional effective concentration (FEC_{smoke}) using the smoke optical density per unit length, OD/m or D_u. The extinction coefficient is derived as the base 10 log of ratio of the initial intensity of a light beam that would meet a person's eye, or photocell in a detector, against the intensity of the light beam in the presence of smoke. See equations 11 and 10 below, for the equations for FEC_{smoke} and the extinction coefficient.

$$OD/_{m} = -log_{10}\left(\frac{I}{I_o}\right) m^{-1}$$

Equation 10 – Extinction Coefficient, Optical Density per unit distance

$$FEC_{smoke} = \frac{OD/_{m}}{0.2}, \qquad for\ small\ enclosures$$

$$FEC_{smoke} = \frac{OD/_{m}}{0.08}, \qquad for\ large\ enclosures$$

Equation 11 – Fractional effective concentration for small and large enclosures

In the above equations, I_o, is the intensity of light transmitted without smoke obstruction, and, I, is the intensity of the light transmitted in the presence of smoke obscuration.

FRACTIONAL EFFECTIVE DOSE

A discussion of tenability, and specifically the factional effective dose (FED) method, is discussed in length in Mr. David A. Purser's SFPE chapter (SFPE-4 Chapter 2-6). The goal of this chapter is to determine the effects from the fire's toxic gases on an occupant and to try to determine when they reach a level that will result in incapacitation or death. The FED method is a way to consider all the different asphyxiant and irritant gasses as a mixture to determine the combined effect. Several assumptions and simplifications have been made to approximate results that must be considered when applying the FED method for determining tenability.

Purser provides the equation for determining the FED for incapacitating dose for all asphyxiant gases (Eq 21 in SFPE-4):

$$F_{IN} = \left[\left(F_{I_{CO}} + F_{I_{CN}} + F_{I_{NO_x}} + FLD_{irr}\right) * VCO_2 + FED_{I_o}\right] \; or \; F_{I_{CO_2}}$$

Where

$F_{IN} = Fraction\ of\ an\ incapacitation\ dose\ of\ all\ asphyxiant\ gases$

$F_{I_{CO}} = Fraction\ of\ incapacitating\ dose\ of\ CO$

$F_{I_{CN}} = Fraction\ of\ incapacitating\ dose\ of\ HCN\ (and\ nitrilesm\ corrected\ for\ NO_2)$

$F_{I_{NO_x}} = Fraction\ of\ incapacitating\ dose\ of\ NO + NO_2\ (= [NO_x\ ppm\ x\ t_{min}]/1500$

$FLD_{irr} = \ Fraction\ of\ irritanr\ dose\ contributing\ to\ hypoxia$

$VCO_2 = Multiplication\ factor\ for\ CO_2 - induced\ hyperventalation$

$FED_{I_o} = Fraction\ of\ incapacitation\ dose\ of\ low - oxygen\ hypoxia$

$F_{I_{CO_2}} = Fraction\ of\ incapacitating\ dose\ of\ CO_2$

Equation 12 - Purser's FED Equation

The procedure for determining the point of untenable conditions in time is to take the derivative of Purser's equation (Equation 12) and complete a numerical analysis based on the fire and smoke model. For our building, we have chosen a moderately sized person that is undergoing light work, such as proceeding in egress, and used the appropriate correlations suggested in Purser's chapter to determine the approximate FED of CO over time. Choosing a smaller person could be more conservative since the %COhb in a person's system is correlated with their mass, and the ventilation rate would be reasonable. Purser gives some suggestion as a starting point for the ventilation rate and incapacitating dose of CO (%COHb) based on a 154 lb. (70 kg) person undergoing different levels of activity. For our model, the fractional incapacitating dose for hydrogen cyanide, $F_{I_{CN}}$, and factional incapacitating dose for nitrous oxide, $F_{I_{NO_x}}$ was omitted for simplicity. Purser indicates that the direct asphyxiant effects of NO_x and HCN can be ignored for a simple analysis without significant error [SFPE-4].

The fractional incapacitating dose for carbon dioxide, $F_{I_{CO}}$, predicts the %COHb concentration in using Equation 13 below.

$$F_{I_{CO}} = \frac{3.317\ x\ 10^{-5}[CO]^{1.036}(V)(t)}{D}$$

Where

$F_{I_{CO}} = Fraction\ of\ incapacitating\ dose\ of\ CO$

$[CO] = Carbon\ monoxide\ concentration\ [ppm]$

$$V = Volume\ of\ air\ breathed\ each\ minute\ \left[{}^{L}/_{min}\right]$$

$$D = \ Exposure\ dose\ for\ incapacitiation\ [\%\ COHb]$$

Equation 13 - Purser's Factional Incapacitating Dose of CO

Purser suggests a value of 25 L/min and 30% for the volume of air breathed and exposure dose for incapacitation, respectively, when undergoing light work, such as walking for egress.

Concentrations of CO_2 are not expected to reach levels that independently could cause incapacitation (~5% CO_2), but it is possible that higher levels of CO_2 could lead to hyperventilation, resulting in increased %COHb levels. For this reason, the fractional incapacitation dose for CO_2, $F_{I_{CO_2}}$, was not used for tenability criteria. Equation 14 was used to calculate the multiplication factor for CO_2 used in Equation 12 above.

$$VCO_2 = e^{\left(\frac{[CO_2]}{5}\right)}$$

Equation 14 – Multiplication factor from CO_2

TEMPERATURE

Hyperthermia is expected to occur as the body's core temperature reaches 104°F [40°C], leading to loss of consciences and serious illness. At core temperatures of 108.5°F [42.5°C] the occupant could die. Several factors such as air humidity, occupant activity, exposure time, and the amount of clothing contributes to the impact from air temperature on the body's core temperature [SFPE-5]. For our building, the occupants are expected to be fully clothed, and undergoing light work. They are also expected to be exposed to elevated temperatures for a short period, as they egress the building. Looking at historic weather data for San Luis Obispo from USA.com, San Luis Obispo has an average relative humidity (RH) of 81%.

NFPA 130, *The Standard for Fixed Guide Way Transit and Passenger Rail Systems*, Appendix B, suggests that thermal burns to the respiratory tract can occur from inhalation of air above 140°F (60°C) that is saturated with water vapor (RH 100%), however Purser and McAllister indicate in their SFPE chapter (SFPE 5 CH 63) that "heat flux and temperature tenability limits design to protect victims from incapacitation from skin burns should be adequate to protect them from burns to the respiratory tract." Purser and McAllister go on to say that inhalation of hot humid gases is less likely to be fatal when exposed for less than 30 minutes. Purser suggests 212°F (100°C) air with <10% RH can be tolerated for 12 minutes, but does not provide suggested tenability limits for air with higher humidity.

This model conservatively assumes the temperature tenability limit of 140°F (60°C), for 100% RH air, with the knowledge that the if the model tenability fails from temperature then additional information regarding

the expected relatively humidity of the air would need to be determined. This tenability level for temperature is considered a safe assumption since the central atrium is not expected to experience significantly increased air temperature that could result in burns and damage to the respiratory tract due to the large volume of air, and the relatively limited time of expected exposure (<15 min). This tenability limit would likely need to be modified for smaller enclosures.

RADIANT HEAT

In comparison to the temperature tenability criteria above, this tenability limit is based on the effects from short-term radiant heat exposure. This type of exposure is expected to result in higher degree skin burns, and high degrees of pain. Incapacitation can result from a high percentage of skin burns, or due to the physiological shock from the burns. In general, if 35% or more of the body is burned, expected survivability is low [SFPE -5]. The source of radiant heat in our model could be from the fire itself or from the hot gases created in the smoke plume. Babrauskas suggests a radiant heat exposure tenability limit of 2.5 kW/m^2 (SFPE-5 Table 63.19), and indicates that this flux is expected to be tolerated for more than 5 minutes. Purser indicates that smoke temperatures of 392°F [200 °C] generally correlate with the heat flux tenability limit.

FDS

FDS MODEL

A FDS Model was developed for the design fire in the central atrium. This model, depicted in Figure 27, has a simplified geometry from the actual building design. Each level has the same floor area, and ceiling height, and the atrium openings have been aligned with the wall in a similar fashion as the actual floor layout. It is not clear how this simplification of geometry effects the fire model. All results from this FDS model should only be interpreted as an indication of potential results, and should not be used for future design or life safety judgment. The goal of this simplified model will be to determine if the tenability limits have been exceeded as discussed in the previous section.

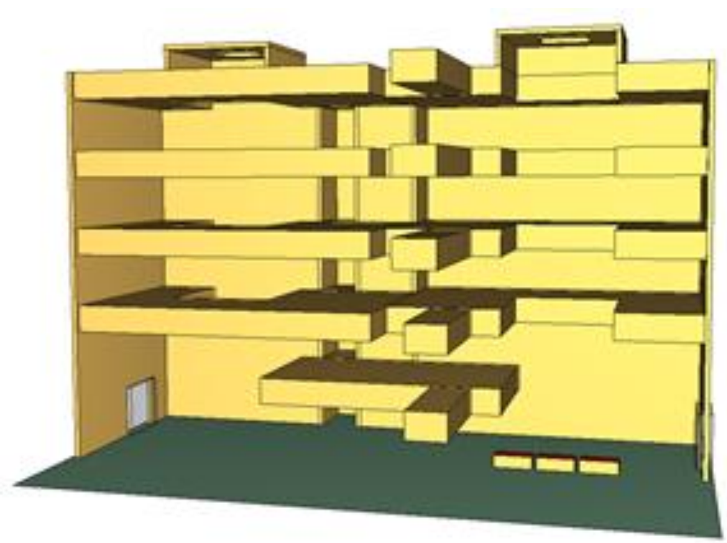


Figure 27 - FDS Fire Model

FIRE MODEL

The selected design fire, discussed in the design fire section, is arranged to be located against the west wall of the south atrium in a similar layout depicted in Figure 27. As discussed in the design fire section, these Coalesse couches are constructed of fire retardant polyurethane foam plastic cushions, covered with a polyester fabric, marked as TB117. These couches were not marked as TB133 complaint so a fire model with limited HRR and CO generation was not used. The Swedish National Testing and Research Institute maintains the SP Fire Database which includes a full-scale fire test of a 70.5 lb. (32 kg), wood frame, three seat, fire rated polyurethane foam, polyester fabric covered couch (Item No. 3:12). This test had a peak release rate (HRR) of 1439.9 kW, which correlates nicely with another test of a 70.5 lb. (32 kg), three-seat couch with fire retardant polyurethane cushions and polyester cover, that was completed by Sundstrom

during the CBUF study. Sundstrom's test had a peak HRR of 1405 kW. In both tests, the polyester cover was the first item to ignite.

The three couches in the FDS model are built as obstructions in the FDS model with the top face to act as a burner. The burner behavior has been coded to closely follow the fire test data from SP.SE, ramping the HRR per unit area up and down at the same data points in the fire test data. The HRR from the FDS model and the fire test are included in Figure 28 below. The raw data from the fire test is included in Appendix F.

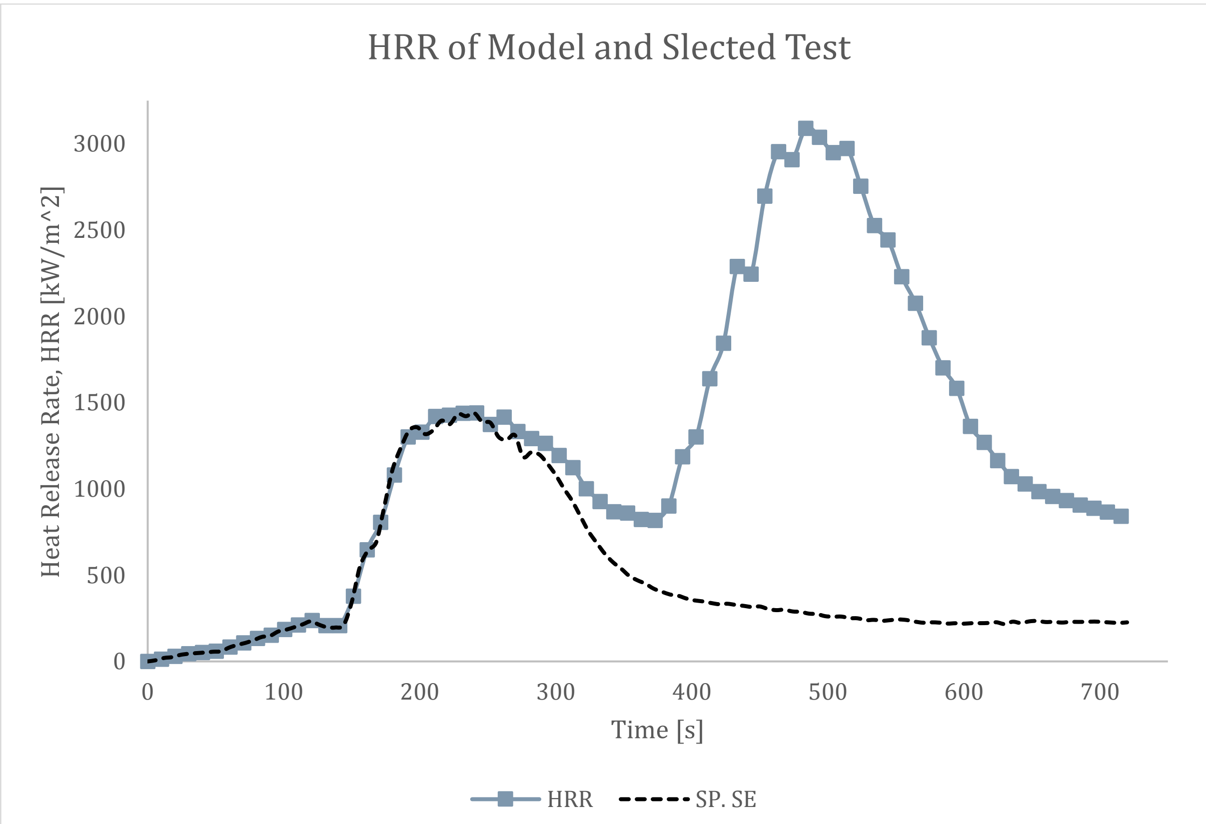


Figure 28 - FDS Model and Fire Test HRR

The HRR for the FDS model starts to deviate from the fire test around 230 seconds because this is the time that the second couch is expected to ignite. Heat flux sensors were placed on the edges of the adjacent couch surfaces to determine the incident heat flux from the fire to the surface. The left corner of the right couch was found to receive approximately 8 kW/m^2 at around 234 seconds of the simulation. The right edge of the left couch recorded 11 kW/m^2 at 278 seconds. The SFPE handbook indicates that the critical heat flux for a polyester fabric is 8 kW/m^2 using the ASTM E2058, fire propagation apparatus, so this is the assumed ignition point of the adjacent couches (SFPE-5 Table A.35). The small couch across from the three couches was not included in this fore model, since the maximum incident heat release rate observed in the

center of the atrium was about 5 kW/m^2 and the material for the small couch is also assumed to be polyester.

Smoke and carbon monoxide yields for the burning polyurethane foam was also taken from the SFPE Handbook, assuming a well-ventilated fire (SFPE-5 Table A.39). Chemical and yield data for polyurethane foam species, GM23, was used since it had the highest smoke yield.

DETECTION AND VENTILATION

The FDS model has beam defectors, and spot type smoke detectors included at the approximate locations in the atrium hall, and across the south atrium opening. The activation set point for the beam type detectors has been set at 50% obscuration, which correlates to the maximum setting on the Xtralis beam detector. The model's photoelectric smoke detectors are using the Cleary model specification characteristics with an obstruction threshold of 0.96 %/ft., which correlates with high sensitivity setting per the FM Global Approval listing for the device. As mentioned in earlier sections, the doors that separate the wings from the central atrium are programmed to close upon activation, and the main atrium doors on level 2 are programed to open. The roof vents are also programmed to open once the alarm is triggered. The FDS model, has also been set to open the atrium roof vents and main doors once an alarm has been triggered.

The model was conducted initially with all openings closed to determine the time of detection. The doors and atrium vents were then coded to open when the system activated.

RESULTS

As indicated in earlier sections, the beam detector on the 4th level reached 50% obscuration at 22.8 seconds. Visibility fell below 33.8 ft. [10 m.] across the hall at 6 ft. on the sixth level at 101.3 seconds. Figures 29 indicates the areas with unacceptable levels of visibility; red and yellow areas indicate areas of visibility below 33.8 ft. Figure 30 illustrates the approximate smoke visualization at that same time.

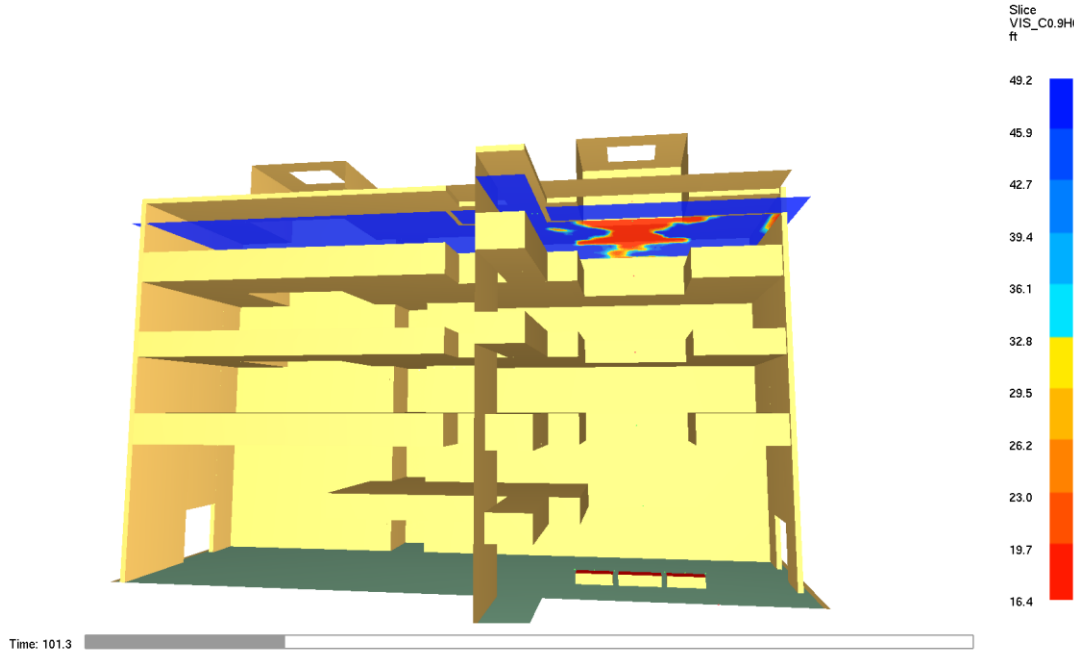


Figure 29 - Loss of Visibility in the south office area – 101.3 seconds

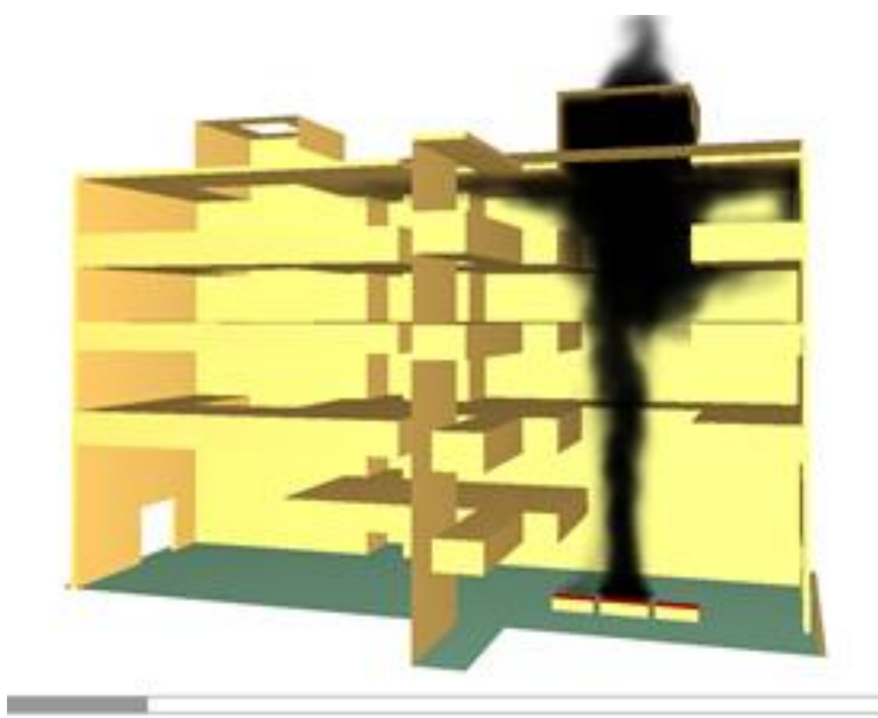


Figure 30 - FDS Smoke visualization at 101.3 seconds

At the time that visibility is lost in the south office area of the of the atrium, the Pathfinder model predicts that all occupants will be waiting near the entrance to exit stair #3. The Pathfinder model also indicates that a single occupant decides to move back across the atrium at 127 seconds arriving at the west hallway at 149 seconds. During that occupant's travel, visibility in the area falls below 33.8 ft., and it is possible that that occupant may become disoriented. Based on the criteria for acceptance in the LSC, tenability is lost at 101.3 seconds, since visibility falls below the acceptable limit at 6 ft. above the highest walking surface. It could be argued that tenability failed at 149 seconds when the occupant attempts to travel to the other side of the atrium, however since this Pathfinder behavior is unverified, and the LSC requirement is more conservative, 101.3 seconds is used for this report.

Figure 31 indicates the level of visibility expected in the central atrium once the 6th floor has been completely evacuated (390 seconds). Figure 32 illustrates the approximate smoke visualization at that same time.

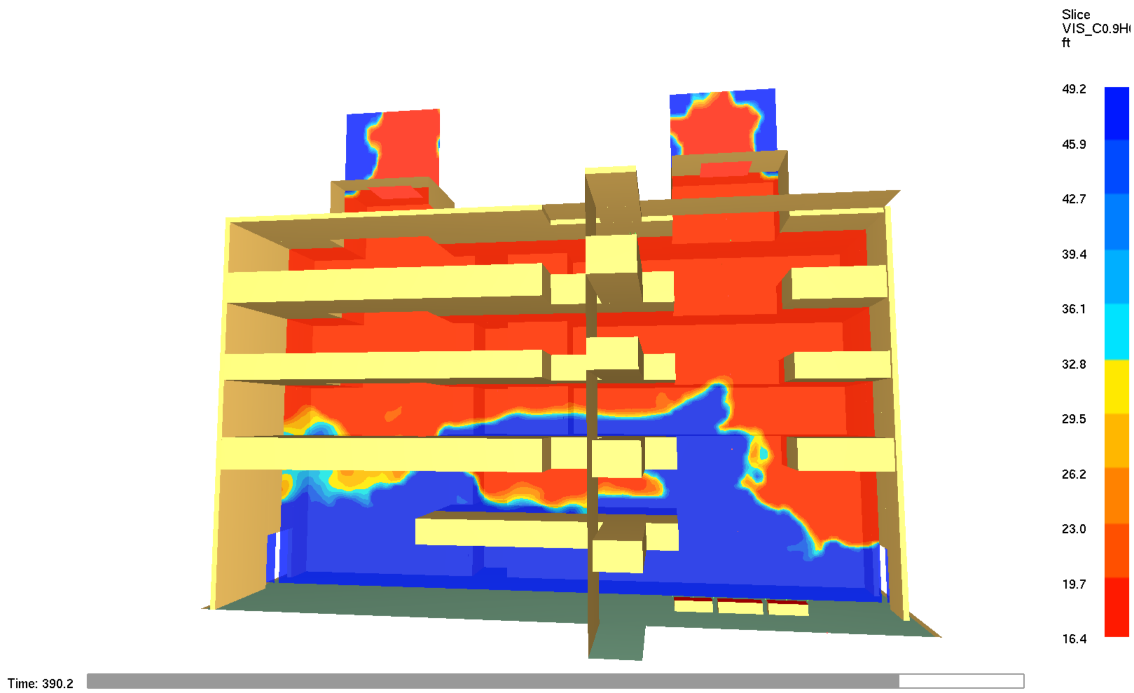


Figure 31 - Visibility at 390 seconds

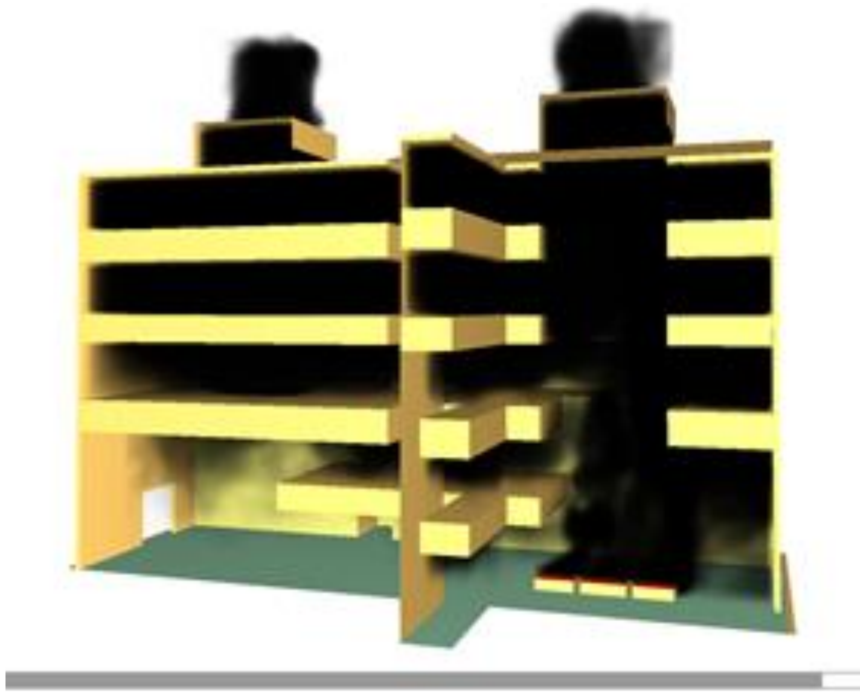


Figure 32 - Smoke visualization at 390 seconds.

Looking at the visibility and smoke visualization at 390 seconds (time needed for evacuation of the 6th level), the occupants of the 6th level will be subjected to smoke for a prolonged period. The FED method discussed in the tenability section has been applied for the area adjacent stair #3. Table 16 tabulates the total FED for the 12-minute exposure, and Figure 32 indicates the expected gas levels.

Table 17 - FED for asphyxiant gases

TIME [min]	1	2	3	4	5	6	7	8	9	10	11	12
CO [ppm]	0	0	3	21	32	34	36	57	67	76	72	59
Co2 [%]	0.04	0.07	0.06	0.13	0.15	0.12	0.14	0.21	0.24	0.21	0.16	0.16
O2 [%]	20.80	20.70	20.70	20.60	20.60	20.60	20.60	20.50	20.40	20.50	20.60	20.60
F'Ico	0.0000	0.0000	0.0001	0.0007	0.0010	0.0011	0.0011	0.0018	0.0022	0.0025	0.0023	0.0019
VCO2	1.008	1.015	1.012	1.026	1.030	1.023	1.028	1.042	1.050	1.044	1.032	1.032
Total	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.002	0.002
F'Io2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total F'IN	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.003	0.003	0.003	0.002
Running Total	0.000	0.001	0.001	0.002	0.003	0.005	0.006	0.009	0.011	0.014	0.017	0.019

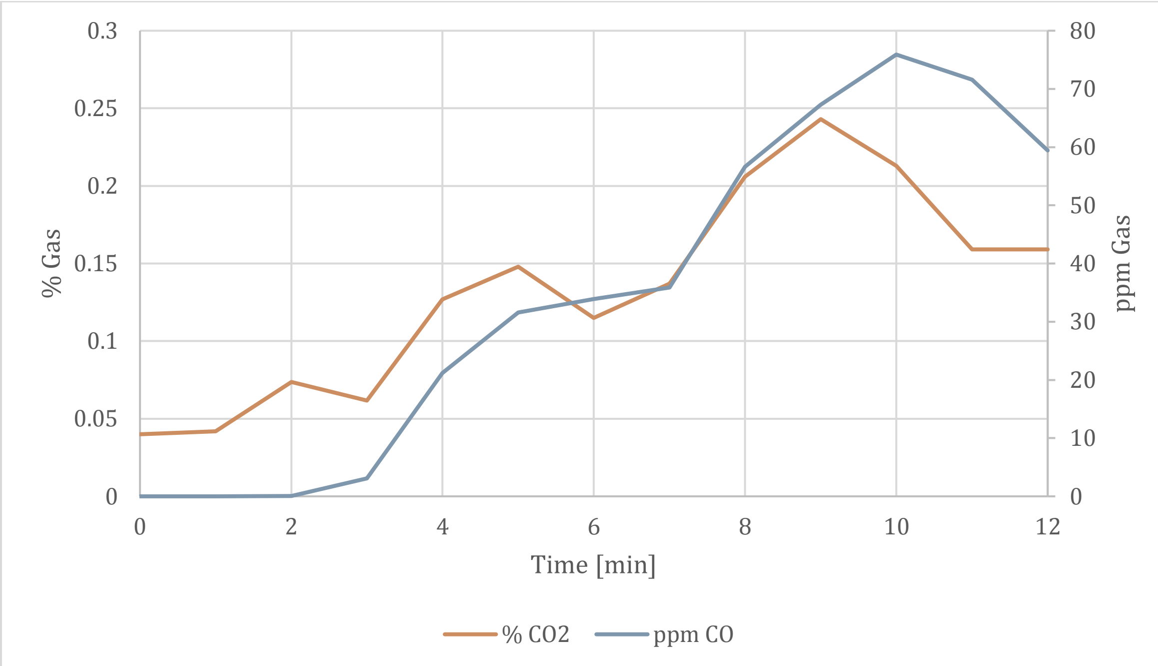


Figure 33- Model Gas Concentrations Stair #3 Door

Tenability due to asphyxaint gases is not expected to be exceeded by the time the building is evacuated. This result is expected because of the large volume of air in the atrium, and naturally provided make-up air, diluting the CO and CO_2 concentrations.

The FDS model indicated that the max air temperature for the atrium reached about 140°F [60° C] in the center of the atrium (See Figure 34 below). Higher air temperatures were recorded in the center of the fire plume; but mostly in the vertical opening of the atrium. Some of the higher temperature smoke plume did extend under the 2nd level ceiling towards the end of the simulation, around 531 s, but did not extent below the 6 ft. level (See Figure 35). Smoke and air temperatures in the same vertical plane of the plume can be seen in Figure 36. Since these elevated air temperatures did not occur in areas that are expected to effect occupants, this model is expected to maintain acceptable air temperatures for tenability.

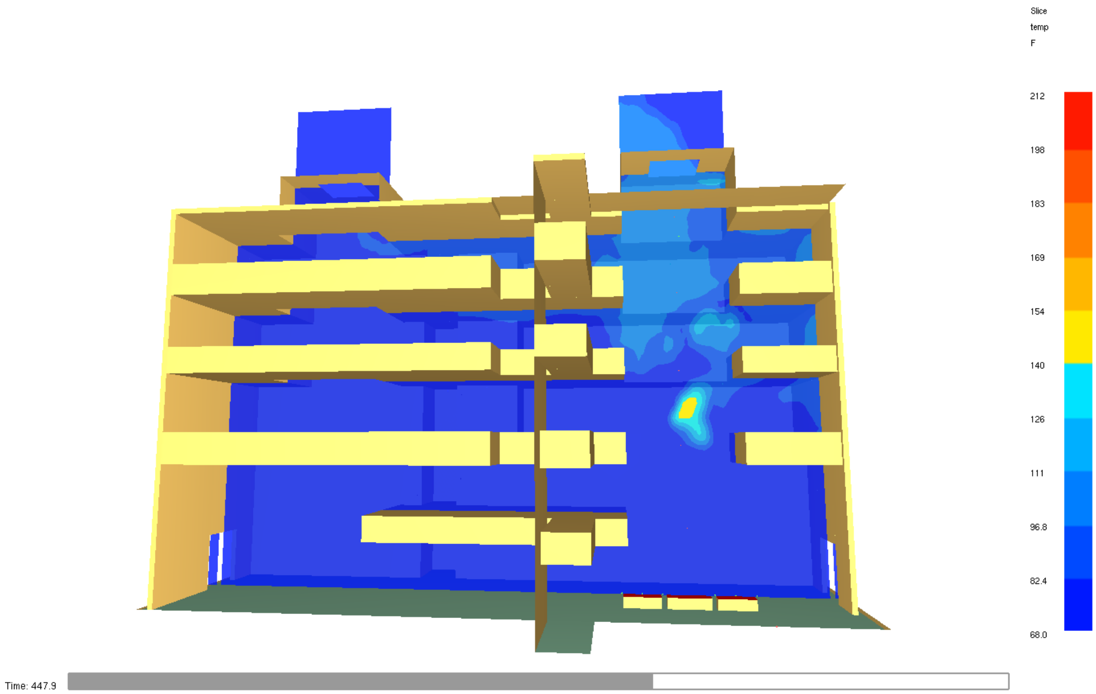


Figure 34 - Temperature distribution in central atrium – 447.9 seconds

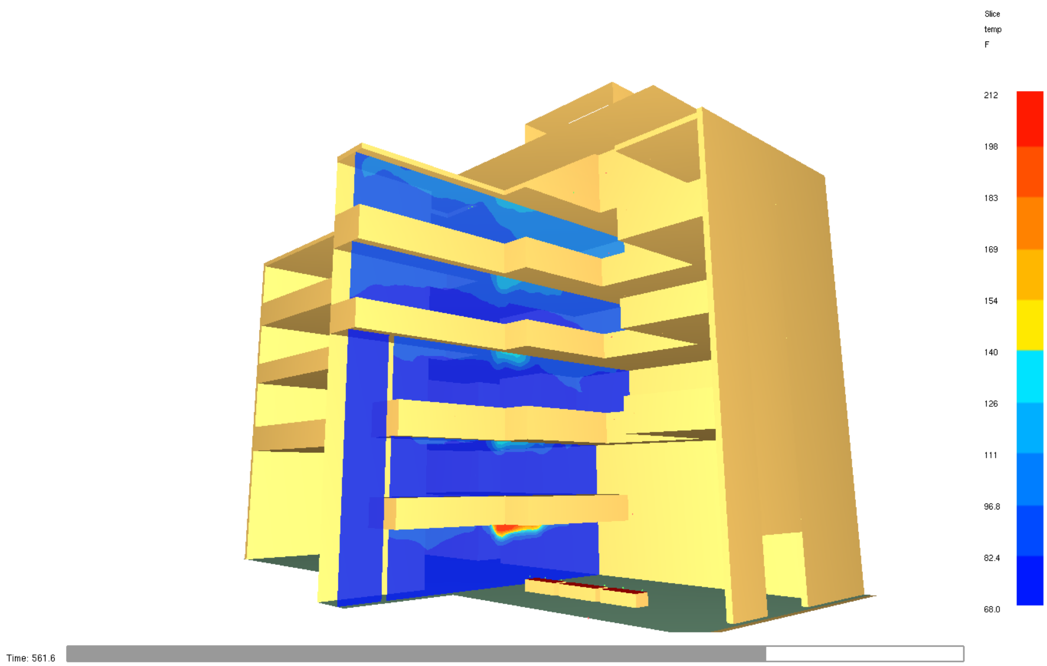


Figure 35 - Air temperatures in the vertical plane of the hallway – 561.6s

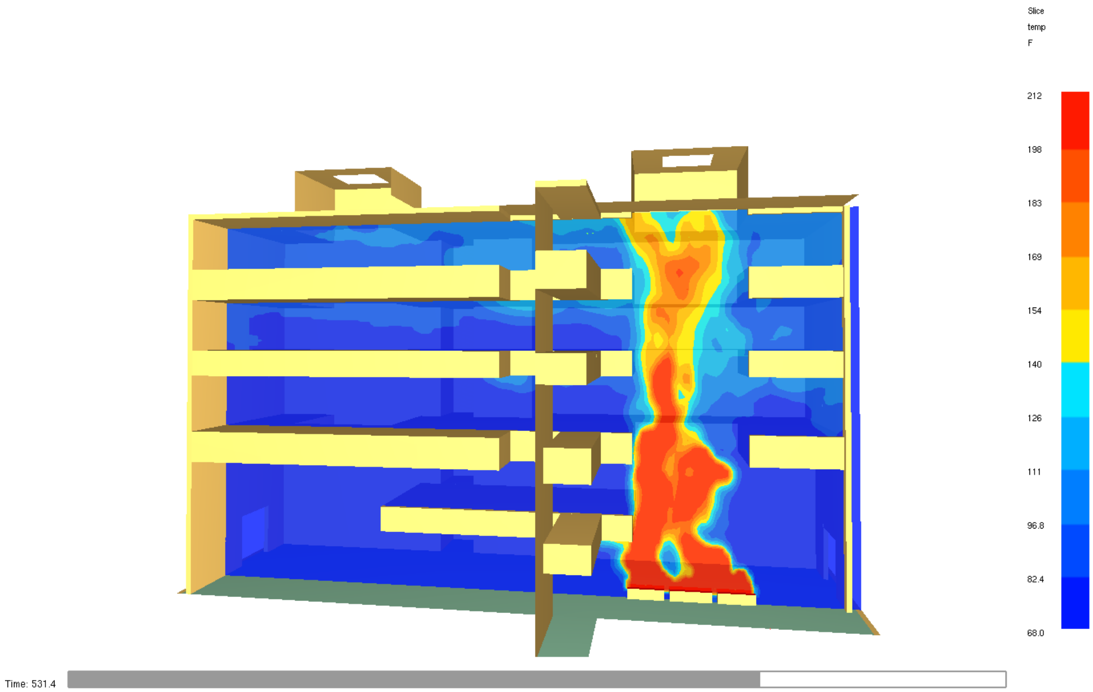


Figure 36 - Smoke temperature in Plume – 531s.

A heat flux of 2.5 kW/m^2 was recorded in the vertical plane of the hallway from Exit Stair #3 at 180 seconds and peaks to over 10 kW/m^2 around 562 seconds. Figure 37 illustrates the predicted heat flux at 561.6 seconds. Since occupants are expected to utilize this area as a means of egress for the duration of the evacuation, this model is also expected to fail due to high levels of heat flux in addition to loss of visibility.

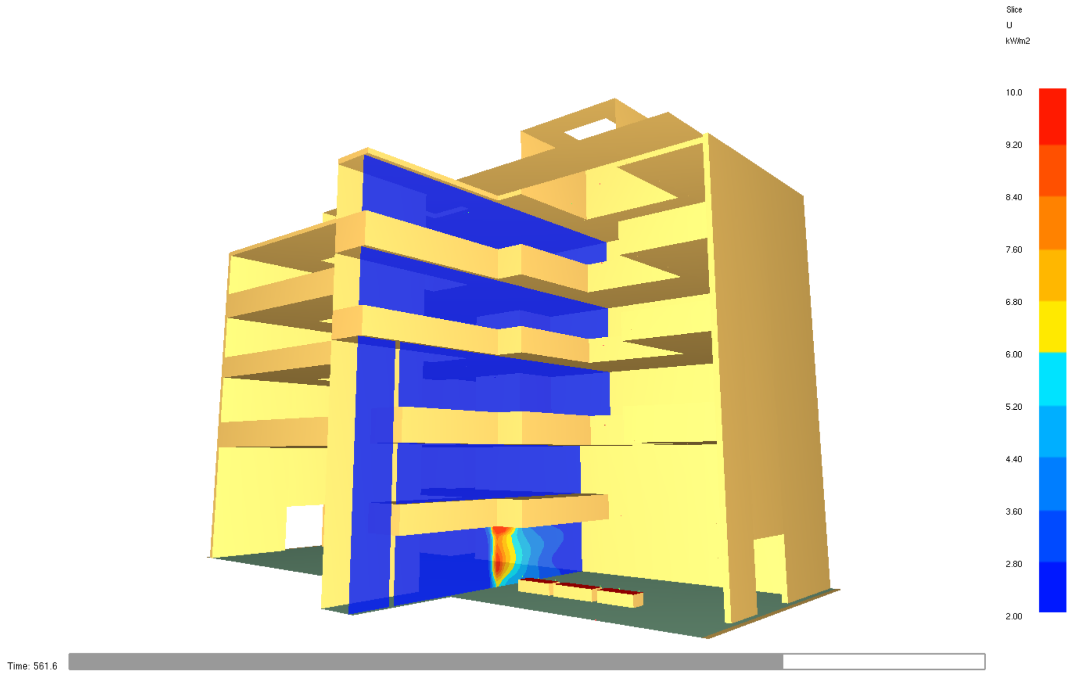


Figure 37 - Incident Heat Flux in Exit Stair #3 Hallway - 561.6s

FDS indicated that our model, and passive smoke control system, is not expected to provide tenable conditions after 101 seconds (1.7 minutes), due to loss of visibility. The model also indicated that even if additional ventilation is provided, tenable conditions still may not be possible due to excessive heat flux in the area adjacent the exit of Exit Stair #3. With the current building design, tenability limits for air temperature, and smoke toxicity are expected to be maintained for the duration of egress. This FDS model indicates that the available safe egress time (ASET) for this building would be 1.7 minutes.

Our Pathfinder model indicated that when occupants are forced to use the north exit door of the central atrium, there was slight improvements in the times needed for clearing some floors, but the total egress travel time required was the same at 10.5 minutes.

Putting together all the occupant factors, and using information from previous fires in similar occupancies, with similar occupant distributions, pre-movement times were established, and added to the detection time from the FDS model and the travel time from the Pathfinder model. These selected and calculated times combined to establish a required safe egress time (RSET) of 12 minutes.

The RSET far exceeds the ASET and thus is not an acceptable design for life safety.

Conclusions

This report has reviewed the structural fire protection, egress, fire protection and fire detection designs for the Warren J. Baker Center for Science building. The designs have been discussed and evaluated against the current set of codes and standards to determine adequacy for prescriptive requirements. A performance based analysis has also been developed to determine the adequacy of the existing passive smoke control system in the central atrium, using more up to date information regarding the occupants of the building, and combustibles stored within. Computer based modeling from Pathfinder and FDS was used to determine ASET and RSET.

Looking at the building design for current code compliance, several deficiencies were found that would need to be addressed to meet current code requirements. Areas that are used for assembly have excessive common travel distances, and assembly use rooms need an additional exit door for egress. The third floor is not provided with enough exit capacity to meet the expected occupant load and there is a corridor on the first floor that has an excessive dead end travel distance.

The structural fire protection design was found to meet the current codes and provides for separation of occupancies, and a smoke control area. The overall building construction meets the requirements for floor area and height limits, and falls just short of being considered a high rise.

The fire detection design has been designed and installed per NFPA 72, which meets requirements for detection and alarm in the LSC for assembly and business use occupancies. Additional spot type, open area, smoke detectors are recommended to meet the current edition of NFPA 72.

The sprinkler design for the building meets the minimum requirement in NFPA 13 for the regular occupancy spaces (Light hazard, OH-1, etc.), The design does not meet the sprinkler spacing requirements in NFPA 13 around the perimeter of the vertical openings, but is acceptable since the engineering analysis was performed based on maintaining the smoke layer above the highest unprotected opening. A second hydraulic model, and hand calculations, indicated that the sprinkler analysis completed at the time of design is likely accurate.

The fire model developed for performance based analysis of the central atrium indicated that, with the current furnishings in the south atrium space, tenable conditions will not be maintained during building evacuation. Adequate visibility is expected to be lost early in the evacuation on the sixth level, and unacceptable levels of heat flux are expected on the second level. The RSET was developed using Pathfinder, and occupant characteristics found for the University. The fire model was developed using FDS, full scale fire test information, fire frequency information, and available information on the furniture in the atrium space.

Recommendations

SMOKE CONTROL

The natural atrium smoke control design provides inadequate measures to maintain tenability for the building. An improved smoke control design is recommended to ensure that tenability is maintained. Additional make-up air supplies may be needed to be able to maintain acceptable air velocity near the fire. Alternatively, the removal of all combustible furnishing from the atrium, or the use of less combustible materials, would likely eliminate the need for increased smoke control in the atrium; additional studies would be needed to confirm.

HEAT FLUX

If the smoke control system was upgraded, without any changes to furnishings, it is expected that untenantable conditions will still be present on the 2^{nd} level near Exit Stair #3's exit into the atrium. A more detailed fire model should be completed to ensure tenable conditions can still be maintained with the current furnishing. The simplified model has modified floor dimensions, with similar floor areas, and since incident heat flux is dependent on distance from the source, it is unclear if the conditions would still be untenable based on more accurate dimensions. Alternatively, as with the smoke control recommendation, the replacement of the current furnishing with noncombustible or less-combustible furnishings would reduce the chances of untenable conditions.

EGRESS

Egress capacity is not acceptable per the current editions of the LSC and IBC. Occupant loads should be limited, or egress will need to be more controlled. One method of additional egress control would be the use of directed and phased evacuation based on the specific fire exposure. Additional training would be needed for the monitoring staff, and fire department personnel. Regular drills should be conducted to ensure that all occupants will be able, and willing to respond appropriately during a fire.

Two separate means of exit are required for Rooms 304 and 306 since they are considered an assembly use with more than 50 occupants. Based on the room size and shape, an additional exit is expected to be difficult due to required remoteness. The most appropriate action is the reduction of occupants below 50 people, which would reclassify the use as business, and remove the requirement for two exits. This occupancy reduction would also eliminate the unacceptable common path distance.

Add an enclosed storage area that extends 8 ft. into the dead-end hallway, and relocate the door for room 254. One of the egress doors for room 241 would be lost, but since the room is business use, only one door is required. Adequate sprinkler protection should be provided for this new storage space, and appropriate signage should be maintained in the corridor to ensure that the egress path is still clear.

APPENDIX A-Construction

FIRE RATED CONSTRUCTION AND EXIT SIGNAGE

Below are the figures that indicate the provided fire rated construction for each floor and the recommended placement for exit signage. The red dashed lines indicate a 2-hr fire barrier and the blue dashed lines indicate a 1-hr rated fire barrier.

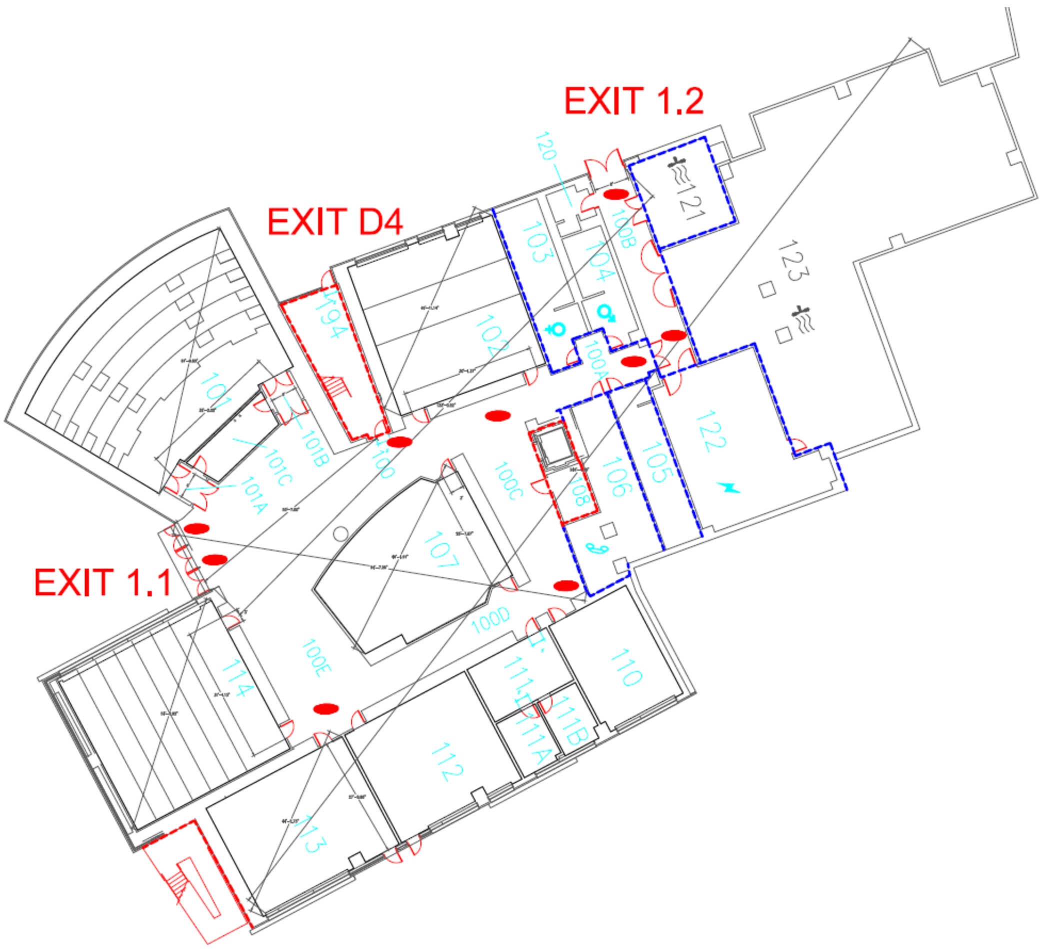


Figure A1 - Level One FR Construction and Exit Signage

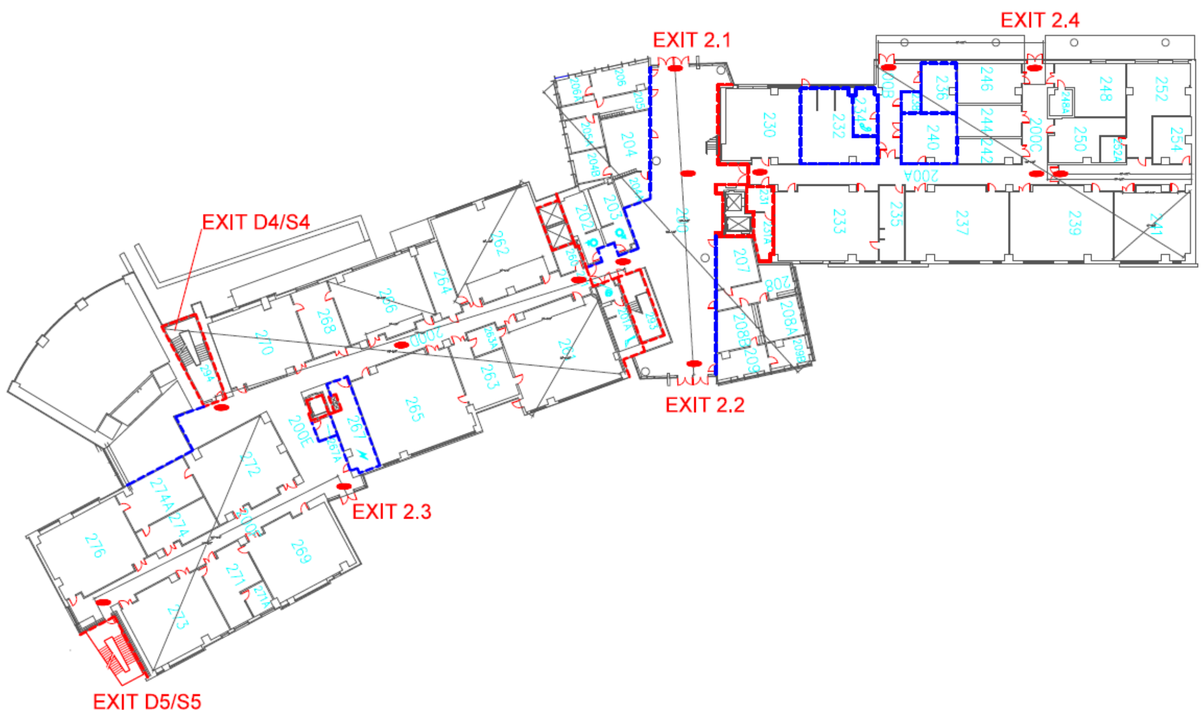


Figure A2 - Level Two FR Construction and Exit Signage

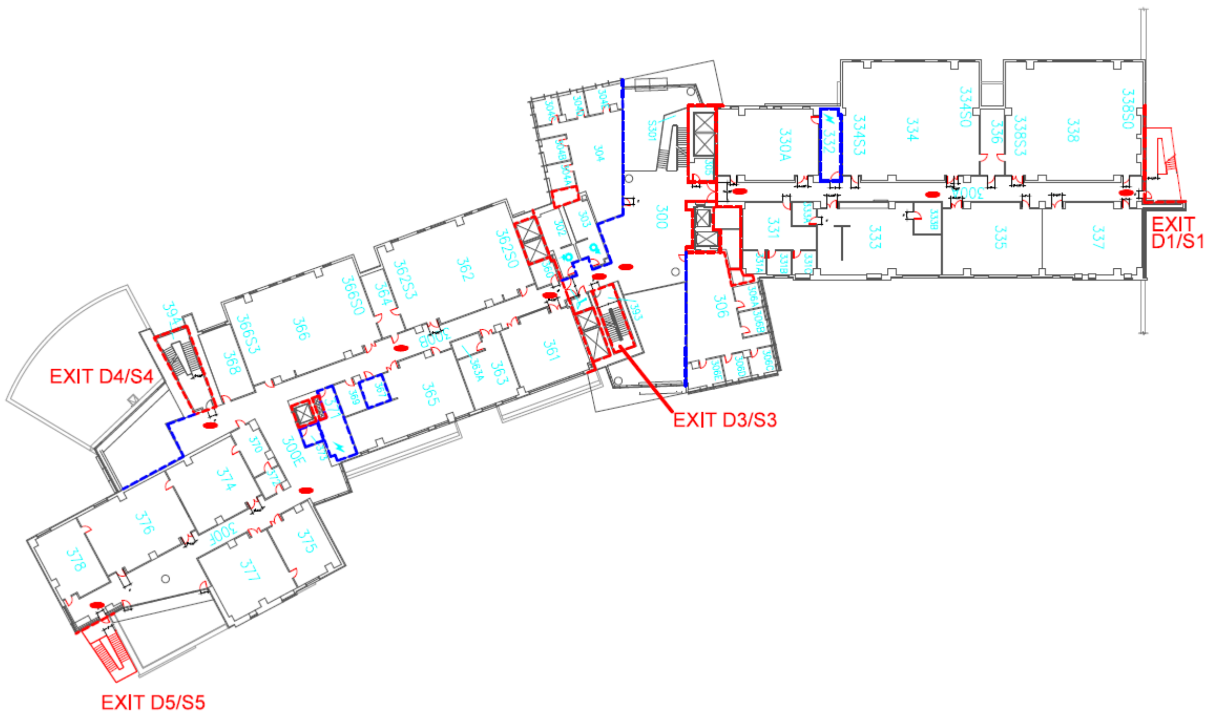


Figure A3 - Level Three FR Construction and Exit Signage

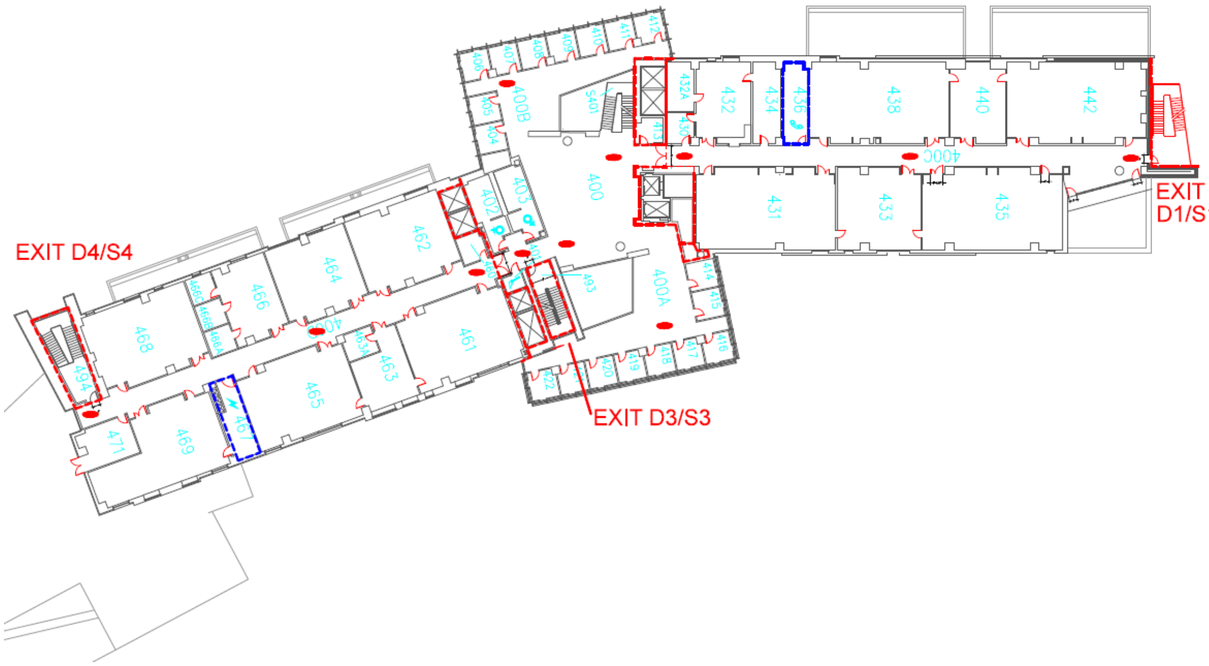


Figure A4 - Level Four FR Construction and Exit Signage

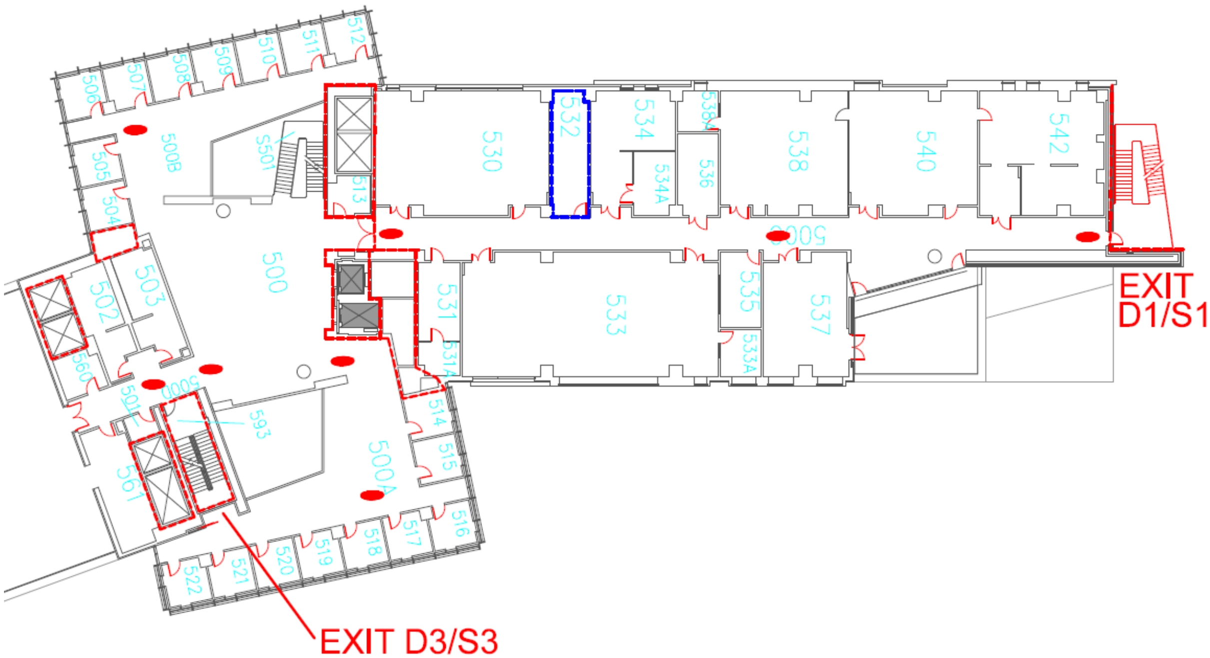


Figure A5 - Level Five FR Construction and Exit Signage

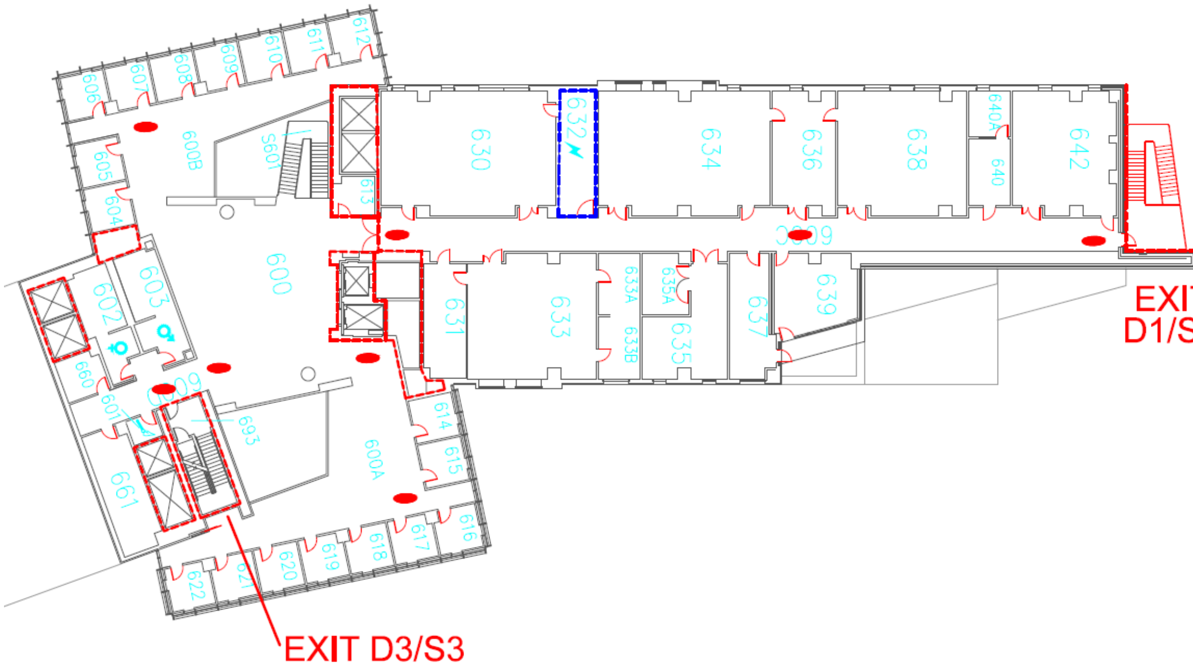


Figure A6- Level six FR Construction and Exit Signage

APPENDIX B-Occupancy

SPECIFIC USE AREAS

The table and figures below illustrate how to the occupancy load was determined based on use.

Space Designation	Color Code
Assembly (>50 Occupants)	
Laboratories	
Class Room (< 50 Students)	
Business (Office)	
Storage	
Mechanical Room	
Electrical Room	
Restroom	
Elevator and Lobbies	
Exit Corridors	
Exit Stairs	

Table B1 Specific Use Areas Key

APPENDIX B-OCCUPANCY

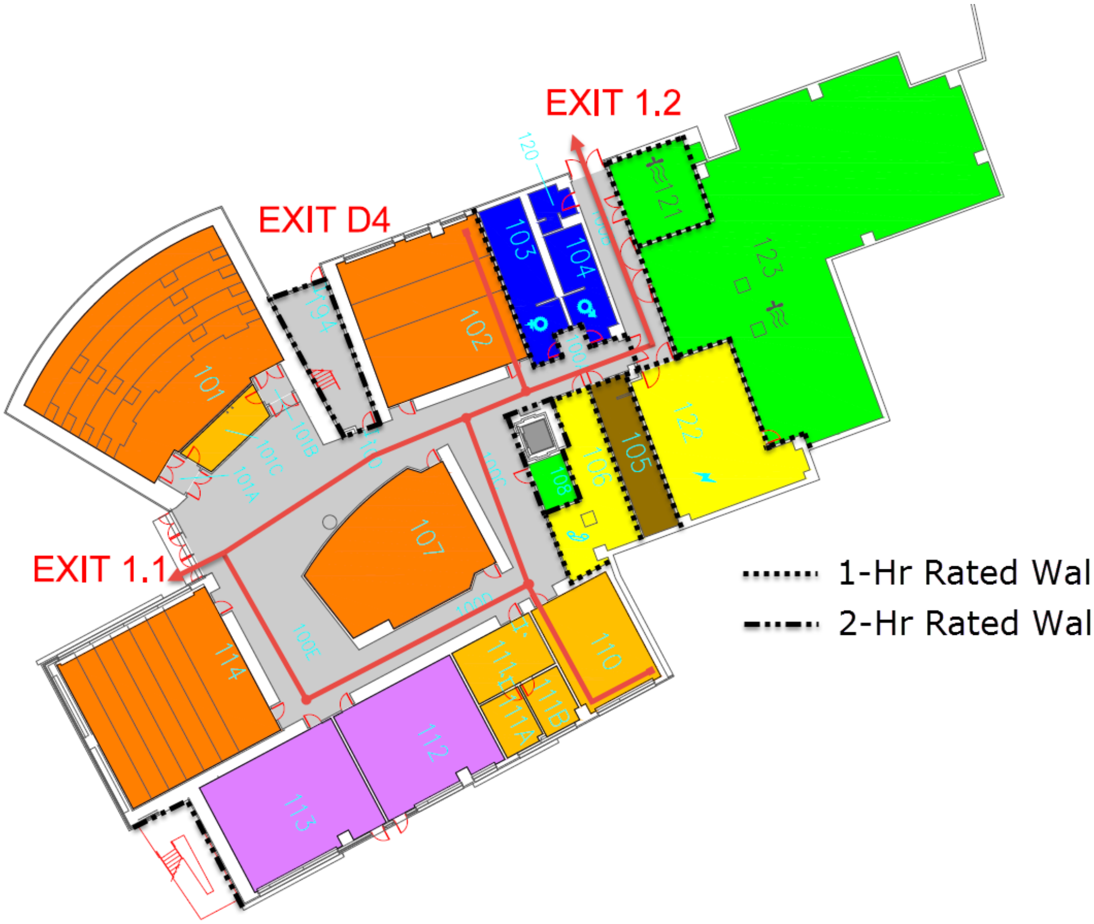


Figure B1-First Floor Use

APPENDIX B-OCCUPANCY

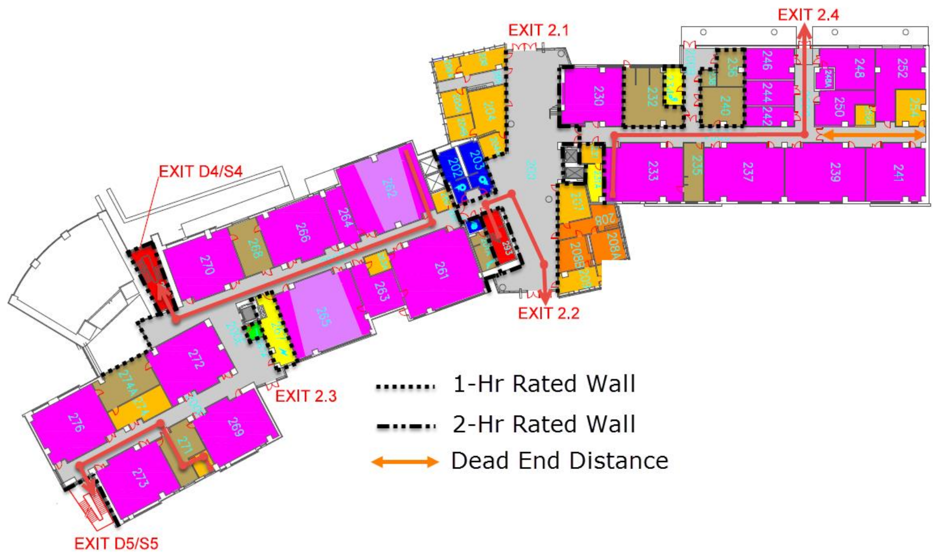


Figure B2 - Second Floor Use

APPENDIX B-OCCUPANCY

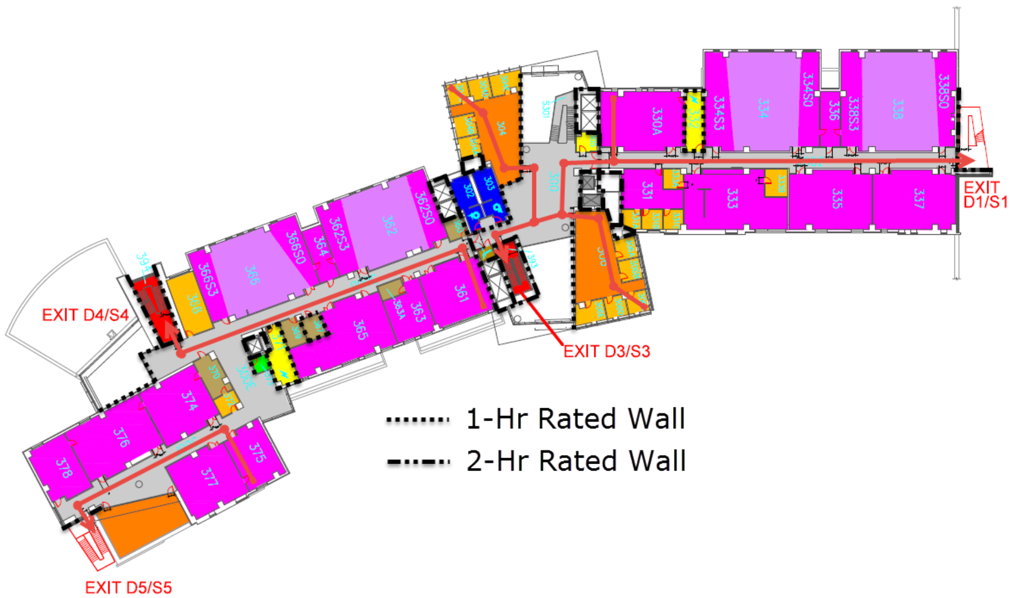


Figure B3 - Third Floor Use

APPENDIX B-OCCUPANCY

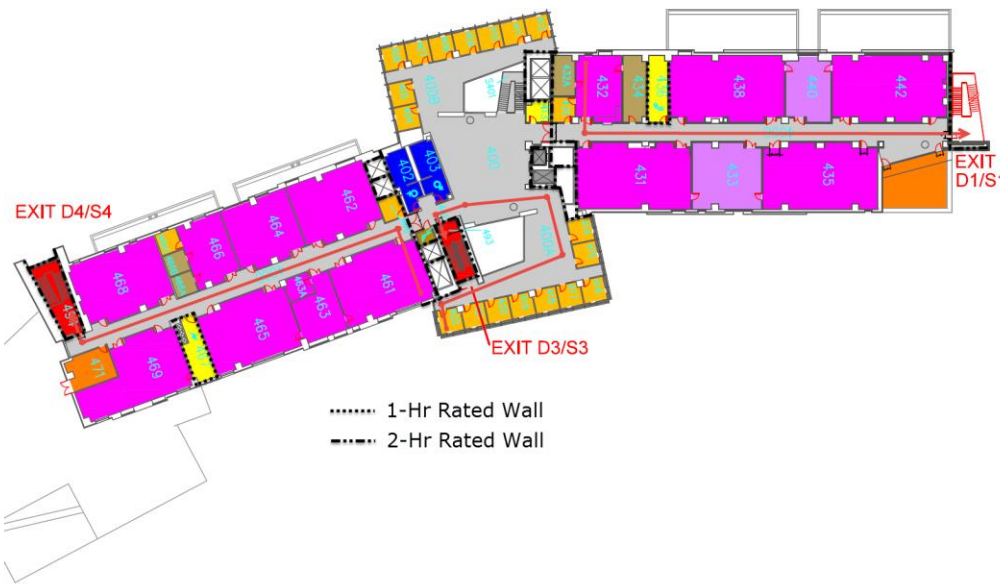


Figure B4 - Fourth Floor Use

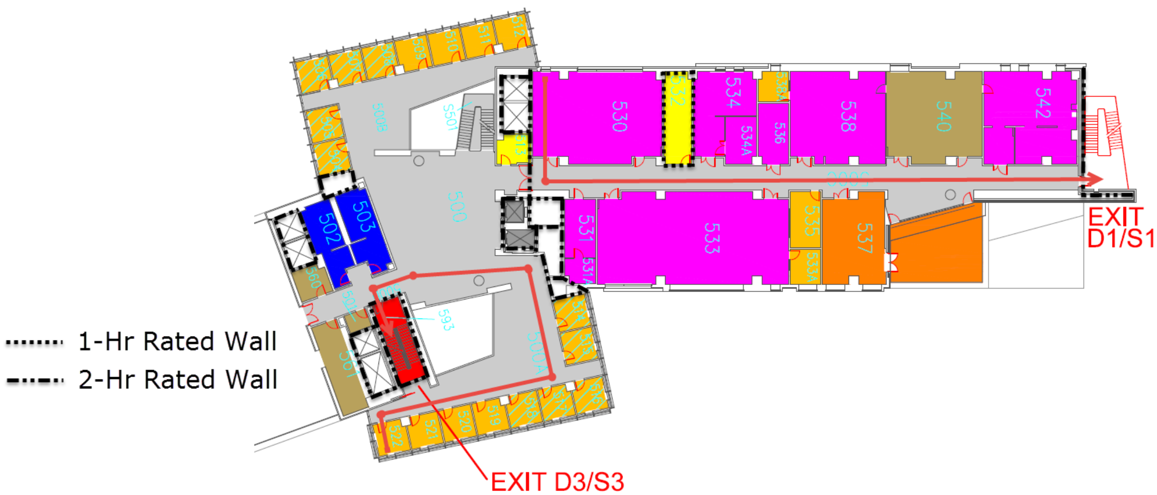


Figure B5 - Fifth Floor Use

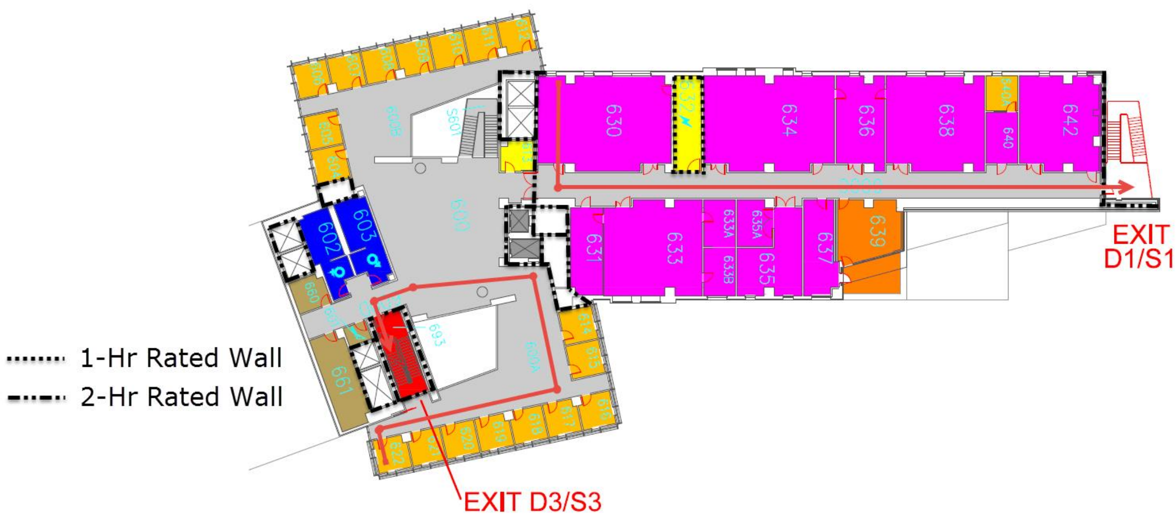


Figure B6 - Sixth Floor Use

APPENDIX B-OCCUPANCY

OCCUPANCY USE DETAILS

Room	Room Use	Area	Lvl	Occupant Load	Load
0101-00	Assembly	1949	1	FIXED	132
0101-C0	Office	173	1	100	2
0102-00	Assembly	1223	1	15	82
0103-00	Restroom	375	1	50	8
0104-00	Restroom	245	1	50	5
0105-00	Custodial Storage	330	1	500	1
0106-00	Electrical Room	515	1	500	1
0107-00	Assembly	1077	1	15	72
0108-00	Electrical Room	94	1	500	0
0110-00	Admin Office	559	1	100	6
0111-00	Other Office	552	1	100	6
0112-00	Class Room	836	1	20	42
0113-00	Class Room	949	1	20	47
0114-00	Lecture	1473	1	FIXED	98
0120-00	Restroom	80	1	50	2
0121-00	Pump Room	389	1	500	1
0122-00	Main Electrical Room	964	1	500	2
0123-00	Mechanical Room	3811	1	500	8
0200-00	Atrium	3675	2	100	37
0201-00	Restroom	50	2	50	1

APPENDIX B-OCCUPANCY

0201-A0	Custodial Storage	170	2	500	0
0202-00	Restroom	248	2	50	5
0203-00	Restroom	271	2	50	5
0204-00	Staff Office	416	2	100	4
0204-A0	Staff Office	146	2	100	1
0204-B0	Admin Office	164	2	100	2
0205-00	Support Office	228	2	100	2
0205-A0	Admin Office	175	2	100	2
0206-00	Staff Office	231	2	100	2
0206-A0	Staff Office	124	2	100	1
0207-00	Office	304	2	100	3
0208-00	Assebmly (Kitchen)	318	2	100	3
0208-A0	Conf Room	257	2	15	17
0208-B0	Conf Room	276	2	15	18
0209-00	Staff Office	207	2	100	2
0209-B0	Admin Office	157	2	100	2
0230-00	Grad Rsrch Lab	880	2	50	18
0231-00	Other Office	106	2	100	1
0231-A0	Electrical Room (Server)	138	2	500	0
0232-00	Gen Storage	713	2	500	1
0233-00	LwDiv Teach Lab	1181	2	50	24
0234-00	Electrical	186	2	500	0

0235-00	Gen Storage	299	2	500	1
0236-00	Gen Storage	263	2	500	1
0237-00	LwDiv Teach Lab	1183	2	50	24
0238-00	Gen Storage	69	2	500	0
0239-00	UpDiv Teach Lab	1183	2	50	24
0240-00	Gen Storage	431	2	500	1
0241-00	Instruction Lab	863	2	50	17
0242-00	Shop	255	2	50	5
0244-00	Shop	335	2	50	7
0246-00	Shop	407	2	50	8
0248-00	Lab	512	2	50	10
0248-A0	Lab	92	2	50	2
0250-00	Lab	431	2	50	9
0252-00	Lab	691	2	50	14
0252-A0	Other Office	109	2	100	1
0254-00	Office	269	2	100	3
0260-00	Other Office	84	2	100	1
0261-00	LwDiv Teach Lab	1498	2	50	30
0262-S0	Lecture Area	323	2	20	16
0262-S1	LwDiv Teach Lab	810	2	50	16
0262-S3	Rsrch Lab Srv	410	2	50	8
0263-00	Imaging Lab	467	2	50	9

APPENDIX B-OCCUPANCY

0263-A0	Office	121	2	100	1
0264-00	Prep Lab	294	2	50	6
0265-S0	Lecture	218	2	20	11
0265-S1	LwDiv Teach Lab	1059	2	50	21
0265-S3	Rsrch Lab Srv	220	2	50	4
0266-00	LwDiv Teach Lab	1016	2	50	20
0267-00	Electrical Room	375	2	500	1
0267-A0	Mechanical Room	58	2	500	0
0268-00	Prep Storage	419	2	500	1
0269-00	UpDiv Teach Lab	1025	2	50	21
0270-00	LwDiv Teach Lab	1008	2	50	20
0271-00	Prep Storage	470	2	500	1
0271-A0	Other Office	106	2	100	1
0272-00	LwDiv Teach Lab	1091	2	50	22
0273-00	LwDiv Teach Lab	1000	2	50	20
0274-00	Prep Storage	368	2	500	1
0274-A0	Prep Office	537	2	100	5
0276-00	LwDiv Teach Lab	1074	2	50	21
0300-00	Atrium	1835	3	100	18
0301-00	Custodial	44	3	500	0
0302-00	Restroom	248	3	50	5
0303-00	Restroom	271	3	50	5

0304-00	Student Work Space	891	3	15	59
0304-A0	Faculty Office	108	3	100	1
0304-B0	Faculty Office	108	3	100	1
0304-C0	Faculty Office	102	3	100	1
0304-D0	Faculty Office	105	3	100	1
0304-E0	Faculty Office	149	3	100	1
0305-00	Electrical Room	94	3	500	0
0306-00	Student Work Space	947	3	15	63
0306-A0	Faculty Office	107	3	100	1
0306-B0	Faculty Office	108	3	100	1
0306-C0	Faculty Office	102	3	100	1
0306-D0	Faculty Office	105	3	100	1
0306-E0	Faculty Office	148	3	100	1
0330-A0	LwDiv Teach Lab	1201	3	50	24
0331-00	Computer Sjop	507	3	50	10
0331-A0	Other Office	94	3	100	1
0331-B0	Other Office	96	3	100	1
0331-C0	Other Office	96	3	100	1
0332-00	Electrical Room	267	3	500	1
0333-00	Tch Lab Serv	1358	3	50	27
0333-A0	Other Office	94	3	100	1
0333-B0	Tch Lab Serv	155	3	100	2

APPENDIX B-OCCUPANCY

0334-S0	Lecture	474	3	20	24
0334-S1	LwDiv Teach Lab	1697	3	50	34
0334-S3	Rsrch Lab Srv	589	3	50	12
0335-00	LwDiv Teach Lab	1183	3	50	24
0336-00	Tch Lab Serv	278	3	50	6
0337-00	LwDiv Teach Lab	1181	3	50	24
0338-S0	Lecture	431	3	20	22
0338-S1	LwDiv Teach Lab	1827	3	50	37
0338-S3	Rsrch Lab Srv	485	3	50	10
0360-00	Gen Storage	101	3	500	0
0361-00	LwDiv Teach Lab	874	3	50	17
0362-S0	Lecture	376	3	20	19
0362-S1	Lab Support	1340	3	50	27
0362-S3	Lab Support	409	3	50	8
0363-00	Maint Shop	491	3	50	10
0363-A0	Gen Storage	91	3	500	0
0365-00	Grad Rsrch Lab	1194	3	50	24
0366-S0	Lecture	378	3	20	19
0366-S1	LwDiv Teach Lab	1420	3	50	28
0366-S3	Rsrch Lab Srv	345	3	50	7
0367-00	Gen Storage	114	3	500	0
0368-00	Office	421	3	100	4

APPENDIX B-OCCUPANCY

0369-00	Storage	137	3	500	0
0370-00	Prep Storage	221	3	500	0
0371-00	Electrical Room	274	3	500	1
0372-00	Other Office	103	3	100	1
0373-00	Mechanical Room	62	3	500	0
0374-00	UpDiv Teach Lab	904	3	50	18
0375-00	Spec Instruction Lab	582	3	50	12
0376-00	UpDiv Teach Lab	1170	3	50	23
0377-00	UpDiv Teach Lab	900	3	50	18
0378-00	Lab	611	3	50	12
NONE	Assembly Terrace	943	3	15	63
0400-00	Atrium	4170	4	100	42
0401-00	Custodial Storage	43	4	500	0
0402-00	Restroom	248	4	50	5
0403-00	Restroom	271	4	50	5
0404-00	Faculty Office	108	4	100	1
0405-00	Faculty Office	108	4	100	1
0406-00	Faculty Office	102	4	100	1
0407-00	Faculty Office	105	4	100	1
0408-00	Faculty Office	105	4	100	1
0409-00	Faculty Office	105	4	100	1
0410-00	Faculty Office	108	4	100	1

0411-00	Faculty Office	105	4	100	1
0412-00	Faculty Office	102	4	100	1
0413-00	Server Electrical Room	94	4	500	0
0414-00	Other Office	107	4	100	1
0415-00	Other Office	108	4	100	1
0416-00	Other Office	102	4	100	1
0417-00	Other Office	105	4	100	1
0418-00	Other Office	105	4	100	1
0419-00	Other Office	105	4	100	1
0420-00	Other Office	108	4	100	1
0421-00	Other Office	105	4	100	1
0422-00	Other Office	102	4	100	1
0430-00	Other Office	113	4	100	1
0431-00	UpDiv Teach Lab	1480	4	50	30
0432-00	Lab Support	597	4	50	12
0432-A0	Gen Storage	180	4	500	0
0433-00	Spec Instruction	893	4	20	45
0434-00	Prep Storage	310	4	500	1
0435-00	UpDiv Teach Lab	1481	4	50	30
0436-00	Electrical Room	267	4	500	1
0438-00	UpDiv Teach Lab	1487	4	50	30
0440-00	Spec Instruction	557	4	20	28

APPENDIX B-OCCUPANCY

0442-00	UpDiv Teach Lab	1457	4	50	29
0460-00	Other Office	101	4	100	1
0461-00	UpDiv Teach Lab	1187	4	50	24
0462-00	UpDiv Teach Lab	1042	4	50	21
0463-00	Spec Instruction	468	4	20	23
0463-A0	Cell Culture Lab	116	4	50	2
0464-00	Spec Instruction Lab	878	4	50	18
0465-00	UpDiv Teach Lab	1182	4	50	24
0466-00	Prep Room	582	4	50	12
0466-A0	Prep Storage	100	4	500	0
0466-B0	Gen Storage	97	4	500	0
0466-C0	Other Office	98	4	100	1
0467-00	electrical Room	259	4	500	1
0468-00	LwDiv Teach Lab	1177	4	50	24
0469-00	UpDiv Teach Lab	1198	4	50	24
0471-00	Lounge	296	4	15	20
NONE	Assembly Terrace	713	4	15	48
0500-00	Atrium	4227	5	100	42
0501-00	Custodial Storage	44	5	500	0
0502-00	Restroom	248	5	50	5
0503-00	Restroom	271	5	50	5
0504-00	Faculty Office	108	5	100	1

0505-00	Faculty Office	108	5	100	1
0506-00	Faculty Office	102	5	100	1
0507-00	Faculty Office	105	5	100	1
0508-00	Faculty Office	105	5	100	1
0509-00	Other Office	105	5	100	1
0510-00	Other Office	108	5	100	1
0511-00	Other Office	105	5	100	1
0512-00	Other Office	102	5	100	1
0513-00	Electrical Room	105	5	500	0
0514-00	Faculty Office	108	5	100	1
0515-00	Faculty Office	108	5	100	1
0516-00	Faculty Office	102	5	100	1
0517-00	Faculty Office	105	5	100	1
0518-00	Faculty Office	105	5	100	1
0519-00	Other Office	105	5	100	1
0520-00	Other Office	108	5	100	1
0521-00	Other Office	105	5	100	1
0522-00	Other Office	102	5	100	1
0530-00	Teaching Lab	1198	5	500	2
0531-00	Lab Support	191	5	50	4
0531-A0	Prep Room	77	5	50	2
0532-00	Electrical Room	267	5	500	1

0533-00	Lab	1806	5	50	36
0533-A0	Other Office	115	5	100	1
0534-00	Fermentation Lab	417	5	50	8
0534-A0	Lab	150	5	50	3
0535-00	Other Office	184	5	100	2
0536-00	Lab Support	193	5	50	4
0537-00	Conf Room	574	5	15	38
0538-00	Polymer Lab	900	5	50	18
0538-A0	Other Office	95	5	100	1
0540-00	Gen Storage	878	5	500	2
0542-00	Coatings Lab	881	5	50	18
0560-00	Gen Storage	107	5	500	0
0561-00	Gen Storage	265	5	500	1
NONE	Assembly Terrace	739	5	15	49
0600-00	Atrium	4213	6	100	42
0601-00	Custodial Storage	45	6	500	0
0602-00	Restroom	248	6	50	5
0603-00	Restroom	271	6	50	5
0604-00	Faculty Office	108	6	100	1
0605-00	Faculty Office	108	6	100	1
0606-00	Faculty Office	102	6	100	1
0607-00	Faculty Office	105	6	100	1

0608-00	Faculty Office	105	6	100	1
0609-00	Faculty Office	105	6	100	1
0610-00	Faculty Office	108	6	100	1
0611-00	Faculty Office	105	6	100	1
0612-00	Faculty Office	102	6	100	1
0613-00	Electrical Room	94	6	500	0
0614-00	Faculty Office	108	6	100	1
0615-00	Faculty Office	108	6	100	1
0616-00	Faculty Office	102	6	100	1
0617-00	Other Office	105	6	100	1
0618-00	Other Office	105	6	100	1
0619-00	Other Office	105	6	100	1
0620-00	Other Office	108	6	100	1
0621-00	Other Office	105	6	100	1
0622-00	Other Office	102	6	100	1
0630-00	Project Lab	1201	6	50	24
0631-00	Lab Prep	274	6	50	5
0632-00	Electrical Room	271	6	500	1
0633-00	LwDiv Teach Lab	900	6	50	18
0633-A0	Lab Support	149	6	50	3
0633-B0	Lab Support	151	6	50	3
0634-00	LwDiv Teach Lab	1195	6	50	24

0635-00	Laser Lab	408	6	50	8
0635-A0	Lab Support	161	6	50	3
0636-00	Lab Prep	423	6	50	8
0637-00	Grad Rsrch Lab	294	6	50	6
0638-00	LwDiv Teach Lab	897	6	50	18
0639-00	Terrace Club	367	6	15	24
0640-00	Electrical Shop	161	6	50	3
0640-A0	Other Office	111	6	100	1
0642-00	Grad Rsrch Lab	729	6	50	15
0660-00	Gen Storage	108	6	500	0
0661-00	Gen Storage	315	6	500	1
NONE	Assembly Terrace	192	6	15	13

Table B2 - Occupancy Use Details

APPENDIX C-Egress

EGRESS CALCULATIONS

	Stair 1	Stair 3	Stair 4	Stair 5	N. Atrium	S. Atrium	W-Wing	E-Wing	1st FLR main	1st Flr Side
Level 1	-	-	180	-	-	-	-	-	1080	480
Level 2	-	-	160	160	720	720	360	360	-	-
Level 3	160	147	160	160	-	-	-	-	-	-
Level 4	160	147	160	-	-	-	-	-	-	-
Level 5	160	147	-	-	-	-	-	-	-	-
Level 6	160	147	-	-	-	-	-	-	-	-

Table C1 - Egress Capacity by Exit Per Floor

Assembly Use Load	
Level 1	383
Level 2	39
Level 3	185
Level 4	67
Level 5	112
Level 6	37
Total	824

Table C2 - Assembly Load Per Floor

APPENDIX D- Msc. Details

ASSEMBLY DETAILS

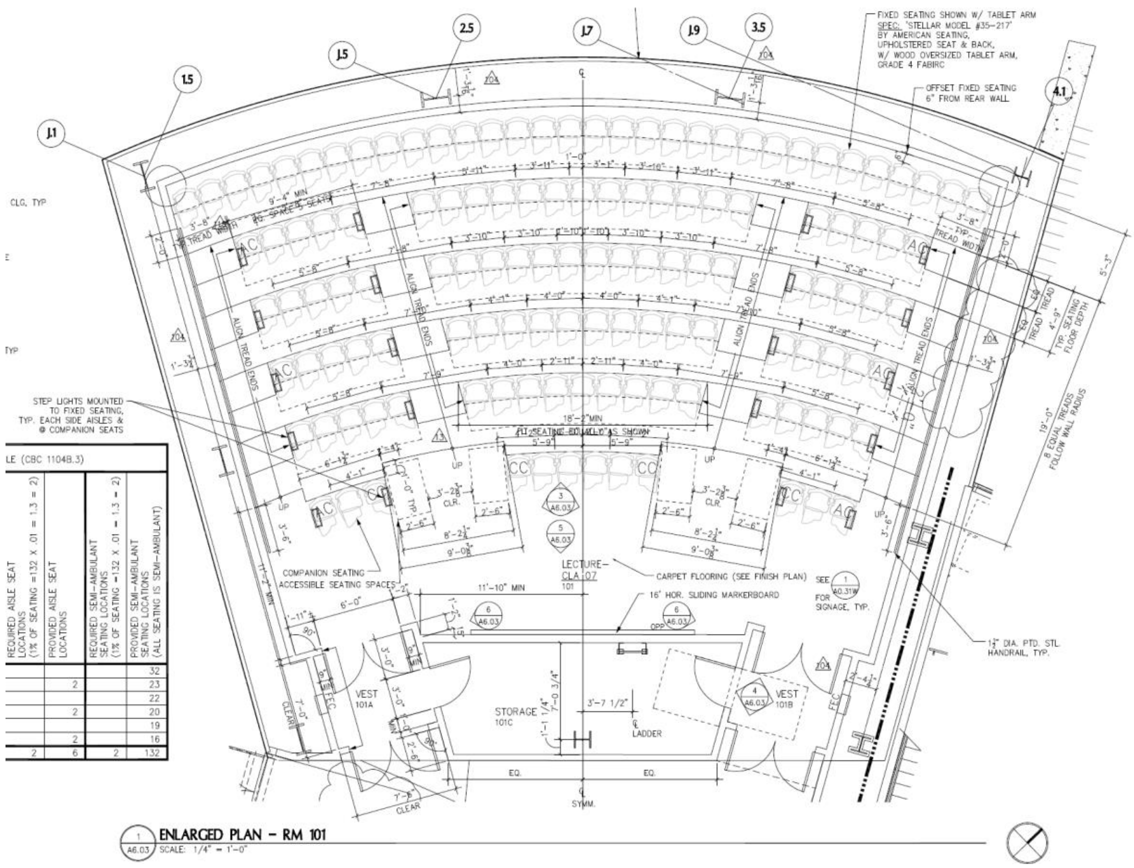


Figure D1 - Plan View of RM 101

APPENDIX D- MSC. DETAILS

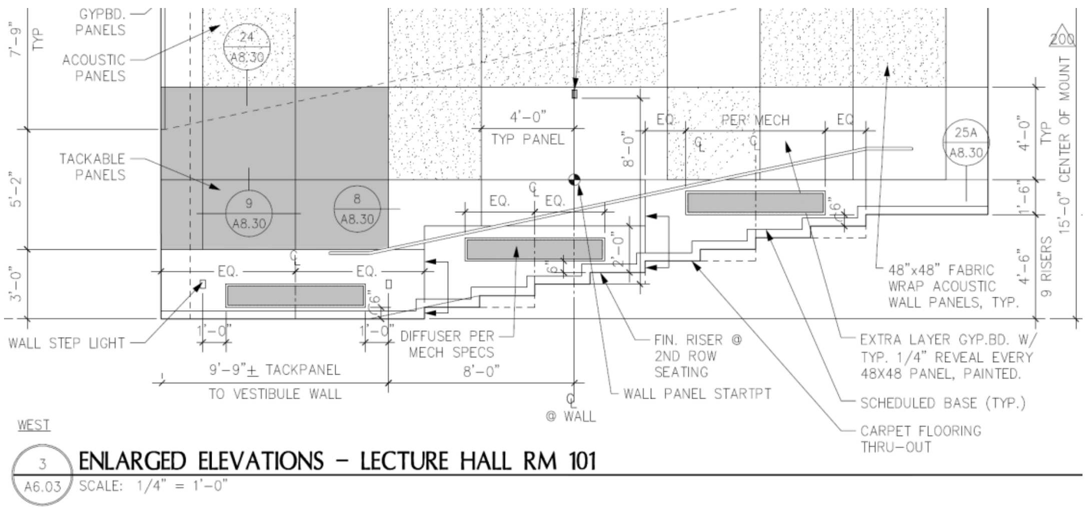


Figure D2- RM 101 Stair Detail

APPENDIX D- MSC. DETAILS

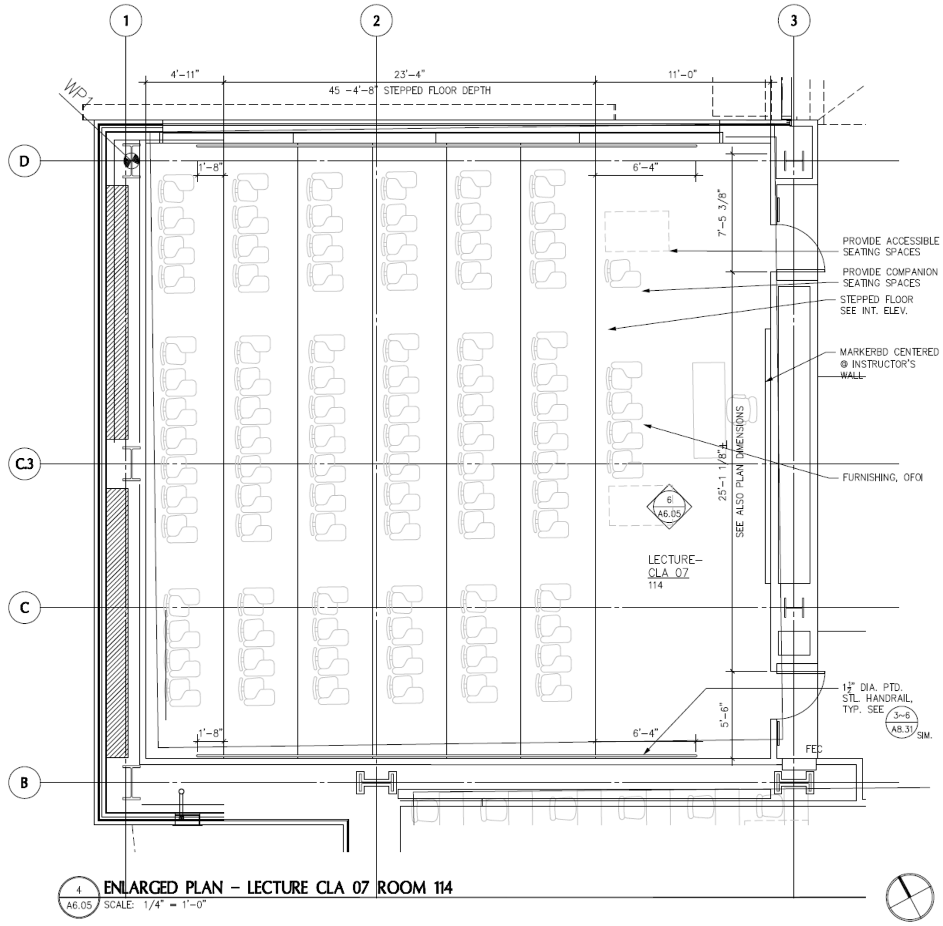


Figure D3 - Plan View RM 114

STAIR DETAILS

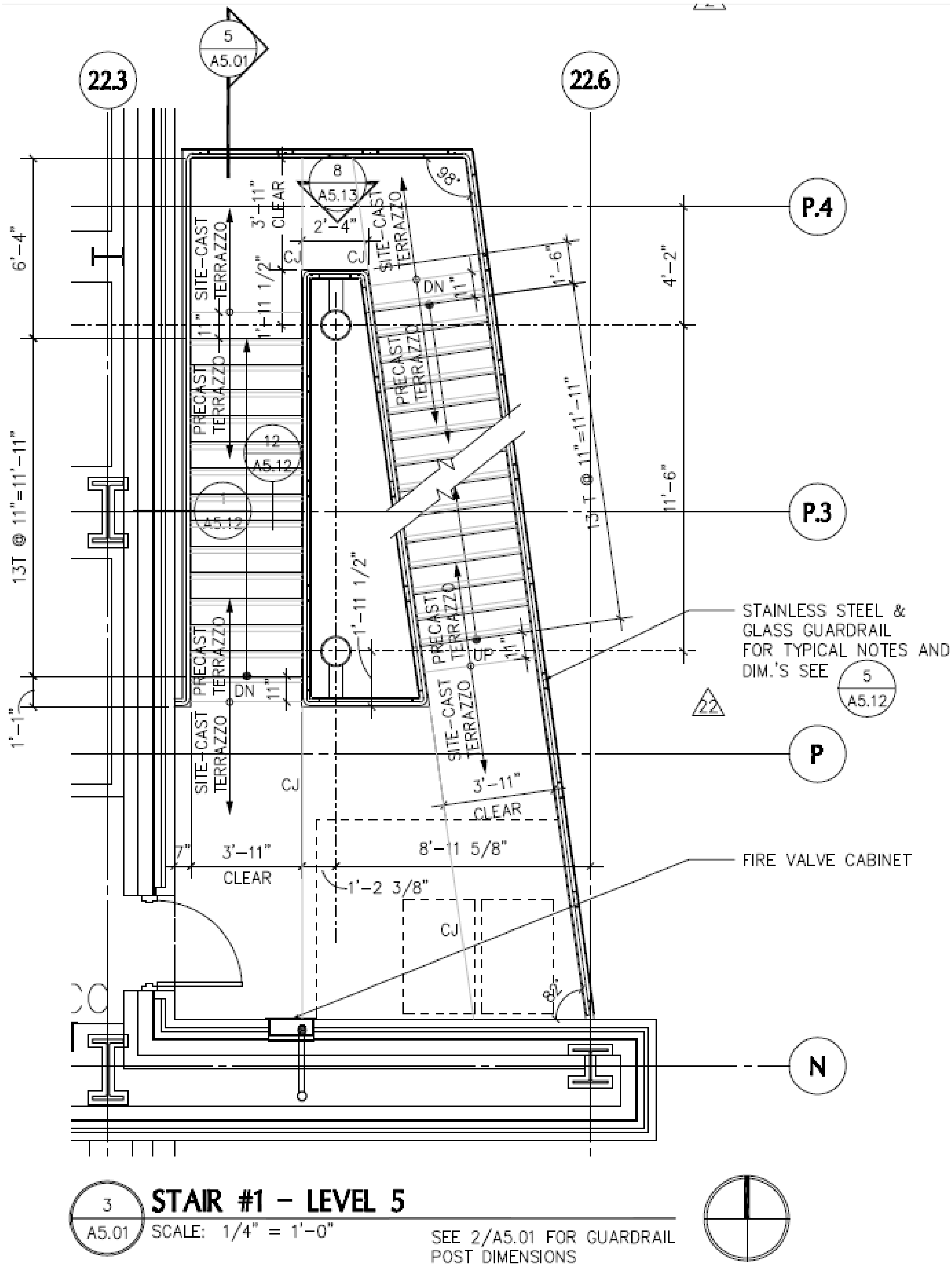


Figure D4 -Stair 1 Detail

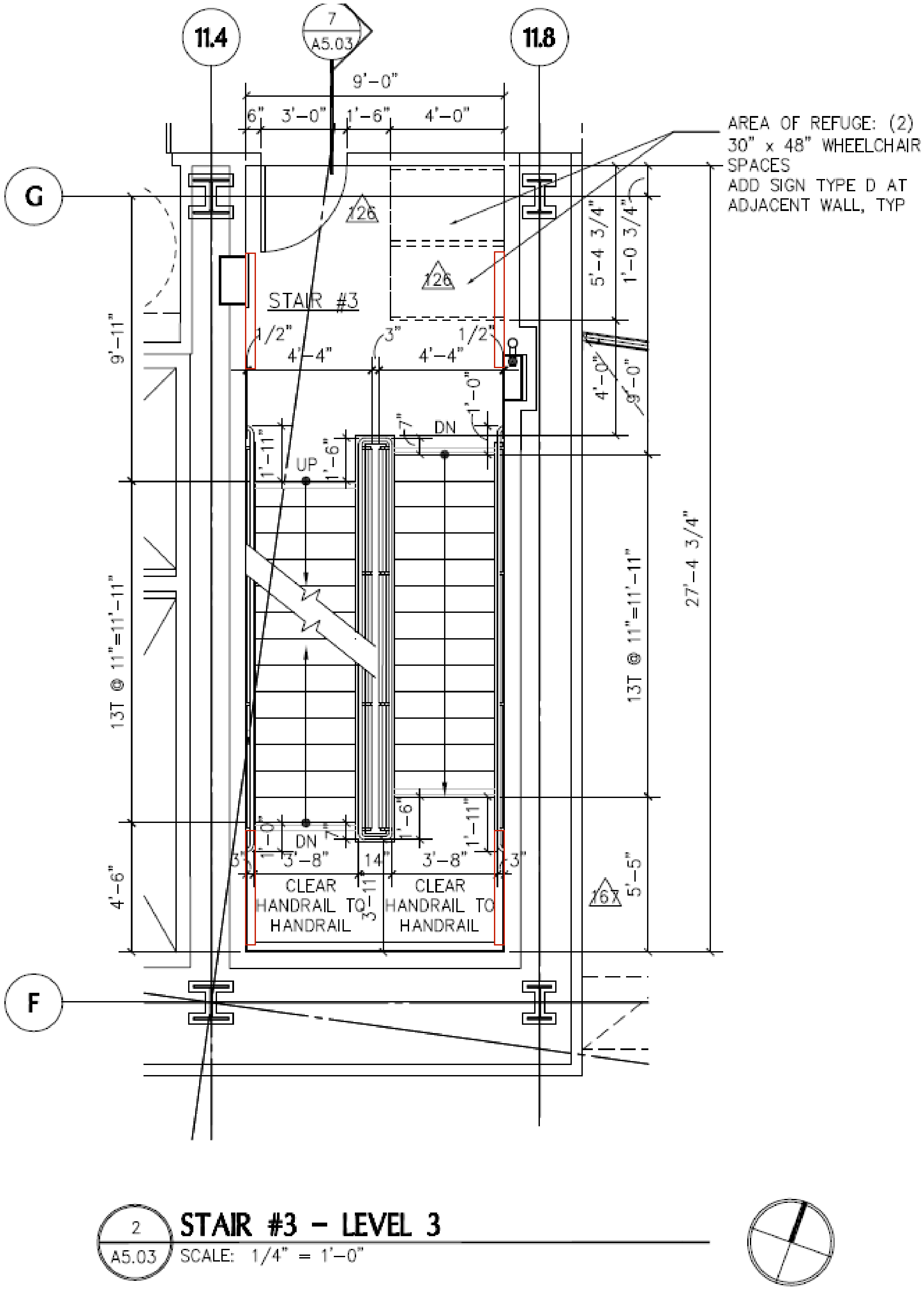


Figure D5- Stair 3 Detail

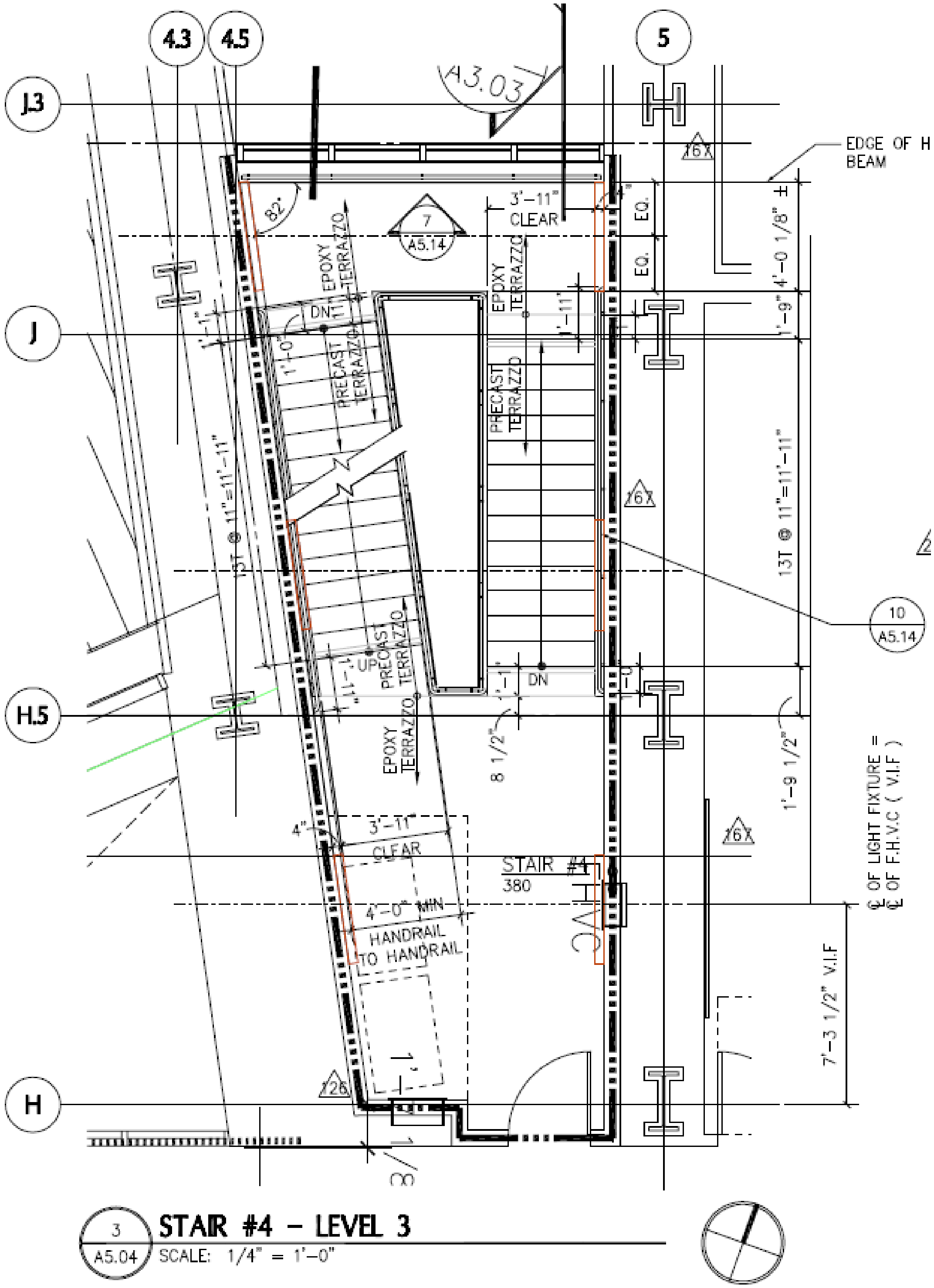


Figure D6- Stair 4 Detail

APPENDIX D- MSC. DETAILS

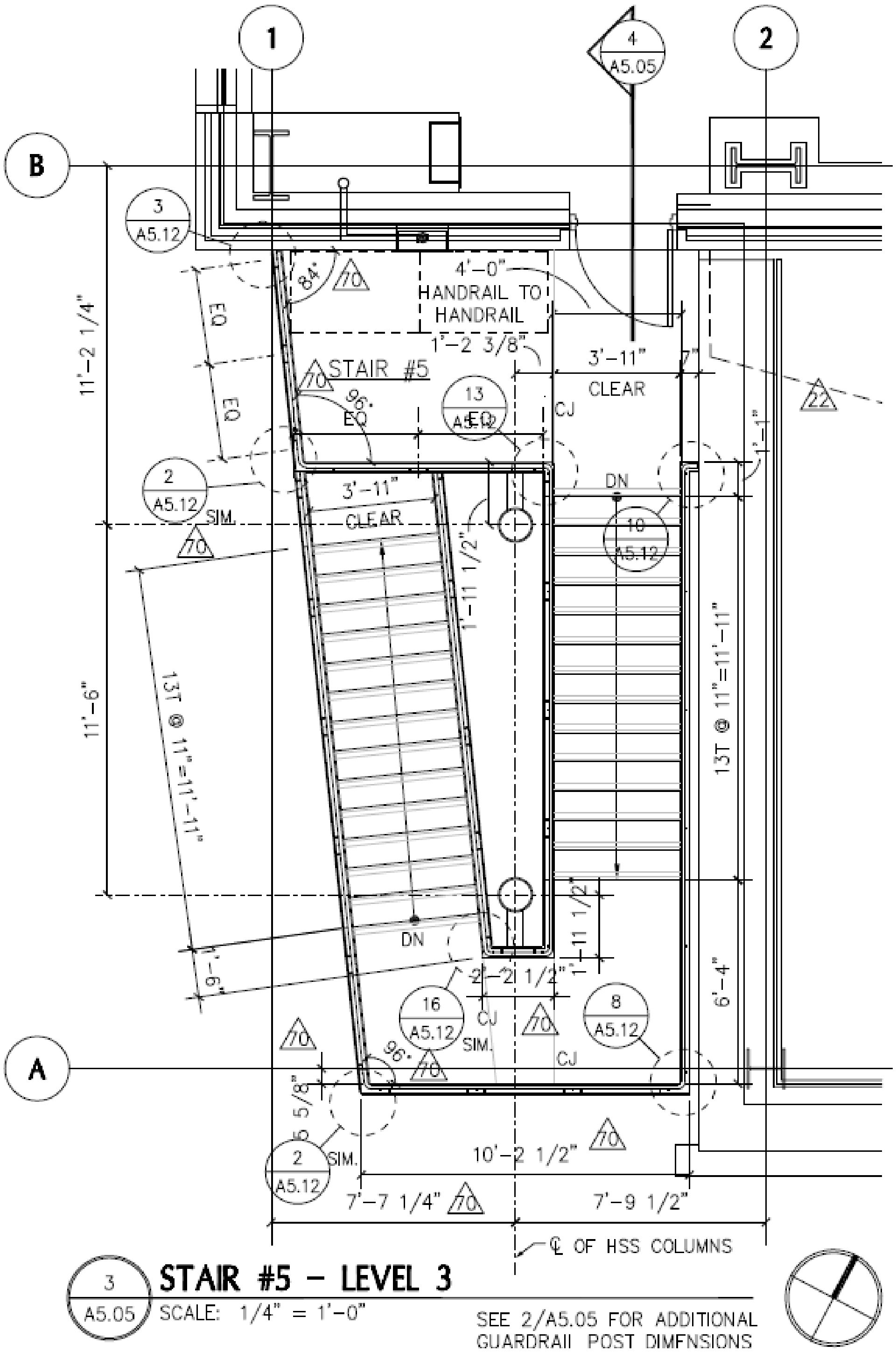


Figure D7 Stair Detail

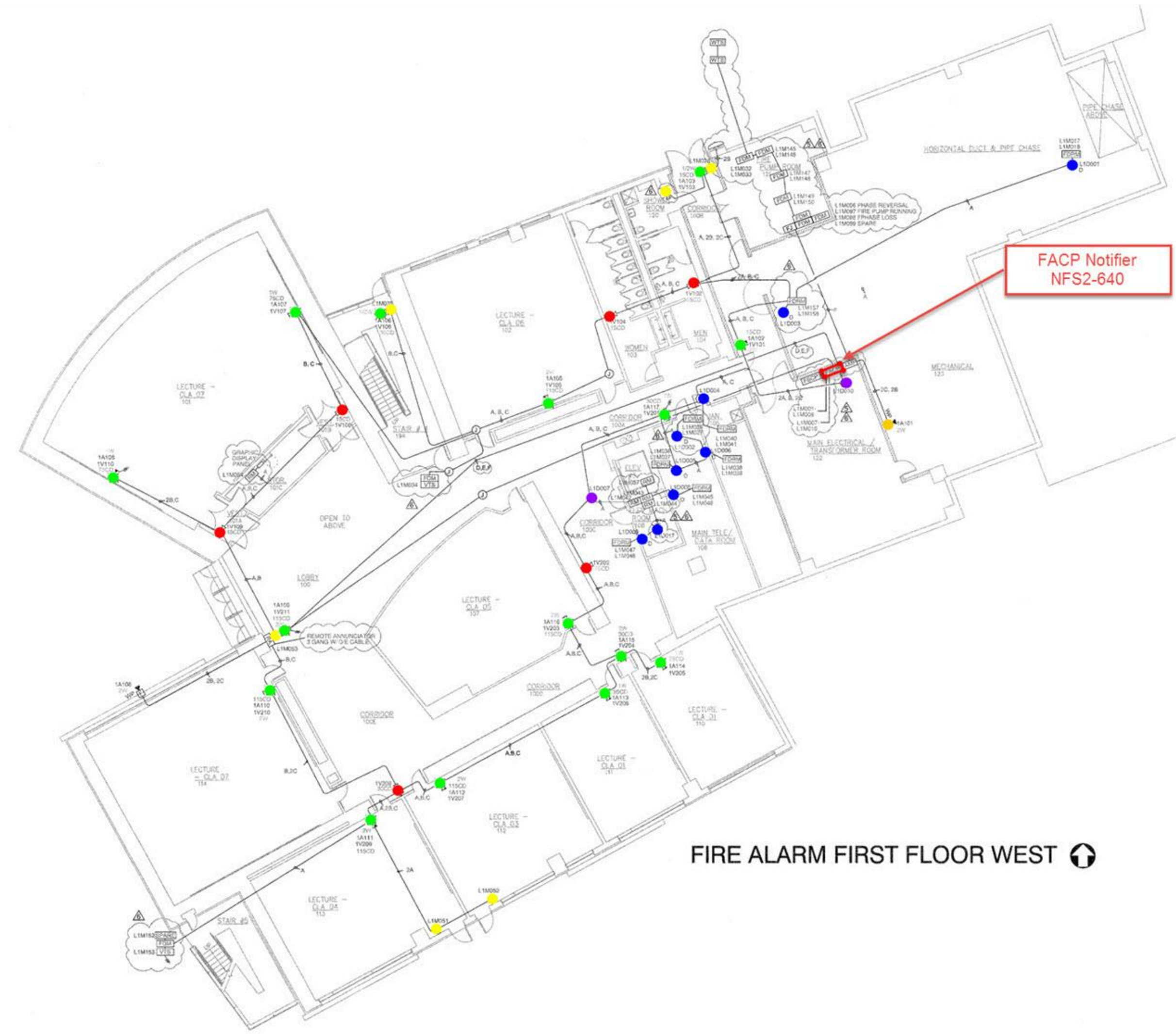
APPENDIX E-Fire Alarm Plans

FIRE ALARM PLANS

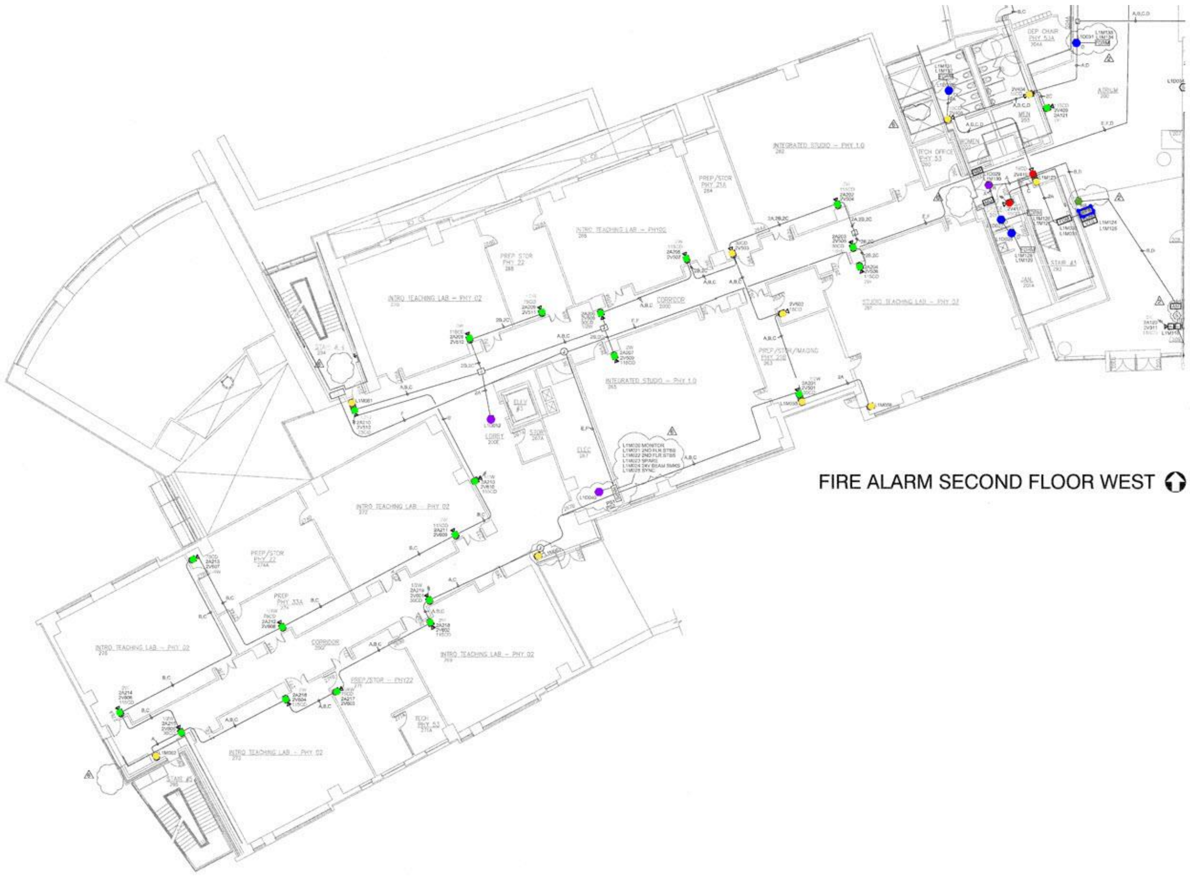
SYMBOL LEGEND

	COUNT	FIRE ALARM SYMBOLS		MODEL #	CSFM LISTING #
6	31		MANUAL PULL STATION	NBG-12LX	7150-0028:0199
	73		STROBE ONLY	SW	7320-1653:201
	165		SPEAKER/STROBE	SPWS	7320-1653:201
	6		SPEAKER ONLY	SPW	7320-1653:201
	7	WP	SPEAKER - WEATHER PROOF	SPWK	7320-1653:201
5	0	H	~~HEAT DETECTOR~~	~~FST-851~~	~~7270-0028:196~~
5	18		SMOKE DETECTOR	FSP-851	7272-0028:206
	64	D	SMOKE DETECTOR - DUCT	DNR	3242-1653:209
5	23	BT	BEAM SMOKE DETECTOR - TRANSMITTER	OSE-SPW	7260-1728:0121
2	15	BR	BEAM SMOKE DETECTOR- RECEIVER	OSI-90	7260-1728:0121
	1	FACP	FIRE ALARM CONTROL PANEL	NFS2-640	7165-0028:0243
	5	RNPS	REMOTE NOTIFICATION POWER SUPPLY	ACPS-610	7315-0028:248
6	4	FATC	FIRE ALARM TERMINAL CABINET	N/A	N/A
	32		END OF LINE RESISTOR	N/A	N/A
	2	RA	REMOTE ANNUNCIATOR	FDU-80	7120-0028:209
	8	MD	MAGNETIC DOOR HOLDER	N/A	BY OTHERS
6	21	AM	ADDRESSABLE MODULE	FMM-1	7300-0028:0219
6	12	RM	RELAY MODULE	FRM-1	7300-0028:219
	16	WFS	WATER FLOW SWITCH	N/A	BY OTHERS
6	10	VTS	VALVE TAMPER SWITCH	N/A	BY OTHERS
5	21	FDM	DUAL MONITOR MODULE	FDM-1	7300-0028:0219
	64	FDRM	DUAL RELAY / MONITOR MODULE	FDRM-1	7300-0028:0219
	12	FJ	FIRE FIGHTER'S PHONE JACKS	FTM-1	7300-1652:0182
	4	DAA2	DIGITAL AUDIO AMPLIFIERS	DAA2	7170-0028:223 7170-0028:224
	1	XP6-R	SIX RELAY CONTROL MODULE	XP6-R	7300-0028:0219
4	1	XP10-M	TEN-INPUT MONITOR MODULE	XP10-M	7300-0028:0219

APPENDIX E-FIRE ALARM PLANS

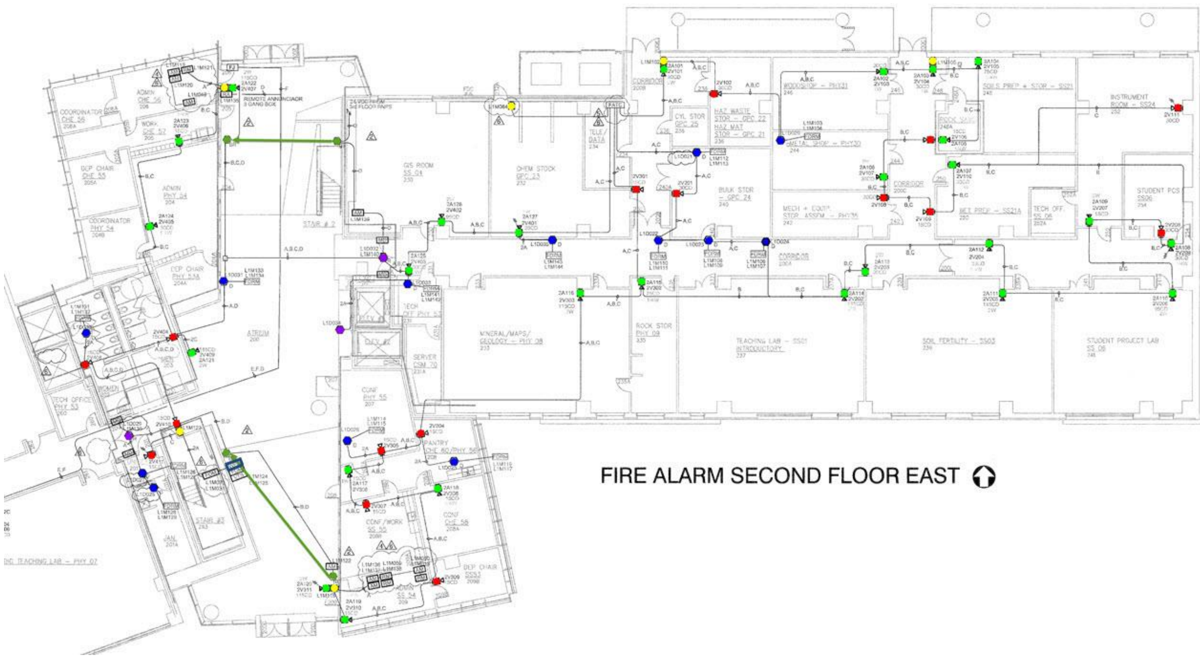


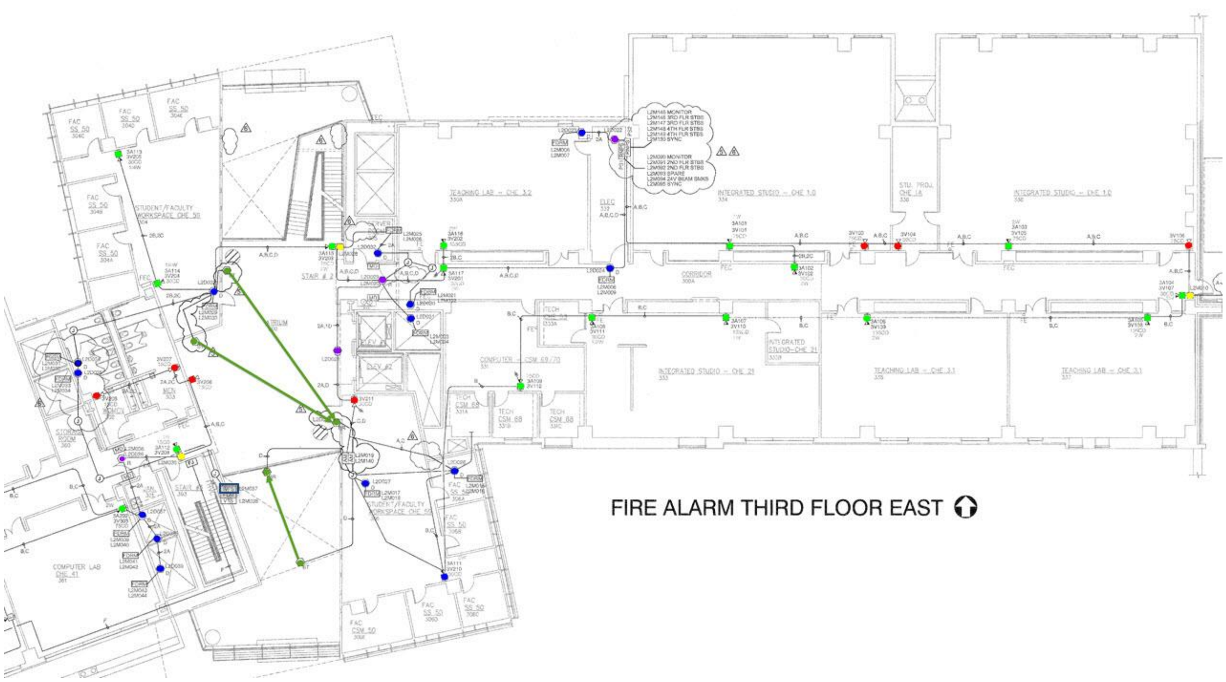
APPENDIX E-FIRE ALARM PLANS



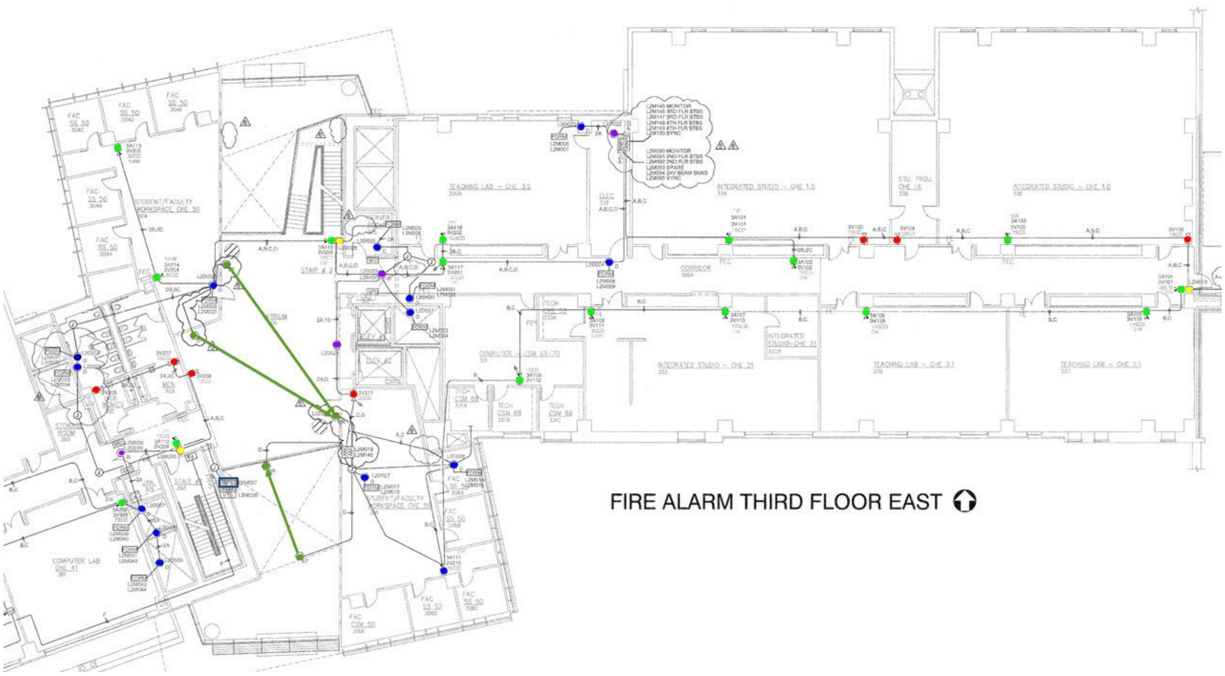
FIRE ALARM SECOND FLOOR WEST

APPENDIX E-FIRE ALARM PLANS





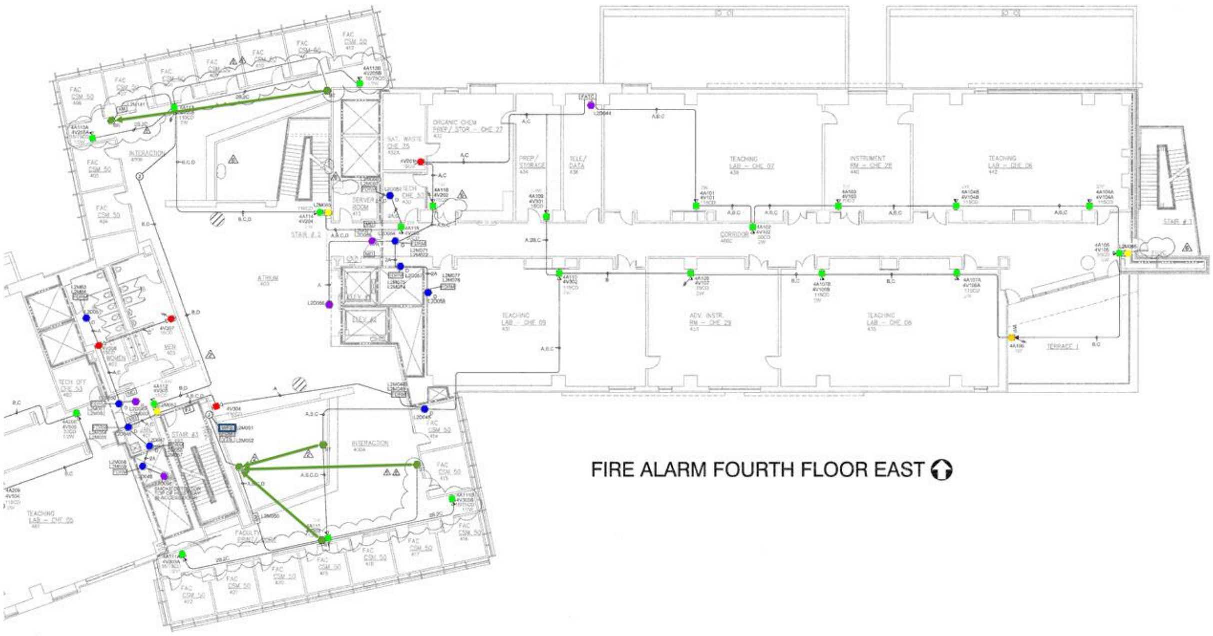
APPENDIX E-FIRE ALARM PLANS



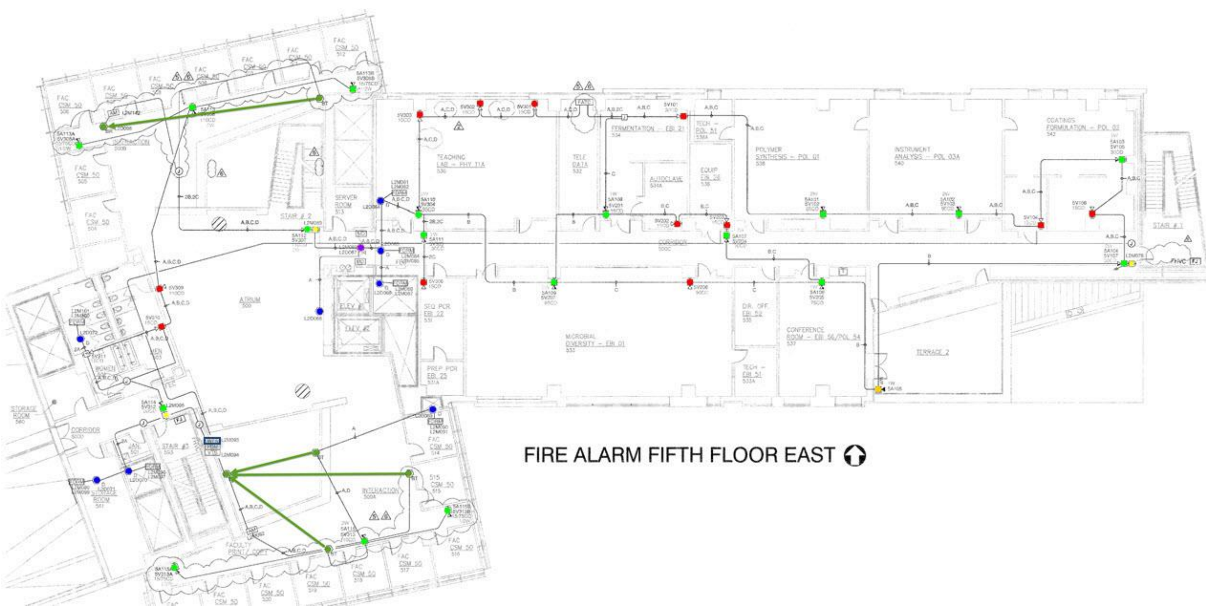
FIRE ALARM THIRD FLOOR EAST

FIRE ALARM FOURTH FLOOR WEST

APPENDIX E-FIRE ALARM PLANS

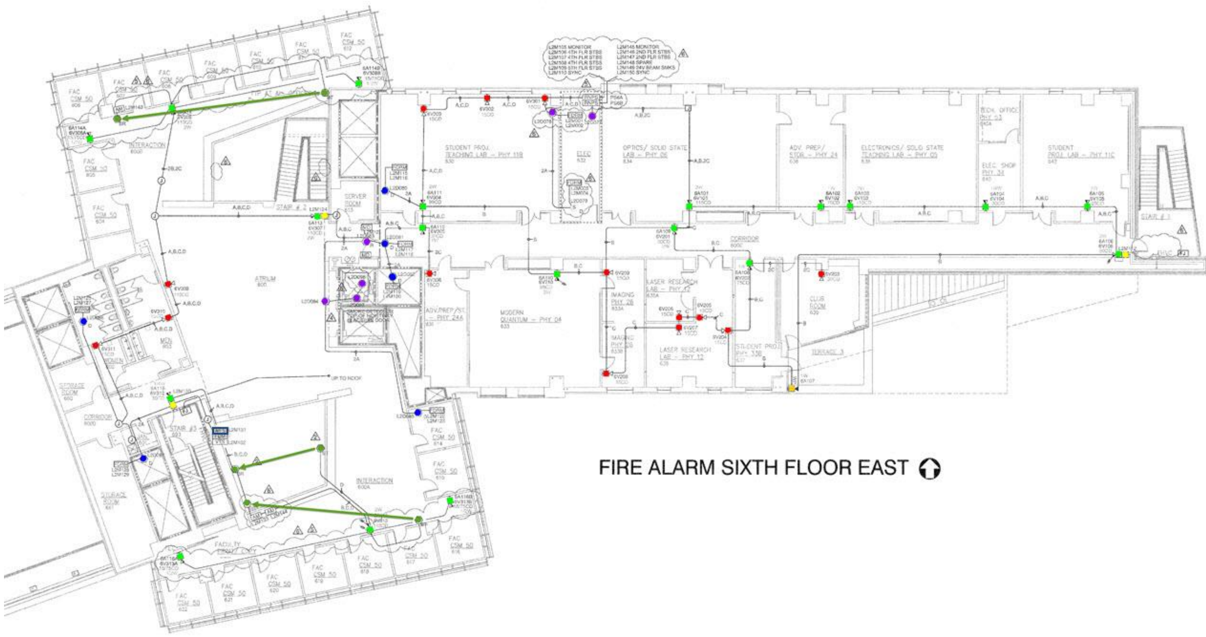


FIRE ALARM FOURTH FLOOR EAST



FIRE ALARM FIFTH FLOOR EAST

APPENDIX E-FIRE ALARM PLANS



FIRE ALARM SIXTH FLOOR EAST

APPENDIX E-FIRE ALARM PLANS

ACTION

EVENT	SUPERVISORY CONDITION AT FACU	TROUBLE CONDITION AT FACU	ALARM CONDITION AT FACU	ACTIVATE FIRE ALARM AUDIO/VISUAL DEVICES AND VOICE ALARM COMMUNICATION	DISPLAY TEXT ON LCD ANNUNCIATOR	ACTIVATE SHUNT TRIP RELAY	SHUTDOWN AIR HANDLER UNIT	ACTIVATE ELEVATOR RECALL	SHUTDOWN INDIVIDUAL ASSOCIATED DAMPERS	DEACTIVATE MAGNETIC DOOR HOLDERS	ACTIVATE SUPERVISORY SIGNAL TO RECEIVING STATION (CAMPUS POLICE)	ACTIVATE TROUBLE SIGNAL TO RECEIVING STATION (CAMPUS POLICE)	ACTIVATE ALARM DIALER SIGNAL TO RECEIVING STATION (CAMPUS POLICE)	BYPASS ALL ALARM OUTPUTS (NOTIFICATION, SHUNTS, RELAY OUTPUTS) FOR TESTING	OPEN ATRUIM DOORS WITH MOTORIZED DOOR OPERATORS	ACTIVATE ATRIUM PASSIVE SMOKE EVACUATION SYSTEM
FIRE ALARM CONTROL UNIT																
PANEL SUPERVISORY CONDITION (TEST BYBASS) ON ACM-24 AT	X				X						X			X		
PANEL TROUBLE CONDITION (AC POWER FAIL, LOW BATTERY, OPEN CIRCUIT, GROUND FAULT, ETC.)		X			X							X				
PANEL ALARM CONDITION			X	X	X		X			X			X			
MANUAL PULL STATION ACTIVATION			X	X	X					X			X			
SPOT SMOKE DETECTOR ACTIVATION			X	X	X					X			X			
DUCT SMOKE DETECTOR ACTIVATION			X	X	X				X	X			X			
AIR HANDLING UNIT DUCT SMOKE DETECTOR ACTIVATION			X	X	X		X						X			
SPRINKLER TAMPER SWITCH	X				X						X		X			
SPRINKLER WATER FLOW ACTIVATION			X	X	X					X			X			
FIRE PUMP RUNNING			X	X	X					X						
FIRE PUMP LOSS OF PH ASE	X				X						X					
FIRE PUMP PHASE REVERSAL	X				X						X		X			
HEAT DETECTOR ACTIVATION (ELEVATOR EQUIPMENT)			X	X	X	X				X			X			
ELEVATOR LOBBY/ EMR SMOKE / ELEVATOR HOISTWAYS			X	X	X			X		X			X			
SHUNT TRIP POWER SUPERVISION	X				X						X					
GENERAL ALARM (ANYWHERE WITHIN THE BUILDING)			X	X	X		X			X			X			
ATRIUM SMOKE CONTORL SYSTEM ALARM			X	X	X					X			X		X	X
BEAM SMOKE DETECTION WITHIN ATRIUM			X	X	X					X			X		X	X
PULL STATION WITHIN ATRIUM			X	X	X					X			X		X	X
SPRINKLER WATER FLOW WITHIN ATRIUM			X	X	X					X			X		X	X

VOLTAGE DROP AND BATTERY CALCULATIONS

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier FACP- Circuit 1V1
Area Covered	1st Floor West
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	1.016

	Distance	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	30	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
1V101	30	23.81	0.187	0.78%	0.066	System Sensor	SCR	ST	15
1V102	20	23.70	0.304	1.27%	0.066	System Sensor	SCR	ST	15
1V103	30	23.53	0.467	1.94%	0.066	System Sensor	SCR	ST	15
1V104	50	23.28	0.718	2.99%	0.066	System Sensor	SCR	ST	15
1V105	50	23.05	0.949	3.95%	0.210	System Sensor	SCR	ST	115
1V106	35	22.93	1.065	4.44%	0.094	System Sensor	SCR	ST	30
1V107	30	22.85	1.148	4.78%	0.158	System Sensor	SCR	ST	75
1V108	35	22.79	1.210	5.04%	0.066	System Sensor	SCR	ST	15
1V109	40	22.74	1.265	5.27%	0.066	System Sensor	SCR	ST	15
1V110	35	22.70	1.299	5.41%	0.158	System Sensor	SCR	ST	75
END		22.70	1.299	5.41%	0.000				
END		22.70	1.299	5.41%	0.000				
END		22.70	1.299	5.41%	0.000				
Totals	355	End of Line Voltage		**22.70**	1.016				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals Current	Totals Distance	Voltage Drop
1.016	355	**1.30**
End of Line Voltage		**22.70**
Percent Drop		5.41%

Standard Wire Resistance in Ohms per 1000 feet.
18=7.77 16=4.89 14=3.07 12=1.98 10=1.24
18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier FACP- Circuit 1V2
Area Covered	1st Floor West
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	1.829

	Distance	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	40	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
1V201	40	23.55	0.449	1.87%	0.094	System Sensor	SCR	ST	30
1V202	45	23.07	0.929	3.87%	0.158	System Sensor	SCR	ST	75
1V203	15	22.93	1.074	4.47%	0.210	System Sensor	SCR	ST	115
1V204	15	22.80	1.200	5.00%	0.094	System Sensor	SCR	ST	30
1V205	15	22.68	1.317	5.49%	0.158	System Sensor	SCR	ST	75
1V206	15	22.58	1.420	5.92%	0.181	System Sensor	SCR	ST	95
1V207	40	22.35	1.649	6.87%	0.210	System Sensor	SCR	ST	115
1V208	10	22.31	1.694	7.06%	0.094	System Sensor	SCR	ST	30
1V209	10	22.27	1.732	7.22%	0.210	System Sensor	SCR	ST	115
1V210	35	22.18	1.822	7.59%	0.210	System Sensor	SCR	ST	115
1V211	15	22.16	1.842	7.67%	0.210	System Sensor	SCR	ST	115
END		22.16	1.842	7.67%	0.000				
END		22.16	1.842	7.67%	0.000				
Totals	255	End of Line Voltage		**22.16**	1.829				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals Current	Totals Distance	Voltage Drop
1.829	255	**1.84**
End of Line Voltage		**22.16**
Percent Drop		7.67%

Standard Wire Resistance in Ohms per 1000 feet.
18=7.77 16=4.89 14=3.07 12=1.98 10=1.24
18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier RNPS, PS1- Circuit 2V1
Area Covered	2nd Floor East
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	1.042

	Distance	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	20	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
2V101	20	23.87	0.128	0.53%	0.094	System Sensor	SCR	ST	30
2V102	20	23.76	0.244	1.02%	0.094	System Sensor	SCR	ST	30
2V103	45	23.52	0.480	2.00%	0.094	System Sensor	SCR	ST	30
2V104	12	23.46	0.536	2.23%	0.094	System Sensor	SCR	ST	30
2V105	12	23.41	0.585	2.44%	0.066	System Sensor	SCR	ST	15
2V106	25	23.32	0.677	2.82%	0.158	System Sensor	SCR	ST	75
2V107	20	23.27	0.732	3.05%	0.094	System Sensor	SCR	ST	30
2V108	5	23.26	0.742	3.09%	0.094	System Sensor	SCR	ST	30
2V109	15	23.23	0.766	3.19%	0.066	System Sensor	SCR	ST	15
2V110	15	23.22	0.783	3.26%	0.094	System Sensor	SCR	ST	30
2V111	70	23.18	0.824	3.43%	0.094	System Sensor	SCR	ST	30
END		23.18	0.824	3.43%	0.000				
END		23.18	0.824	3.43%	0.000				
Totals	259	End of Line Voltage		**23.18**	1.042				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals Current	Totals Distance	Voltage Drop
1.042	259	**0.82**
End of Line Voltage		**23.18**
Percent Drop		3.43%

Standard Wire Resistance in Ohms per 1000 feet.
18=7.77 16=4.89 14=3.07 12=1.98 10=1.24
18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier RNPS, PS1- Circuit 2V2
Area Covered	2nd Floor East
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	1.137

	Distance	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	35	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
2V201	35	23.76	0.244	1.02%	0.094	System Sensor	SCR	ST	30
2V202	60	23.37	0.629	2.62%	0.210	System Sensor	SCR	ST	115
2V203	15	23.29	0.705	2.94%	0.094	System Sensor	SCR	ST	30
2V204	40	23.11	0.887	3.70%	0.094	System Sensor	SCR	ST	30
2V205	15	23.05	0.946	3.94%	0.210	System Sensor	SCR	ST	115
2V206	40	22.95	1.053	4.39%	0.181	System Sensor	SCR	ST	95
2V207	33	22.90	1.105	4.60%	0.066	System Sensor	SCR	ST	15
2V208	20	22.87	1.128	4.70%	0.094	System Sensor	SCR	ST	30
2V209	5	22.87	1.130	4.71%	0.094	System Sensor	SCR	ST	30
END		22.87	1.130	4.71%	0.000				
END		22.87	1.130	4.71%	0.000				
END		22.87	1.130	4.71%	0.000				
END		22.87	1.130	4.71%	0.000				
Totals	263	End of Line Voltage		**22.87**	1.137				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals Current	Totals Distance	Voltage Drop
1.137	263	**1.13**
End of Line Voltage		**22.87**
Percent Drop		4.71%

Standard Wire Resistance in Ohms per 1000 feet.
18=7.77 16=4.89 14=3.07 12=1.98 10=1.24
18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

APPENDIX E-FIRE ALARM PLANS

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier RNPS, PS1- Circuit 2V3
Area Covered	2nd Floor East
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	1.106

	Distance	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	22	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage: At Device	Voltage: Drop from source	Voltage: Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
2V301	22	23.85	0.149	0.62%	0.066	System Sensor	SCR	ST	15
2V302	22	23.71	0.290	1.21%	0.158	System Sensor	SCR	ST	75
2V303	15	23.63	0.371	1.55%	0.210	System Sensor	SCR	ST	115
2V304	55	23.40	0.598	2.49%	0.066	System Sensor	SCR	ST	15
2V305	10	23.36	0.635	2.65%	0.066	System Sensor	SCR	ST	15
2V306	10	23.33	0.668	2.79%	0.066	System Sensor	SCR	ST	15
2V307	10	23.30	0.698	2.91%	0.066	System Sensor	SCR	ST	15
2V308	17	23.26	0.740	3.08%	0.066	System Sensor	SCR	ST	15
2V309	25	23.21	0.793	3.30%	0.066	System Sensor	SCR	ST	15
2V310	30	23.16	0.843	3.51%	0.066	System Sensor	SCR	ST	15
2V311	5	23.15	0.850	3.54%	0.210	System Sensor	SCR	ST	115
END		23.15	0.850	3.54%	0.000				
END		23.15	0.850	3.54%	0.000				
Totals	221	End of Line Voltage		**23.15**	1.106				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals: Current	Totals: Distance	Voltage Drop
1.106	221	**0.85**
End of Line Voltage		**23.15**
Percent Drop		3.54%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier RNPS, PS1- Circuit 2V4
Area Covered	2nd Floor East
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	1.300

	Distance	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	22	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage: At Device	Voltage: Drop from source	Voltage: Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
2V401	22	23.82	0.176	0.73%	0.181	System Sensor	SCR	ST	95
2V402	22	23.67	0.327	1.36%	0.181	System Sensor	SCR	ST	95
2V403	15	23.59	0.413	1.72%	0.094	System Sensor	SCR	ST	30
2V404	55	23.30	0.698	2.91%	0.066	System Sensor	SCR	ST	15
2V405	10	23.25	0.746	3.11%	0.094	System Sensor	SCR	ST	30
2V406	10	23.21	0.788	3.28%	0.066	System Sensor	SCR	ST	15
2V407	10	23.17	0.826	3.44%	0.210	System Sensor	SCR	ST	115
2V408	17	23.13	0.868	3.62%	0.066	System Sensor	SCR	ST	15
2V409	25	23.08	0.921	3.84%	0.210	System Sensor	SCR	ST	115
2V410	30	23.05	0.945	3.94%	0.066	System Sensor	SCR	ST	15
2V411	5	23.05	0.947	3.95%	0.066	System Sensor	SCR	ST	15
END		23.05	0.947	3.95%	0.000				
END		23.05	0.947	3.95%	0.000				
Totals	221	End of Line Voltage		**23.05**	1.300				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals: Current	Totals: Distance	Voltage Drop
1.300	221	**0.95**
End of Line Voltage		**23.05**
Percent Drop		3.95%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier FACP- Circuit 2V5
Area Covered	2nd Floor West
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	1.808

	Distance	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	60	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage: At Device	Voltage: Drop from source	Voltage: Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
2V501	60	23.33	0.666	2.78%	0.094	System Sensor	SCR	ST	30
2V502	23	23.09	0.908	3.78%	0.066	System Sensor	SCR	ST	15
2V503	25	22.84	1.161	4.84%	0.094	System Sensor	SCR	ST	30
2V504	30	22.55	1.447	6.03%	0.210	System Sensor	SCR	ST	115
2V505	13	22.45	1.547	6.45%	0.094	System Sensor	SCR	ST	30
2V506	8	22.40	1.598	6.66%	0.210	System Sensor	SCR	ST	115
2V507	68	22.06	1.945	8.10%	0.210	System Sensor	SCR	ST	115
2V508	11	22.01	1.994	8.31%	0.094	System Sensor	SCR	ST	30
2V509	46	21.86	2.143	8.93%	0.210	System Sensor	SCR	ST	115
2V510	48	21.76	2.236	9.32%	0.210	System Sensor	SCR	ST	115
2V511	20	21.74	2.256	9.40%	0.158	System Sensor	SCR	ST	75
2V512	60	21.74	2.256	9.40%	0.158	System Sensor	SCR	ST	75
END		21.74	2.256	9.40%					
Totals	412	End of Line Voltage		**21.74**	1.808				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals: Current	Totals: Distance	Voltage Drop
1.808	412	**2.26**
End of Line Voltage		**21.74**
Percent Drop		9.40%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier FACP- Circuit 2V6
Area Covered	2nd Floor West
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	1.712

	Distance	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	40	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage: At Device	Voltage: Drop from source	Voltage: Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
2V601	40	23.58	0.420	1.75%	0.094	System Sensor	SCR	ST	30
2V602	30	23.28	0.719	2.99%	0.210	System Sensor	SCR	ST	115
2V603	30	23.02	0.978	4.07%	0.158	System Sensor	SCR	ST	75
2V604	25	22.83	1.170	4.87%	0.210	System Sensor	SCR	ST	115
2V605	30	22.64	1.361	5.67%	0.094	System Sensor	SCR	ST	30
2V606	20	22.52	1.477	6.16%	0.210	System Sensor	SCR	ST	115
2V607	60	22.25	1.749	7.29%	0.158	System Sensor	SCR	ST	75
2V608	40	22.11	1.891	7.88%	0.158	System Sensor	SCR	ST	75
2V609	50	21.98	2.020	8.41%	0.210	System Sensor	SCR	ST	115
2V610	25	21.95	2.052	8.55%	0.210	System Sensor	SCR	ST	115
END		21.95	2.052	8.55%	0.000				
END		21.95	2.052	8.55%	0.000				
END		21.95	2.052	8.55%	0.000				
Totals	350	End of Line Voltage		**21.95**	1.712				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals: Current	Totals: Distance	Voltage Drop
1.712	350	**2.05**
End of Line Voltage		**21.95**
Percent Drop		8.55%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

	Fire Alarm Voltage Drop Calculations		
Project Name	Cal Poly Building 52: Computer Math and Science		
Panel / Circuit #	Notifier RNPS, PS2- Circuit 3V1		
Area Covered	3rd Floor East		
Nominal System Voltage	24		
Minimum Device Voltage	20		
Total Circuit Current	1.920	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	48	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
3V101	48	23.43	0.566	2.36%	0.158	System Sensor	SCR	ST	75
3V102	8	23.35	0.652	2.72%	0.094	System Sensor	SCR	ST	30
3V103	38	22.96	1.042	4.34%	0.158	System Sensor	SCR	ST	75
3V104	8	22.88	1.116	4.65%	0.094	System Sensor	SCR	ST	30
3V105	25	22.67	1.333	5.55%	0.158	System Sensor	SCR	ST	75
3V106	40	22.36	1.642	6.84%	0.158	System Sensor	SCR	ST	75
3V107	11	22.28	1.716	7.15%	0.094	System Sensor	SCR	ST	30
3V108	15	22.19	1.809	7.54%	0.228	System Sensor	SCRH	ST	135
3V109	65	21.88	2.120	8.83%	0.228	System Sensor	SCRH	ST	135
3V110	33	21.77	2.231	9.30%	0.228	System Sensor	SCRH	ST	135
3V111	30	21.71	2.290	9.54%	0.094	System Sensor	SCR	ST	30
3V112	33	21.66	2.336	9.74%	0.228	System Sensor	SCRH	ST	135
END		21.66	2.336	9.74%	0.000				
Totals	354	End of Line Voltage		21.66	1.920				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage
Current	Distance	Drop
1.920	354	2.34
End of Line Voltage		21.66
Percent Drop		9.74%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

	Fire Alarm Voltage Drop Calculations		
Project Name	Cal Poly Building 52: Computer Math and Science		
Panel / Circuit #	Notifier RNPS, PS2- Circuit 3V2		
Area Covered	3rd Floor East		
Nominal System Voltage	24		
Minimum Device Voltage	20		
Total Circuit Current	1.212	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	80	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
3V201	80	23.40	0.595	2.48%	0.094	System Sensor	SCR	ST	30
3V202	10	23.34	0.664	2.77%	0.228	System Sensor	SCRH	ST	135
3V203	40	23.12	0.883	3.68%	0.158	System Sensor	SCR	ST	75
3V204	50	22.89	1.107	4.61%	0.094	System Sensor	SCR	ST	30
3V205	32	22.77	1.233	5.14%	0.094	System Sensor	SCR	ST	30
3V206	65	22.55	1.450	6.04%	0.158	System Sensor	SCR	ST	75
3V207	8	22.53	1.469	6.12%	0.066	System Sensor	SCR	ST	15
3V208	20	22.49	1.508	6.28%	0.066	System Sensor	SCR	ST	15
3V209	40	22.43	1.570	6.54%	0.066	System Sensor	SCR	ST	15
3V210	75	22.34	1.657	6.90%	0.094	System Sensor	SCR	ST	30
3V211	65	22.31	1.694	7.06%	0.094	System Sensor	SCR	ST	30
END		22.31	1.694	7.06%					
END		22.31	1.694	7.06%	0.000				
Totals	485	End of Line Voltage		22.31	1.212				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage
Current	Distance	Drop
1.212	485	1.69
End of Line Voltage		22.31
Percent Drop		7.06%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

	Fire Alarm Voltage Drop Calculations		
Project Name	Cal Poly Building 52: Computer Math and Science		
Panel / Circuit #	Notifier RNPS, PS5- Circuit 3V3		
Area Covered	3rd Floor West		
Nominal System Voltage	24		
Minimum Device Voltage	20		
Total Circuit Current	1.418	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	17	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
3V301	17	23.85	0.148	0.62%	0.094	System Sensor	SCR	ST	30
3V302	65	23.32	0.676	2.82%	0.094	System Sensor	SCR	ST	30
3V303	50	22.95	1.054	4.39%	0.158	System Sensor	SCR	ST	75
3V304	20	22.81	1.186	4.94%	0.094	System Sensor	SCR	ST	30
3V305	30	22.63	1.366	5.69%	0.158	System Sensor	SCR	ST	75
3V306	30	22.48	1.517	6.32%	0.158	System Sensor	SCR	ST	75
3V307	20	22.40	1.598	6.66%	0.158	System Sensor	SCR	ST	75
3V308	30	22.31	1.691	7.05%	0.094	System Sensor	SCR	ST	30
3V309	25	22.25	1.754	7.31%	0.094	System Sensor	SCR	ST	30
3V310	15	22.22	1.783	7.43%	0.158	System Sensor	SCR	ST	75
3V311	35	22.18	1.817	7.57%	0.158	System Sensor	SCR	ST	75
END		22.18	1.817	7.57%	0.000				
END		22.18	1.817	7.57%	0.000				
Totals	337	End of Line Voltage		22.18	1.418				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage
Current	Distance	Drop
1.418	337	1.82
End of Line Voltage		22.18
Percent Drop		7.57%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

	Fire Alarm Voltage Drop Calculations		
Project Name	Cal Poly Building 52: Computer Math and Science		
Panel / Circuit #	Notifier RNPS, PS5- Circuit 3V4		
Area Covered	3rd Floor West		
Nominal System Voltage	24		
Minimum Device Voltage	20		
Total Circuit Current	1.492	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	40	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
3V401	40	23.63	0.366	1.53%	0.094	System Sensor	SCR	ST	30
3V402	12	23.53	0.469	1.96%	0.066	System Sensor	SCR	ST	15
3V403	12	23.43	0.568	2.36%	0.066	System Sensor	SCR	ST	15
3V404	40	23.12	0.879	3.66%	0.094	System Sensor	SCR	ST	30
3V405	20	22.98	1.022	4.26%	0.181	System Sensor	SCR	ST	95
3V406	25	22.83	1.175	4.89%	0.094	System Sensor	SCR	ST	30
3V407	50	22.55	1.450	6.04%	0.094	System Sensor	SCR	ST	30
3V408	15	22.48	1.524	6.35%	0.158	System Sensor	SCR	ST	75
3V409	40	22.32	1.682	7.01%	0.210	System Sensor	SCR	ST	115
3V410	30	22.24	1.762	7.34%	0.181	System Sensor	SCR	ST	95
3V411	50	22.16	1.840	7.67%	0.094	System Sensor	SCR	ST	30
3V412	20	22.14	1.860	7.75%	0.066	System Sensor	SCR	ST	15
3V413	20	22.13	1.872	7.80%	0.094	System Sensor	SCR	ST	30
Totals	374	End of Line Voltage		22.13	1.492				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage
Current	Distance	Drop
1.492	374	1.87
End of Line Voltage		22.13
Percent Drop		7.80%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier RNPS, PS2- Circuit 4V1
Area Covered	4th Floor East
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	1.250

	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device: 50	14	3.07
Wire Gauge for balance of circuit	14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
4V101	50	23.62	0.384	1.60%	0.210	System Sensor	SCR	ST	115
4V102	20	23.49	0.511	2.13%	0.094	System Sensor	SCR	ST	30
4V103	25	23.34	0.657	2.74%	0.158	System Sensor	SCR	ST	75
4V104	46	23.12	0.879	3.66%	0.210	System Sensor	SCR	ST	115
4V105	41	22.98	1.025	4.27%	0.210	System Sensor	SCR	ST	115
4V106	120	22.70	1.296	5.40%	0.210	System Sensor	SCR	ST	115
4V107	53	22.65	1.347	5.61%	0.158	System Sensor	SCR	ST	75
END		22.65	1.347	5.61%	0.000				
END		22.65	1.347	5.61%	0.000				
END		22.65	1.347	5.61%	0.000				
END		22.65	1.347	5.61%	0.000				
END		22.65	1.347	5.61%	0.000				
END		22.65	1.347	5.61%	0.000				
Totals	355	End of Line Voltage		**22.65**	1.250				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals Current	Totals Distance	Voltage Drop
1.250	355	**1.35**
End of Line Voltage		**22.65**
Percent Drop		5.61%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than

the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier RNPS, PS2- Circuit 4V2
Area Covered	4th Floor East
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	0.722

	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device: 60	14	3.07
Wire Gauge for balance of circuit	14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
4V201	60	23.73	0.266	1.11%	0.066	System Sensor	SCR	ST	15
4V202	15	23.67	0.326	1.36%	0.158	System Sensor	SCR	ST	75
4V203	15	23.63	0.372	1.55%	0.094	System Sensor	SCR	ST	30
4V204	25	23.57	0.434	1.81%	0.202	System Sensor	SCR	ST	110
4V205	70	23.48	0.521	2.17%	0.202	System Sensor	SCR	ST	110
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
Totals	185	End of Line Voltage		**23.48**	0.722				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals Current	Totals Distance	Voltage Drop
0.722	185	**0.52**
End of Line Voltage		**23.48**
Percent Drop		2.17%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than

the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier RNPS, PS3- Circuit 4V3
Area Covered	4th Floor East
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	0.878

	Wire Gauge	Ohm's Per 1000
Distance from source to 1st device: 37	14	3.07
Wire Gauge for balance of circuit	14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
4V301	37	23.80	0.199	0.83%	0.066	System Sensor	SCR	ST	15
4V302	17	23.72	0.284	1.18%	0.210	System Sensor	SCR	ST	115
4V303	104	23.33	0.669	2.79%	0.202	System Sensor	SCR	ST	110
4V304	70	23.16	0.841	3.50%	0.202	System Sensor	SCR	ST	110
4V305	20	23.14	0.865	3.60%	0.066	System Sensor	SCR	ST	15
4V306	30	23.11	0.889	3.70%	0.066	System Sensor	SCR	ST	15
4V307	20	23.10	0.897	3.74%	0.066	System Sensor	SCR	ST	15
END		23.10	0.897	3.74%	0.000				
END		23.10	0.897	3.74%	0.000				
END		23.10	0.897	3.74%	0.000				
END		23.10	0.897	3.74%	0.000				
END		23.10	0.897	3.74%	0.000				
END		23.10	0.897	3.74%	0.000				
Totals	298	End of Line Voltage		**23.10**	0.878				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals Current	Totals Distance	Voltage Drop
0.878	298	**0.90**
End of Line Voltage		**23.10**
Percent Drop		3.74%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than

the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

APPENDIX E-FIRE ALARM PLANS

Fire Alarm Voltage Drop Calculations				
Project Name	Cal Poly Building 52: Computer Math and Science			
Panel / Circuit #	Notifier RNPS, PS5- Circuit 4V4			
Area Covered	4th Floor West			
Nominal System Voltage	24			
Minimum Device Voltage	20			
Total Circuit Current	0.897		Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	50		14	3.07
Wire Gauge for balance of circuit			14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
4V401	50	23.72	0.275	1.15%	0.094	System Sensor	SCR	ST	30
4V402	40	23.53	0.473	1.97%	0.066	System Sensor	SCR	ST	15
4V403	10	23.48	0.518	2.16%	0.094	System Sensor	SCR	ST	30
4V404	40	23.32	0.676	2.82%	0.210	System Sensor	SCR	ST	115
4V405	20	23.27	0.729	3.04%	0.181	System Sensor	SCR	ST	95
4V406	45	23.20	0.799	3.33%	0.158	System Sensor	SCR	ST	75
4V407	30	23.18	0.816	3.40%	0.094	System Sensor	SCR	ST	30
END	0	23.18	0.816	3.40%	0.000				
END	0	23.18	0.816	3.40%	0.000				
END	0	23.18	0.816	3.40%	0.000				
END	0	23.18	0.816	3.40%	0.000				
END	0	23.18	0.816	3.40%	0.000				
END	0	23.18	0.816	3.40%	0.000				
Totals	235	End of Line Voltage		**23.18**	0.897				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage Drop
Current	Distance	
0.897	235	**0.82**
End of Line Voltage		**23.18**
Percent Drop		3.40%

Standard Wire Resistance in Ohms per 1000 feet.
18=7.77 16=4.89 14=3.07 12=1.98 10=1.24
18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors
Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations				
Project Name	Cal Poly Building 52: Computer Math and Science			
Panel / Circuit #	Notifier RNPS, PS5- Circuit 4V5			
Area Covered	4th Floor West			
Nominal System Voltage	24			
Minimum Device Voltage	20			
Total Circuit Current	1.129		Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	37		14	3.07
Wire Gauge for balance of circuit			14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
4V501	37	23.74	0.256	1.07%	0.210	System Sensor	SCR	ST	115
4V502	50	23.46	0.539	2.24%	0.158	System Sensor	SCR	ST	75
4V503	7	23.43	0.571	2.38%	0.066	System Sensor	SCR	ST	15
4V504	25	23.32	0.678	2.83%	0.210	System Sensor	SCR	ST	115
4V505	40	23.20	0.797	3.32%	0.094	System Sensor	SCR	ST	30
4V506	30	23.13	0.869	3.62%	0.210	System Sensor	SCR	ST	115
4V507	35	23.09	0.908	3.78%	0.181	System Sensor	SCR	ST	95
END	0	23.09	0.908	3.78%	0.000				
END	0	23.09	0.908	3.78%	0.000				
END	0	23.09	0.908	3.78%	0.000				
END	0	23.09	0.908	3.78%	0.000				
END	0	23.09	0.908	3.78%	0.000				
END	0	23.09	0.908	3.78%	0.000				
Totals	224	End of Line Voltage		**23.09**	1.129				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage Drop
Current	Distance	
1.129	224	**0.91**
End of Line Voltage		**23.09**
Percent Drop		3.78%

Standard Wire Resistance in Ohms per 1000 feet.
18=7.77 16=4.89 14=3.07 12=1.98 10=1.24
18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors
Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations				
Project Name	Cal Poly Building 52: Computer Math and Science			
Panel / Circuit #	Notifier RNPS, PS3- Circuit 5V1			
Area Covered	5th Floor East			
Nominal System Voltage	24			
Minimum Device Voltage	20			
Total Circuit Current	0.776		Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	48		14	3.07
Wire Gauge for balance of circuit			14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
5V101	28	23.87	0.133	0.56%	0.094	System Sensor	SCR	ST	30
5V102	64	23.60	0.401	1.67%	0.181	System Sensor	SCR	ST	95
5V103	32	23.50	0.500	2.08%	0.181	System Sensor	SCR	ST	95
5V104	25	23.45	0.549	2.29%	0.066	System Sensor	SCR	ST	15
5V105	14	23.43	0.571	2.38%	0.094	System Sensor	SCR	ST	30
5V106	18	23.41	0.588	2.45%	0.066	System Sensor	SCR	ST	15
5V107	18	23.40	0.599	2.50%	0.094	System Sensor	SCR	ST	30
END		23.40	0.599	2.50%	0.000				
END		23.40	0.599	2.50%	0.000				
END		23.40	0.599	2.50%	0.000				
END		23.40	0.599	2.50%	0.000				
END		23.40	0.599	2.50%	0.000				
END		23.40	0.599	2.50%	0.000				
Totals	219	End of Line Voltage		**23.40**	0.776				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage Drop
Current	Distance	
0.776	219	**0.60**
End of Line Voltage		**23.40**
Percent Drop		2.50%

Standard Wire Resistance in Ohms per 1000 feet.
18=7.77 16=4.89 14=3.07 12=1.98 10=1.24
18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors
Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations				
Project Name	Cal Poly Building 52: Computer Math and Science			
Panel / Circuit #	Notifier RNPS, PS3- Circuit 5V2			
Area Covered	5th Floor East			
Nominal System Voltage	24			
Minimum Device Voltage	20			
Total Circuit Current	0.812		Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	35		14	3.07
Wire Gauge for balance of circuit			14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
5V201	35	23.83	0.174	0.73%	0.066	System Sensor	SCR	ST	15
5V202	20	23.73	0.266	1.11%	0.066	System Sensor	SCR	ST	15
5V203	15	23.67	0.329	1.37%	0.066	System Sensor	SCR	ST	15
5V204	5	23.65	0.348	1.45%	0.094	System Sensor	SCR	ST	30
5V205	20	23.59	0.411	1.71%	0.158	System Sensor	SCR	ST	75
5V206	33	23.52	0.485	2.02%	0.181	System Sensor	SCR	ST	95
5V207	33	23.48	0.521	2.17%	0.181	System Sensor	SCR	ST	95
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
END		23.48	0.521	2.17%	0.000				
Totals	161	End of Line Voltage		**23.48**	0.812				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage Drop
Current	Distance	
0.812	161	**0.52**
End of Line Voltage		**23.48**
Percent Drop		2.17%

Standard Wire Resistance in Ohms per 1000 feet.
18=7.77 16=4.89 14=3.07 12=1.98 10=1.24
18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors
Notes:
Wire resistance is doubled in the calculations for two wires (Positive and Negative)
The voltage calculated to the last device must not be lower than
the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

APPENDIX E-FIRE ALARM PLANS

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier RNPS, PS3- Circuit 5V3
Area Covered	5th Floor East
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	1.573

		Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	15	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
5V301	15	23.86	0.145	0.60%	0.066	System Sensor	SCR	ST	15
5V302	15	23.72	0.284	1.18%	0.066	System Sensor	SCR	ST	15
5V303	15	23.58	0.416	1.73%	0.066	System Sensor	SCR	ST	15
5V304	25	23.37	0.627	2.61%	0.181	System Sensor	SCR	ST	95
5V305	8	23.31	0.686	2.86%	0.094	System Sensor	SCR	ST	30
5V306	15	23.21	0.787	3.28%	0.066	System Sensor	SCR	ST	15
5V307	60	22.83	1.168	4.87%	0.202	System Sensor	SCR	ST	110
5V308	70	22.47	1.526	6.36%	0.202	System Sensor	SCR	ST	110
5V309	45	22.30	1.700	7.08%	0.202	System Sensor	SCR	ST	110
5V310	10	22.27	1.726	7.19%	0.066	System Sensor	SCR	ST	15
5V311	20	22.23	1.771	7.38%	0.066	System Sensor	SCR	ST	15
5V312	30	22.17	1.825	7.61%	0.094	System Sensor	SCR	ST	30
5V313	80	22.08	1.924	8.02%	0.202	System Sensor	SCR	ST	110
Totals	408	End of Line Voltage		**22.08**	1.573				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage
Current	Distance	Drop
1.573	408	**1.92**
End of Line Voltage		**22.08**
Percent Drop		8.02%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than

the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier RNPS, PS4- Circuit 6V1
Area Covered	6th Floor East
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	0.947

		Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	50	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
6V101	50	23.71	0.291	1.21%	0.210	System Sensor	SCR	ST	115
6V102	32	23.56	0.436	1.81%	0.158	System Sensor	SCR	ST	75
6V103	10	23.53	0.471	1.96%	0.210	System Sensor	SCR	ST	115
6V104	32	23.46	0.544	2.26%	0.094	System Sensor	SCR	ST	30
6V105	25	23.41	0.586	2.44%	0.181	System Sensor	SCR	ST	95
6V106	20	23.40	0.597	2.49%	0.094	System Sensor	SCR	ST	30
END		23.40	0.597	2.49%					
END		23.40	0.597	2.49%					
END		23.40	0.597	2.49%					
END		23.40	0.597	2.49%					
END		23.40	0.597	2.49%					
END		23.40	0.597	2.49%					
END		23.40	0.597	2.49%					
Totals	169	End of Line Voltage		**23.40**	0.947				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage
Current	Distance	Drop
0.947	169	**0.60**
End of Line Voltage		**23.40**
Percent Drop		2.49%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than

the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Voltage Drop Calculations

Project Name	Cal Poly Building 52: Computer Math and Science
Panel / Circuit #	Notifier RNPS, PS4- Circuit 6V2
Area Covered	6th Floor East
Nominal System Voltage	24
Minimum Device Voltage	20
Total Circuit Current	0.923

		Wire Gauge	Ohm's Per 1000
Distance from source to 1st device	62	14	3.07
Wire Gauge for balance of circuit		14	3.07

Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
6V201	62	23.65	0.351	1.46%	0.094	System Sensor	SCR	ST	30
6V202	30	23.50	0.504	2.10%	0.158	System Sensor	SCR	ST	75
6V203	20	23.41	0.586	2.44%	0.094	System Sensor	SCR	ST	30
6V204	45	23.25	0.746	3.11%	0.066	System Sensor	SCR	ST	15
6V205	10	23.22	0.777	3.24%	0.066	System Sensor	SCR	ST	15
6V206	10	23.20	0.805	3.35%	0.066	System Sensor	SCR	ST	15
6V207	5	23.18	0.816	3.40%	0.066	System Sensor	SCR	ST	15
6V208	30	23.13	0.874	3.64%	0.066	System Sensor	SCR	ST	15
6V209	30	23.08	0.919	3.83%	0.066	System Sensor	SCR	ST	15
6V210	15	23.06	0.936	3.90%	0.181	System Sensor	SCR	ST	95
END		23.06	0.936	3.90%					
END		23.06	0.936	3.90%					
END		23.06	0.936	3.90%					
Totals	257	End of Line Voltage		**23.06**	0.923				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage
Current	Distance	Drop
0.923	257	**0.94**
End of Line Voltage		**23.06**
Percent Drop		3.90%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than

the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

APPENDIX E-FIRE ALARM PLANS

	Fire Alarm Voltage Drop Calculations								
Project Name	Cal Poly Building 52: Computer Math and Science								
Panel / Circuit #	Notifier RNPS, PS4- Circuit 6V3								
Area Covered	6th Floor East								
Nominal System Voltage		24							
Minimum Device Voltage		20							
Total Circuit Current	1.573		Wire Gauge	Ohm's Per 1000					
Distance from source to 1st device		12	14	3.07					
Wire Gauge for balance of circuit			14	3.07					
Device Number	Distance from previous device	Voltage At Device	Voltage Drop from source	Voltage Percent Drop	Current in amps.	Device Model #		Device Type	Candela Rating
6V301	12	23.88	0.116	0.48%	0.066	System Sensor	SCR	ST	15
6V302	12	23.77	0.227	0.95%	0.066	System Sensor	SCR	ST	15
6V303	12	23.67	0.333	1.39%	0.066	System Sensor	SCR	ST	15
6V304	20	23.50	0.502	2.09%	0.181	System Sensor	SCR	ST	95
6V305	10	23.42	0.575	2.40%	0.094	System Sensor	SCR	ST	30
6V306	10	23.36	0.643	2.68%	0.066	System Sensor	SCR	ST	15
6V307	25	23.20	0.802	3.34%	0.202	System Sensor	SCR	ST	110
6V308	75	22.82	1.185	4.94%	0.202	System Sensor	SCR	ST	110
6V309	50	22.62	1.378	5.74%	0.202	System Sensor	SCR	ST	110
6V310	15	22.58	1.417	5.91%	0.066	System Sensor	SCR	ST	15
6V311	20	22.54	1.462	6.09%	0.066	System Sensor	SCR	ST	15
6V312	25	22.49	1.507	6.28%	0.094	System Sensor	SCR	ST	30
6V313	80	22.39	1.607	6.69%	0.202	System Sensor	SCR	ST	110
Totals	366	End of Line Voltage		**22.39**	1.573				

Point to Point Method

CIRCUIT IS WITHIN LIMITS

Totals		Voltage
Current	Distance	Drop
1.573	366	**1.61**
End of Line Voltage		**22.39**
Percent Drop		6.69%

Standard Wire Resistance in Ohms per 1000 feet.

18=7.77 16=4.89 14=3.07 12=1.98 10=1.24

18-14 Awg = Solid Conductors 12-10 Awg = Stranded Conductors

Notes:

Wire resistance is doubled in the calculations for two wires (Positive and Negative)

The voltage calculated to the last device must not be lower than

the manufactures listed minimum operating voltage (IE: rated operating voltage 20-32 VDC).

Fire Alarm Control Panel Battery Calculation

Battery Calculations for: FACP Notifier NFS-640 | Project: Cal Poly Building 52

ITEM	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QTY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QTY		TOTAL ALARM CURRENT PER ITEM
FACP	Fire Alarm Control Unit	0.2850	X	1	=	0.2850	0.2850	X	1	=	0.2850
UDACT	Universal Dialer	0.0400	X	1	=	0.0400	0.1000	X	1	=	0.1000
FDU-80	Remote Annunciator	0.0643	X	2	=	0.1286	0.0643	X	2	=	0.1286
APS-6	Power Supply Amp	0.0000	X	1	=	0.0000	0.0250	X	1	=	0.0250
OSE-SPV	Beam Smoke Emitter	0.0035	X	10	=	0.0350	0.0035	X	10	=	0.0350
OSI-90	Beam Smoke Imager	0.0310	X	10	=	0.3100	0.0310	X	10	=	0.3100
PULL	Manual Pull (addressable)	0.0004	X	29	=	0.0116	0.0004	X	29	=	0.0116
FRM-1	Relay Module	0.0017	X	9	=	0.0153	0.0022	X	9	=	0.0198
FSP-851	Smoke Detector	0.0003	X	16	=	0.0048	0.0003	X	16	=	0.0048
FDM-1	Dual Monitor Module	0.0008	X	18	=	0.0144	0.0064	X	18	=	0.1152
SPK	Speaker Only	0.0000	X	3	=	0.0000	0.0008	X	3	=	0.0024
SR	Strobe Only 15CD	0.0000	X	7	=	0.0000	0.0660	X	7	=	0.4620
SR	Strobe Only 30CD	0.0000	X	6	=	0.0000	0.0940	X	6	=	0.5640
SR	Strobe Only 75CD	0.0000	X	2	=	0.0000	0.1580	X	2	=	0.3160
FTM-1	Fire Fighter Phone Jack	0.0075	X	12	=	0.0900	0.0075	X	12	=	0.0900
XP6-R	Six Relay Control Module	0.0015	X	1	=	0.0015	0.0320	X	1	=	0.0320
XP10-M	10-Input Monitor Module	0.0035	X	1	=	0.0035	0.0550	X	1	=	0.0550
SPSR	Speaker Strobes 15CD	0.0000	X	3	=	0.0000	0.0710	X	3	=	0.2130
SPSR	Speaker Strobes 30CD	0.0000	X	14	=	0.0000	0.0960	X	14	=	1.3440
SPSR	Speaker Strobes 75CD	0.0000	X	14	=	0.0000	0.1530	X	14	=	2.1420
SPSR	Speaker Strobes 95CD	0.0000	X	3	=	0.0000	0.1760	X	3	=	0.5280
SPSR	Speaker Strobes 115CD	0.0000	X	16	=	0.0000	0.2050	X	16	=	3.2800
FST-851	Heat Detector (addresable)	0.0004	X	4	=	0.0016	0.0004	X	4	=	0.0016
FMM-1	Monitor Module	0.0037	X	19	=	0.0703	0.0037	X	19	=	0.0703
FDRM-1	Dual Relay/Monitor Module	0.0013	X	64	=	0.0832	0.0240	X	64	=	1.5360
DNR	Duct Smoke Detectors	0.0003	X	64	=	0.0192	0.0003	X	64	=	0.0192
				TOTAL SYSTEM STANDBY CURRENT (AMPS)		1.1140		TOTAL SYSTEM ALARM CURRENT (AMPS)			11.6905

REQUIRED STANDBY TIME (HRS)		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS)		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
24	X	1.1140	=	26.7348	0.250	X	11.6905	=	2.9226

REQUIRED STANDBY CAPACITY (AMP-HOURS)		REQUIRED ALARM CAPACITY (AMP-HOURS)		TOTAL CAPACITY (AMP-HOURS)	TOTAL CAPACITY (AMP-HOURS)		SAFETY FACTOR (%)		ADJUSTED BATTERY CAPACITY (AMP-HOURS)
26.73	+	2.9226	=	29.6574	29.6574	+	20%	=	35.6

Fire Alarm Control Panel Battery Calculation

Battery Calculations for: RNPS 3- 5TH FLOOR EAST | Project: Cal Poly Building 52

ITEM	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QTY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QTY		TOTAL ALARM CURRENT PER ITEM
RNPS	Remote Power Supply	0.1300	X	1	=	0.1300	0.1300	X	1	=	0.1300
SPK	Speaker Only	0.0000	X	1	=	0.0000	0.0008	X	1	=	0.0008
SR	Strobe Only 15CD	0.0000	X	15	=	0.0000	0.0660	X	15	=	0.9900
SR	Strobe Only 30CD	0.0000	X	6	=	0.0000	0.0940	X	6	=	0.5640
SR	Strobe Only 75CD	0.0000	X	1	=	0.0000	0.1580	X	1	=	0.1580
SR	Strobe Only 95CD	0.0000	X	5	=	0.0000	0.1810	X	1	=	0.1810
SR	Strobe Only 110CD	0.0000	X	6	=	0.0000	0.2020	X	6	=	1.2120
SR	Strobe Only 115CD	0.0000	X	1	=	0.0000	0.2100	X	1	=	0.2100
SRH	Strobe Only 135CD	0.0000	X	0	=	0.0000	0.2280	X	0	=	0.0000
				TOTAL SYSTEM STANDBY CURRENT (AMPS)		0.1300		TOTAL SYSTEM ALARM CURRENT (AMPS)			3.4458

REQUIRED STANDBY TIME (HRS) UFC 4-021-01 & UFC3-600-10N		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) UFC 4-021-01 & UFC3-600-10N		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
24	X	0.1300	=	3.1200	0.250	X	3.4458	=	0.8615

REQUIRED STANDBY CAPACITY (AMP-HOURS)		REQUIRED ALARM CAPACITY (AMP-HOURS)		TOTAL CAPACITY (AMP-HOURS)	TOTAL CAPACITY (AMP-HOURS)		SAFETY FACTOR (%)		ADJUSTED BATTERY CAPACITY (AMP-HOURS)
3.12	+	0.8615	=	3.9815	3.9815	+	20%	=	4.8

APPENDIX E-FIRE ALARM PLANS

Fire Alarm Control Panel Battery Calculation

Battery Calculations for:	RNPS 1- 2ND FLOOR EAST	Project:	Cal Poly Building 52

ITEM	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QTY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QTY		TOTAL ALARM CURRENT PER ITEM
RNPS	Remote Power Supply	0.1300	X	1	=	0.1300	0.1300	X	1	=	0.1300
SPK	Speaker Only	0.0000	X	0	=	0.0000	0.0008	X	0	=	0.0000
SR	Strobe Only 15CD	0.0000	X	16	=	0.0000	0.0660	X	16	=	1.0560
SR	Strobe Only 30CD	0.0000	X	16	=	0.0000	0.0940	X	16	=	1.5040
SR	Strobe Only 75CD	0.0000	X	2	=	0.0000	0.1580	X	2	=	0.3160
SR	Strobe Only 95CD	0.0000	X	3	=	0.0000	0.1810	X	1	=	0.1810
SR	Strobe Only 115CD	0.0000	X	6	=	0.0000	0.2100	X	6	=	1.2600
					TOTAL SYSTEM STANDBY CURRENT (AMPS)	0.1300				TOTAL SYSTEM ALARM CURRENT (AMPS)	4.4470

REQUIRED STANDBY TIME (HRS) UFC 4-021-01 & UFC3-600-10N		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) UFC 4-021-01 & UFC3-600-10N		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
24	X	0.1300	=	3.1200	0.250	X	4.4470	=	1.1118

REQUIRED STANDBY CAPACITY (AMP-HOURS)		REQUIRED ALARM CAPACITY (AMP-HOURS)		TOTAL CAPACITY (AMP-HOURS)	TOTAL CAPACITY (AMP-HOURS)		SAFETY FACTOR (%)		ADJUSTED BATTERY CAPACITY (AMP-HOURS)
3.12	+	1.1118	=	4.2318	4.2318	+	20%	=	5.1

Fire Alarm Control Panel Battery Calculation

Battery Calculations for:	RNPS 4- 6TH FLOOR EAST	Project:	Cal Poly Building 52

ITEM	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QTY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QTY		TOTAL ALARM CURRENT PER ITEM
RNPS	Remote Power Supply	0.1300	X	1	=	0.1300	0.1300	X	1	=	0.1300
SPK	Speaker Only	0.0000	X	1	=	0.0000	0.0008	X	1	=	0.0008
SR	Strobe Only 15CD	0.0000	X	12	=	0.0000	0.0660	X	12	=	0.7920
SR	Strobe Only 30CD	0.0000	X	6	=	0.0000	0.0940	X	6	=	0.5640
SR	Strobe Only 75CD	0.0000	X	2	=	0.0000	0.1580	X	2	=	0.3160
SR	Strobe Only 95CD	0.0000	X	3	=	0.0000	0.1810	X	1	=	0.1810
SR	Strobe Only 110CD	0.0000	X	4	=	0.0000	0.2020	X	4	=	0.8080
SR	Strobe Only 115CD	0.0000	X	2	=	0.0000	0.2100	X	2	=	0.4200
SRH	Strobe Only 135CD	0.0000	X	0	=	0.0000	0.2280	X	0	=	0.0000
					TOTAL SYSTEM STANDBY CURRENT (AMPS)	0.1300				TOTAL SYSTEM ALARM CURRENT (AMPS)	3.2118

REQUIRED STANDBY TIME (HRS) UFC 4-021-01 & UFC3-600-10N		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) UFC 4-021-01 & UFC3-600-10N		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
24	X	0.1300	=	3.1200	0.250	X	3.2118	=	0.8030

REQUIRED STANDBY CAPACITY (AMP-HOURS)		REQUIRED ALARM CAPACITY (AMP-HOURS)		TOTAL CAPACITY (AMP-HOURS)	TOTAL CAPACITY (AMP-HOURS)		SAFETY FACTOR (%)		ADJUSTED BATTERY CAPACITY (AMP-HOURS)
3.12	+	0.8030	=	3.9230	3.9230	+	20%	=	4.7

Fire Alarm Control Panel Battery Calculation

Battery Calculations for:	RNPS 2- 3RD & 4TH FLOOR EAST	Project:	Cal Poly Building 52

ITEM	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QTY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QTY		TOTAL ALARM CURRENT PER ITEM
RNPS	Remote Power Supply	0.1300	X	1	=	0.1300	0.1300	X	1	=	0.1300
SPK	Speaker Only	0.0000	X	1	=	0.0000	0.0008	X	1	=	0.0008
SR	Strobe Only 15CD	0.0000	X	4	=	0.0000	0.0660	X	4	=	0.2640
SR	Strobe Only 30CD	0.0000	X	12	=	0.0000	0.0940	X	12	=	1.1280
SR	Strobe Only 75CD	0.0000	X	9	=	0.0000	0.1580	X	9	=	1.4220
SR	Strobe Only 95CD	0.0000	X	0	=	0.0000	0.1810	X	1	=	0.1810
SR	Strobe Only 110CD	0.0000	X	2	=	0.0000	0.2020	X	2	=	0.4040
SR	Strobe Only 115CD	0.0000	X	5	=	0.0000	0.2100	X	5	=	1.0500
SRH	Strobe Only 135CD	0.0000	X	5	=	0.0000	0.2280	X	5	=	1.1400
					TOTAL SYSTEM STANDBY CURRENT (AMPS)	0.1300				TOTAL SYSTEM ALARM CURRENT (AMPS)	5.7198

REQUIRED STANDBY TIME (HRS) UFC 4-021-01 & UFC3-600-10N		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) UFC 4-021-01 & UFC3-600-10N		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
24	X	0.1300	=	3.1200	0.250	X	5.7198	=	1.4300

REQUIRED STANDBY CAPACITY (AMP-HOURS)		REQUIRED ALARM CAPACITY (AMP-HOURS)		TOTAL CAPACITY (AMP-HOURS)	TOTAL CAPACITY (AMP-HOURS)		SAFETY FACTOR (%)		ADJUSTED BATTERY CAPACITY (AMP-HOURS)
3.12	+	1.4300	=	4.5500	4.5500	+	20%	=	5.5

Fire Alarm Control Panel Battery Calculation

Battery Calculations for:	RNPS 5- 4TH FLOOR WEST	Project:	Cal Poly Building 52

ITEM	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QTY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QTY		TOTAL ALARM CURRENT PER ITEM
RNPS	Remote Power Supply	0.1300	X	1	=	0.1300	0.1300	X	1	=	0.1300
SPK	Speaker Only	0.0000	X	1	=	0.0000	0.0008	X	1	=	0.0008
SR	Strobe Only 15CD	0.0000	X	5	=	0.0000	0.0660	X	5	=	0.3300
SR	Strobe Only 30CD	0.0000	X	16	=	0.0000	0.0940	X	16	=	1.5040
SR	Strobe Only 75CD	0.0000	X	8	=	0.0000	0.1580	X	8	=	1.2640
SR	Strobe Only 95CD	0.0000	X	4	=	0.0000	0.1810	X	1	=	0.1810
SR	Strobe Only 110CD	0.0000	X	0	=	0.0000	0.2020	X	0	=	0.0000
SR	Strobe Only 115CD	0.0000	X	5	=	0.0000	0.2100	X	5	=	1.0500
SRH	Strobe Only 135CD	0.0000	X	0	=	0.0000	0.2280	X	0	=	0.0000
					TOTAL SYSTEM STANDBY CURRENT (AMPS)	0.1300				TOTAL SYSTEM ALARM CURRENT (AMPS)	4.4598

REQUIRED STANDBY TIME (HRS) UFC 4-021-01 & UFC3-600-10N		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) UFC 4-021-01 & UFC3-600-10N		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
24	X	0.1300	=	3.1200	0.250	X	4.4598	=	1.1150

REQUIRED STANDBY CAPACITY (AMP-HOURS)		REQUIRED ALARM CAPACITY (AMP-HOURS)		TOTAL CAPACITY (AMP-HOURS)	TOTAL CAPACITY (AMP-HOURS)		SAFETY FACTOR (%)		ADJUSTED BATTERY CAPACITY (AMP-HOURS)
3.12	+	1.1150	=	4.2350	4.2350	+	20%	=	5.1

APPENDIX F-Fire Test Data

SP.SE, ITEM 3:12 FIRE TEST DATA

HRR Data truncated at 420 seconds.

Keyword	Value
Material1	Fabric: 100% Polyester FR Treated ; Interliner: Polyester Wadding
Material2	HR Urethane Foam
Material3	
Material4	
Product	
Object	CBUF 3:12 Three seat sofa
Scenario	
Method	Furniture full-scale calorimeter (CBUF)
Reference	CBUF - Fire Safety of Upholstered Furniture, EC Report EUR 16477 EN, contact SP for more information.
Comment	Loose seat and back fully upholstered to ground
Owner	
IsPublic	1
ImportDate	2005-11-03 16:26:15

Scalar	Value
Peak heat release (kW)	1439.9
Total heat release (MJ)	437.4
Initial mass (g)	32006
Total massloss (g)	18550
Average heat of combustion (MJ/kg)	23.58

Time (s)	HRR (kW)	SPR (m2/s)
0	0	0
6	7.053	0
12	20.026	.004
18	24.969	.019
24	37.856	.065
30	44.466	.158
36	48.315	.22
42	51.663	.269
48	56.306	.308
54	58.986	.454
60	80.827	.614
66	95.983	1.191

72	107.715	.973
78	123.611	1.498
84	142.203	1.684
90	148.371	2.072
96	173.596	2.391
102	184.456	2.271
108	199.014	2.888
114	215.029	2.647
120	232.567	2.769
126	212.754	3.013
132	197.458	2.229
138	196.56	2.202
144	209.69	2.314
150	343.721	4.201
156	548.274	8.61
162	642.997	9.672
168	690.457	10.881
174	900.096	11.833
180	1112.078	16.014
186	1236.452	16.796
192	1336.187	17.78
198	1357.041	17.569
204	1317.458	17.012
210	1340.853	16.905
216	1395.516	17.931
222	1374.599	16.991
228	1433.223	16.339
234	1421.362	17.445
240	1439.945	17.292
246	1387.202	16.549
252	1383.02	15.528
258	1300.518	14.87
264	1285.574	13.664
270	1310.674	13.829
276	1185.695	13.048
282	1211.919	12.136
288	1198.333	12.466
294	1144.733	10.648
300	1079.959	9.373
306	1001.967	8.355
312	931.403	7.487
318	842.82	5.858
324	754.893	4.833

330	687.869	4.007
336	624.855	3.668
342	575.197	3.268
348	538.085	2.947
354	495.724	2.474
360	470.399	2.3
366	449.971	2.258
372	421.571	2.082
378	404.181	2.168
384	387.788	2.025
390	380.812	2.057
396	364.555	2.025
402	353.815	1.86
408	348.01	1.932
414	338.709	1.839
420	331.614	1.813

APPENDIX G-Fire Protection Design & Drawings

TABLE 13.2.1 *Discharge Criteria for Miscellaneous Storage Up to 12 ft (3.7 m) in Height*

Commodity		Type of Storage	Storage Height ft	Storage Height m	Maximum Ceiling Height ft	Maximum Ceiling Height m	Design Curve Figure 13.2.1	Note	Inside Hose gpm	Inside Hose L/min	Total Combined Inside and Outside Hose gpm	Total Combined Inside and Outside Hose L/min	Duration (minutes)
Class I to Class IV													
Class I		Solid-piled, palletized, bin box, shelf, single-, double-, multiple-row rack, and back-to-back shelf storage	≤12	≤3.7	—	—	OH1		0, 50, 100	0, 190, 380	250	950	90
Class II			≤10	≤3.0	—	—	OH1		0, 50, 100	0, 190, 380	250	950	90
Class II			>10 to ≤12	>3.0 to ≤3.7	—	—	OH2		0, 50, 100	0, 190, 380	250	950	90
Class III			≤12	≤3.7	—	—	OH2		0, 50, 100	0, 190, 380	250	950	90
Class IV			≤10	≤3.0	—	—	OH2		0, 50, 100	0, 190, 380	250	950	90
Class IV		Palletized, bin box, shelf, and solid-piled	>10 to ≤12	>3.0 to ≤3.7	32	10	OH2		0, 50, 100	0, 190, 380	250	950	90
		Single-, double-, multiple-row rack and back-to-back shelf storage	>10 to ≤12	>3.0 to ≤3.7	32	10	EH1		0, 50, 100	0, 190, 380	500	1900	120
Group A Plastic Storage													
Cartoned	Unexpanded and expanded	Solid-piled, palletized, bin box, shelf, single-, double-, multiple-row rack, and back-to-back shelf storage	≤5	≤1.5	—	—	OH2		0, 50, 100	0, 190, 380	250	950	90
			>5 to ≤10	>1.5 to ≤3.0	15	4.6	EH1		0, 50, 100	0, 190, 380	500	1900	120
			>5 to ≤10	>1.5 to ≤3.0	20	6.1	EH2		0, 50, 100	0, 190, 380	500	1900	120
			>10 to ≤12	>3.0 to ≤3.7	17	5.2	EH2		0, 50, 100	0, 190, 380	500	1900	120
		Solid-piled, palletized, bin box, shelf, and back-to-back shelf storage	>10 to ≤12	>3.0 to ≤3.7	32	10	EH2		0, 50, 100	0, 190, 380	500	1900	120
		Single-, double-, multiple-row rack	>10 to ≤12	>3.0 to ≤3.7	32	10	OH2	+ 1 level of in-rack	0, 50, 100	0, 190, 380	250	950	90
Exposed	Unexpanded and expanded	Solid-piled, palletized, bin box, shelf, single-, double-, multiple-row rack, and back-to-back shelf storage	≤5	≤1.5	—	—	OH2		0, 50, 100	0, 190, 380	250	950	90
		Solid-piled, palletized, bin box, shelf, and back-to-back shelf storage	>5 to ≤8	>1.5 to ≤2.4	28	8.5	EH2		0, 50, 100	0, 190, 380	500	1900	120
		Solid-piled, palletized, bin box, shelf, single-, double-, multiple-row rack, and back-to-back shelf storage	>5 to ≤10	>1.5 to ≤3.0	15	4.6	EH2		0, 50, 100	0, 190, 380	500	1900	120
	Unexpanded	Solid-piled, palletized, bin box, shelf, single-, double-, multiple-row rack, and back-to-back shelf storage	>5 to ≤10	>1.5 to ≤3.0	20	6.1	EH2		0, 50, 100	0, 190, 380	500	1900	120

(Continues)

TABLE 13.2.1 *Continued*

Commodity		Type of Storage	Storage Height		Maximum Ceiling Height		Design Curve Figure 13.2.1	Note	Inside Hose		Total Combined Inside and Outside Hose		Duration (minutes)
			ft	m	ft	m			gpm	L/min	gpm	L/min	
	Expanded	Single-, double-, multiple-row rack	>5 to ≤10	>1.5 to ≤3.0	20	6.1	OH2	+1 level of in-rack	0, 50, 100	0, 190, 380	250	950	90
	Unexpanded and expanded	Solid-piled, palletized, bin box, shelf, and back-to-back shelf storage	>10 to ≤12	>3.0 to ≤3.7	17	5.2	EH2		0, 50, 100	0, 190, 380	500	1900	120
		Single-, double-, multiple-row rack	>10 to ≤12	>3.0 to ≤3.7	17	5.2	EH2		0, 50, 100	0, 190, 380	500	1900	120
			>10 to ≤12	>3.0 to ≤3.7	32	10	OH2	+1 level of in-rack	0, 50, 100	0, 190, 380	250	950	90
Tire Storage													
Tires		On floor, on side	>5 to ≤12	>1.5 to ≤3.7	32	10	EH1		0, 50, 100	0, 190, 380	500	1900	120
		On floor, on tread, or on side	≤5	≤1.5	—	—	OH2		0, 50, 100	0, 190, 380	250	950	90
		Single-, double-, or multiple-row racks on tread or on side	≤5	≤1.5	—	—	OH2		0, 50, 100	0, 190, 380	250	950	90
		Single-row rack, portable, on tread or on side	>5 to ≤12	>1.5 to ≤3.7	32	10	EH1		0, 50, 100	0, 190, 380	500	1900	120
		Single-row rack, fixed, on tread or on side	>5 to ≤12	>1.5 to ≤3.7	32	10	EH1		0, 50, 100	0, 190, 380	500	1900	120
			>5 to ≤12	>1.5 to ≤3.7	32	10	OH2	+1 level of in-rack	0, 50, 100	0, 190, 380	250	950	90
Rolled Paper Storage													
Heavyweight and mediumweight		On end	≤10	≤3.0	30	9.1	OH2		0, 50, 100	0, 190, 380	250	950	90
Tissue and lightweight		On end	≤10	≤3.0	30	9.1	EH1		0, 50, 100	0, 190, 380	250	950	120

Figure G1 - NFPA 13 Table 13.2.1

APPENDIX G-FIRE PROTECTION DESIGN & DRAWINGS

Figure G1 - First Floor Sprinkler Design

APPENDIX G-FIRE PROTECTION DESIGN & DRAWINGS

Figure G2 - Second Floor West

APPENDIX G-FIRE PROTECTION DESIGN & DRAWINGS

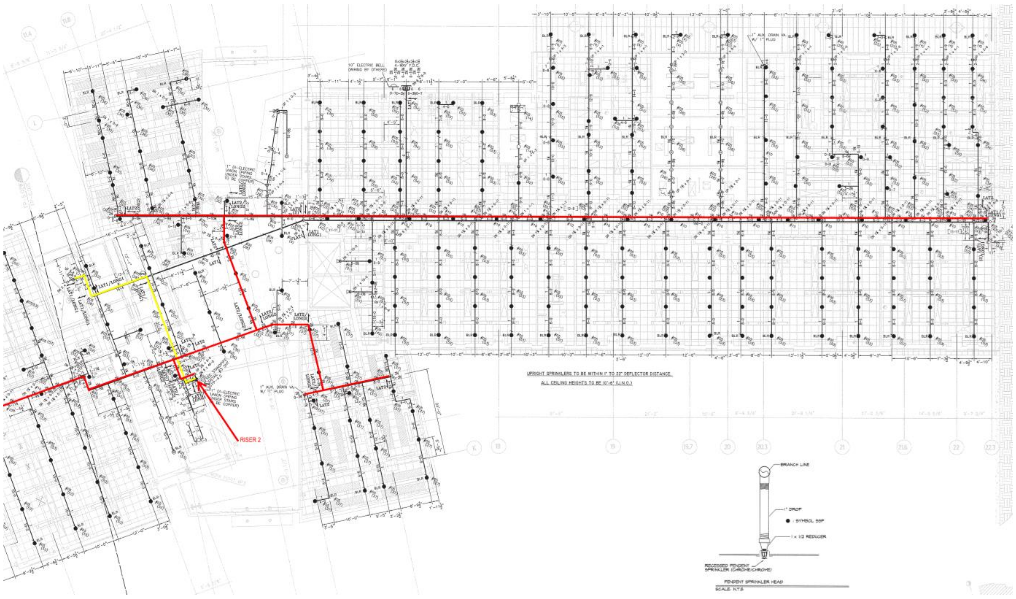


Figure G3 - Second Floor East

APPENDIX G-FIRE PROTECTION DESIGN & DRAWINGS

Figure G4 - Third Level West

APPENDIX G-FIRE PROTECTION DESIGN & DRAWINGS

Figure G5 - Third Floor East

APPENDIX G-FIRE PROTECTION DESIGN & DRAWINGS

Figure G6 - Fourth Floor West

APPENDIX G-FIRE PROTECTION DESIGN & DRAWINGS

Figure G7 - Fourth Floor East

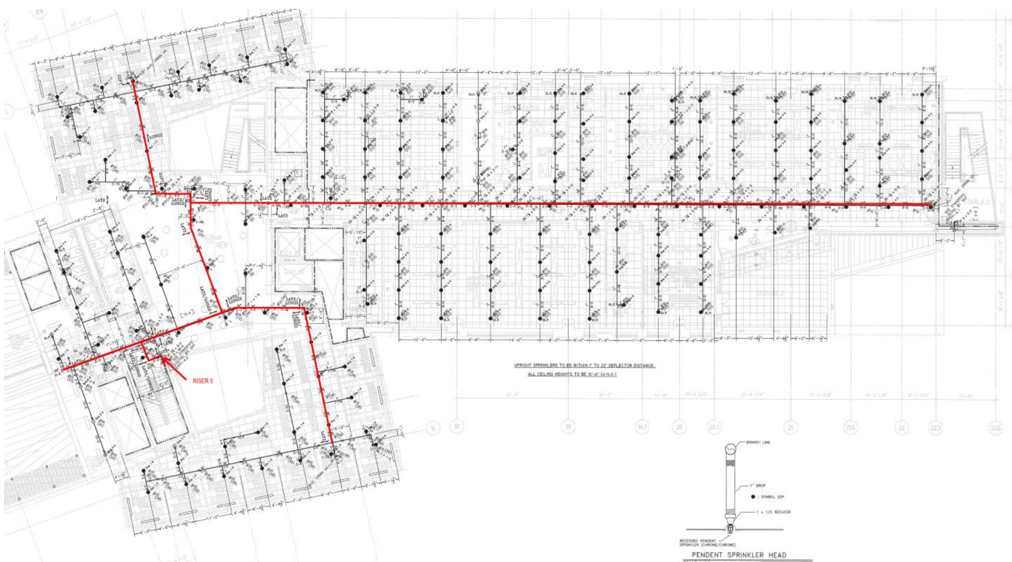


Figure G8 - Fifth Floor

APPENDIX G-FIRE PROTECTION DESIGN & DRAWINGS

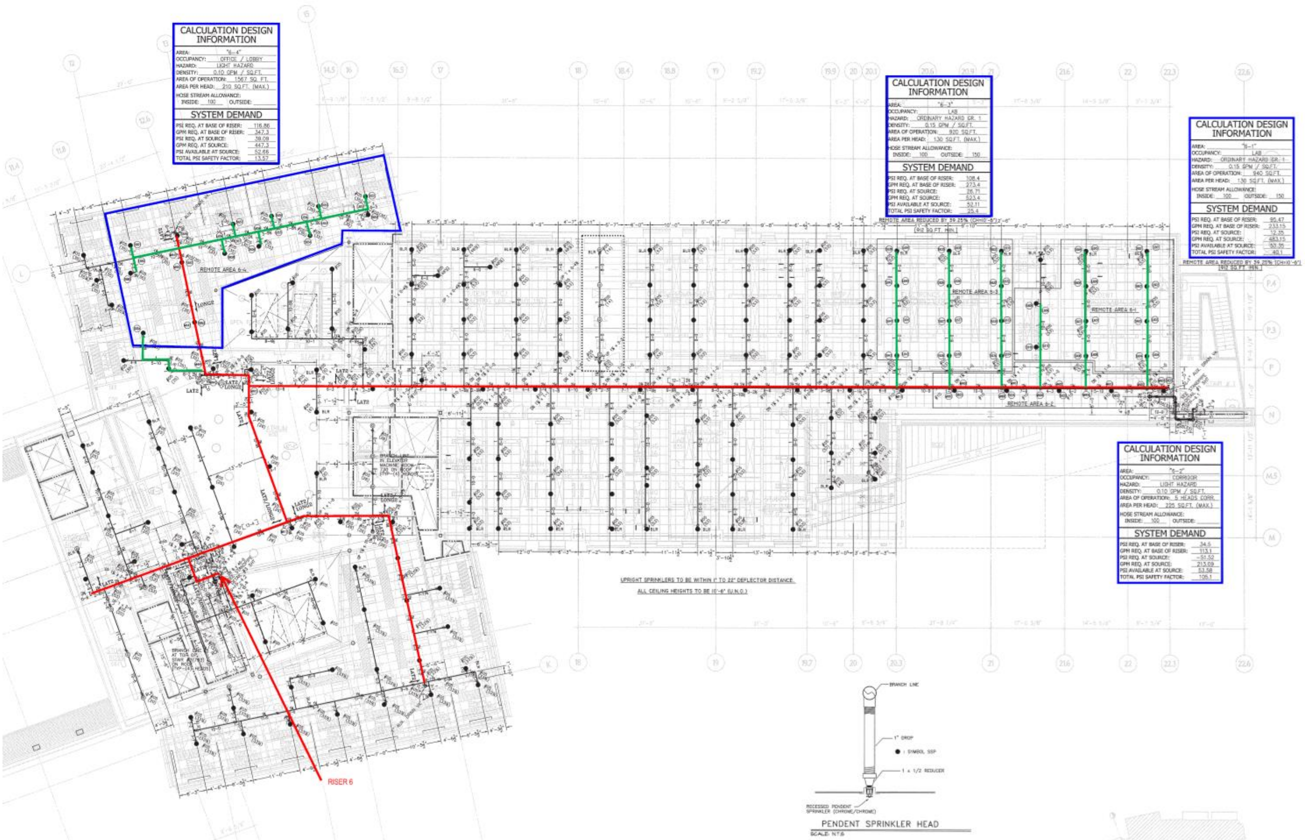


Figure G10 - Sixth Floor

APPENDIX H- Hydraulics Hand Calculation

Node 1 Node 2	Elev 1 Elev 2	K-Factor 1 K-Factor 2	Flow added (q) Total flow (Q)	Nominal ID Actual ID	Fittings quantity x (name) = length	L F T	C Factor Pf per ft	total (Pt) elev (Pe) frict (Pf)	NOTES
	(ft)	(gpm/psi½)	(gpm)	(in)	(ft)	(ft)	(psi)	(psi)	

COMPUTER SIMULATION DATA

Path No: 1

h7 n19	60.54 61.04	5.6	14.8 14.8	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.0744	7 -0.2 0.2	
n19 n18	61.04 61.04		0 14.8	1 1.049	1x(fm.Tee-Br)=5	3.08 5 8.08	120 0.0744	7 0 0.6	
n18 n17	61.04 61.04		15 29.8	1 1.049		10.71 0 10.71	120 0.2709	7.6 0 2.9	
n17 n16	61.04 61.04		17.4 47.1	1 1.049		3.29 0 3.29	120 0.6347	10.5 0 2.1	
n16 n15	61.04 61.04		19 66.2	1.25 1.38		7.71 0 7.71	120 0.3126	12.6 0 2.4	
n15 n14	61.04 61.04		20.7 86.9	1.25 1.38		3.79 0 3.79	120 0.518	15 0 2	
n14 n13	61.04 61.04		22 108.9	1.25 1.38		5.21 0 5.21	120 0.7873	16.9 0 4.1	
n13 n3	61.04 61.04		24.6 133.5	1.5 1.61		3.29 0 3.29	120 0.5416	21 0 1.8	
n3 n6	61.04 61.04		25.6 159.1	1.5 1.61	1x(fm.Tee-Br)=8	10 8 18	120 0.7493	22.8 0 13.5	
n6 n4	61.04 61.04		93.5 252.5	2.5 2.469		3.17 0 3.17	120 0.2198	36.3 0 0.7	
n4 n11	61.04 61.04		33.3 285.8	2.5 2.469		14 0 14	120 0.2765	37 0 3.9	

n11 n31	61.04 61.04		35 320.8	2.5 2.469	1x(fm.Tee-Br)=12	10.79 12 22.79	120 0.3424	40.9 0 7.8	
n31 n36	61.04 61.04		34.7 355.5	2.5 2.469	1x(fm.90A)=6	3.33 6 9.33	120 0.4141	48.7 0 3.9	
n36 n37	61.04 60.29		0 355.5	2.5 2.469	1x(fm.90A)=6	0.75 6 6.75	120 0.4141	52.5 0.3 2.8	
n37 n38	60.29 60.29		0 355.5	2.5 2.469	1x(fm.90A)=6	6.83 6 12.83	120 0.4141	55.7 0 5.3	
n38 n39	60.29 60.29		0 355.5	2.5 2.469	1x(fm.45)=3 1x(fm.90A)=6	34.08 9 43.08	120 0.4141	61 0 17.8	

Path No: 1

n39 n40	60.29 60.29		0 355.5	2.5 2.469	1x(fm.90A)=6	20.38 6 26.38	120 0.4141	78.8 0 10.9	
n40 n41	60.29 62.54		0 355.5	2.5 2.469	1x(fm.90A)=6	2.25 6 8.25	120 0.4141	89.7 -1 3.4	
n41 n42	62.54 62.54		0 355.5	2.5 2.469	1x(fm.90A)=6	3.83 6 9.83	120 0.4141	92.2 0 4.1	
n42 n43	62.54 62.54		0 355.5	2.5 2.469	1x(fm.90A)=6	4.67 6 10.67	120 0.4141	96.2 0 4.4	
n43 n44	62.54 62.54		0 355.5	2.5 2.469	1x(fm.90A)=6	4 6 10	120 0.4141	100.7 0 4.1	
n44 n45	62.54 56.75		0 355.5	2.5 2.469	1x(fm.90A)=6	5.79 6 11.79	120 0.4141	104.8 2.5 4.9	
n45 n46	56.75 56.75		0 355.5	2.5 2.469	1x(fm.Tee-Br)=12	1 12 13	120 0.4141	112.2 0 5.4	
n46 n48	56.75 16.5		0 355.5	6 6.065	1x(fm.90A)=14	54.82 14 68.82	120 0.0052	117.6 17.4 0.4	
n48 n49	16.5 16.5		0 355.5	6 6.065	1x(fm.Gate)=3 1x(fm.90A)=14	3 17 20	120 0.0052	135.4 0 0.1	

n49 n50	16.5 16.5		0 355.5	6 6.065	1x(fm.90A)=14	31.17 14 45.17	120 0.0052	135.5 0 0.2	
n50 n51	16.5 16.5		0 355.5	6 6.065	1x(fm.90A)=14	16.44 14 30.44	120 0.0052	135.7 0 0.2	
n51 n52	16.5 16.5		0 355.5	6 6.065	1x(fm.90A)=14	6.17 14 20.17	120 0.0052	135.9 0 0.1	
n52 n53	16.5 15.42		0 355.5	6 6.065	1x(fm.90A)=14	1.08 14 15.08	120 0.0052	136 0.5 0.1	
n53 n54	15.42 15.42		0 355.5	6 6.065	1x(fm.90A)=14	3.92 14 17.92	120 0.0052	136.5 0 0.1	
n54 n55	15.42 0.00		0 355.5	6 6.065	1x(fm.90A)=14	15.42 14 29.42	120 0.0052	136.6 6.7 0.2	
n55 n56	0.00 0.00		0 355.5	6 6.065	1x(fm.90A)=14	71.75 14 85.75	120 0.0052	143.5 0 0.4	

Path No: 1

n56 n58	0.00 -10.83		0 355.5	8 8.329	1x(fm.90A)=18	10.83 18 28.83	120 0.0011	143.9 4.7 0.0	
n58 src1	-10.83 -10.83		0 355.5	8 8.329		3.92 0 3.92	120 0.0011	148.6 0 0	
src1								**148.6**	

Path No: 2

h8 n21	60.54 61.04	5.6	15 15	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.0757	7.1 -0.2 0.2	
n21 n18	61.04 61.04		0 15	1 1.049	1x(fm.Tee-Br)=5	1.16 5 6.16	120 0.0757	7.1 0 0.5	
n18								**7.6**	

Path No: 3

h9 n23	60.54 61.04	5.6	17.4 17.4	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.1	9.6 -0.2 0.2	

n23 n17	61.04 61.04		0 17.4	1 1.049	1x(fm.Tee-Br)=5	3.08 5 8.08	120 0.1	9.7 0 0.8	
n17								**10.5**	

Path No: 4

h10 n25	60.54 61.04	5.6	19 19	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.118	11.5 -0.2 0.3	
n25 n16	61.04 61.04		0 19	1 1.049	1x(fm.Tee-Br)=5	3.17 5 8.17	120 0.118	11.6 0 1	
n16								**12.6**	

Path No: 5

h14 n30	60.54 61.04	5.6	20.7 20.7	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.1387	13.7 -0.2 0.3	
n30 n15	61.04 61.04		0 20.7	1 1.049	1x(fm.Tee-Br)=5	3.08 5 8.08	120 0.1387	13.8 0 1.1	
n15								**15**	

Path No: 6

h13 n28	60.54 61.04	5.6	22 22	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.1553	15.5 -0.2 0.4	
n28 n14	61.04 61.04		0 22	1 1.049	1x(fm.Tee-Br)=5	3.17 5 8.17	120 0.1553	15.7 0 1.3	
n14								**16.9**	

Path No: 7

h12 n26	60.54 61.04	5.6	24.6 24.6	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.1898	19.2 -0.2 0.5	
n26 n13	61.04 61.04		0 24.6	1 1.049	1x(fm.Tee-Br)=5	3.08 5 8.08	120 0.1898	19.5 0 1.5	
n13								**21**	

Path No: 8

h1 n1	60.54 61.04	5.6	25.6 25.6	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.2044	20.9 -0.2 0.5	

n1 n3	61.04 61.04		0 25.6	1 1.049	1x(fm.Tee-Br)=5	3.17 5 8.17	120 0.2044	21.1 0 1.7	
n3								**22.8**	

Path No: 9

h6 n10	60.54 61.04	5.6	30.2 30.2	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.2786	29.1 -0.2 0.7	
n10 n7	61.04 61.04		0 30.2	1 1.049	1x(fm.Tee-Br)=5	3.17 5 8.17	120 0.2786	29.6 0 2.3	
n7 n6	61.04 61.04		30.2 60.5	1.25 1.38	1x(fm.Tee-Br)=6	10.67 6 16.67	120 0.2646	31.9 0 4.4	
n6								**36.3**	

Path No: 10

h5 n8	60.54 61.04	5.6	30.2 30.2	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.2788	29.2 -0.2 0.7	
n8 n7	61.04 61.04		0 30.2	1 1.049	1x(fm.Tee-Br)=5	3.08 5 8.08	120 0.2788	29.6 0 2.3	
n7								**31.9**	

Path No: 11

h4 n5	60.54 61.04	5.6	33 33	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.3275	34.7 -0.2 0.8	
n5 n6	61.04 61.04		0 33	1 1.049		3.08 0 3.08	120 0.3275	35.3 0 1	
n6								**36.3**	

Path No: 12

h3 n4	60.54 61.04	5.6	33.3 33.3	1 1.049	1x(fm.Tee-Br)=5	0.5 5 5.5	120 0.3335	35.4 -0.2 1.8	
n4								**37**	

Path No: 13

h15 n35	60.54 61.04	5.6	34.7 34.7	1 1.049	1x(fm.90A)=2	0.5 2 2.5	120 0.359	38.3 -0.2 0.9	

n35 n34	61.04 61.04		0 34.7	1 1.049	1x(fm.90A)=2	6.33 2 8.33	120 0.359	39 0 3	
n34 n33	61.04 61.04		0 34.7	1 1.049	1x(fm.90A)=2	5.83 2 7.83	120 0.359	42 0 2.8	
n33 n32	61.04 61.04		0 34.7	1 1.049	1x(fm.90A)=2	0.67 2 2.67	120 0.359	44.8 0 1	
n32 n31	61.04 61.04		0 34.7	1 1.049		8.17 0 8.17	120 0.359	45.7 0 2.9	
n31								**48.7**	

Path No: 14

h11 n11	60.54 61.04	5.6	35 35	1 1.049	1x(fm.Tee-Br)=5	0.5 5 5.5	120 0.3657	39.1 -0.2 2	
n11								**40.9**	

* Pressures are balanced to a high degree of accuracy. Values may vary by 0.1 psi due to display rounding.

* Maximum Velocity of 25.07 ft/s occurs in the following pipe(s): (n6-n3)

APPENDIX H- HYDRAULICS HAND CALCULATION

HAND CALCULATIONS

Project name:		FPE 523 Project Design Area 1-1											Date:		5-Mar-16
Step No.	Nozzle Ident and Location	Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
1	S101	q		S40		L	12	C=	120	Pt	9.0	Pt		k=	5.6
	to			1.049		F				Pe		Pv		Q=	0.10*168=16.8
	L102	Q	16.8			T	12	pf	0.089	Pf	1.1	Pn		Pt=	(16.8/5.6)^2=9
2	S102	q	17.8			L	12	C=	120	Pt	10.1	Pt		k=	5.6
	to			1.049		F				Pe		Pv		q=	5.6*sqrt(10.1)=17.8
	L103	Q	34.6			T	12	pf	0.337	Pf	4.0	Pn			
3	S103	q	21.0			L	8.54	C=	120	Pt	14.1	Pt		k=	5.6
	to			1.049	1-T	F	4			Pe		Pv		q=	5.6*sqrt(14.1)=21.0
	M101	Q	**55.6**			T	12.54	pf	0.811	Pf	10.2	Pn			
		q				L		C=		Pt	**24.3**	Pt			
						F				Pe		Pv			
		Q				T		pf		Pf		Pn			
4	S104	q				L	3.46	C=	120	Pt	9.0	Pt		k=	5.6
	to			1.049	1-T	F	4			Pe		Pv		Q=	.10*168=16.8
	M101	Q	16.8			T	7.46	pf	0.089	Pf	0.7	Pn		Pt=	(16.8/5.6)^2=9
		q				L		C=		Pt	9.7	Pt		k(bl)=	16.8/sqrt(9.7)=5.4
						F				Pe		Pv		q=	5.4*sqrt(24.3)=26.6
		Q	**26.6**			T		pf		Pf		Pn			
5	M101	q				L	2.54	C=	120	Pt	24.3	Pt			
	to			1.049	1-T	F	4			Pe	-1.1	Pv			
	CM	Q	**82.2**			T	6.54	pf	1.672	Pf	10.9	Pn			
6	CM	q		S10		L	14	C=	120	Pt	**34.1**	Pt		k(bl)=	82.2/sqrt(34.1)=14.1
	to			2.635		F				Pe		Pv			
	M102	Q	82.2			T	14	pf	0.019	Pf	0.3	Pn			
7	M102	q	82.3	S10		L	14	C=	120	Pt	34.4	Pt			
	to			2.635		F				Pe		Pv		q=	14.1*sqrt(34.1)=82.3
	M103		164.5			T	14	pf	0.068	Pf	1.0	Pn			
8	M103	q	83.9			L	118.167	C=	120	Pt	35.4	Pt			
	to			2.635	2-T, 1-H	F	27			Pe		Pv		q=	14.1*sqrt(35.4)=83.9
	M105	Q	248.4			T	145.167	pf	0.146	Pf	21.2	Pn			
9	M105	q		S10		L	109.83	C=	120	Pt	56.5	Pt			
	to			3.26	2-T,3-E	F	51			Pe		Pv			
	TOR	Q	248.4			T	160.83	pf	0.052	Pf	8.3	Pn			
10	TOR	q				L	10.167	C=	120	Pt	64.8	Pt			
	to			3.26	1-E	F	7			Pe	65.4	Pv			
	BOR	Q	**248.4**			T	17.167	pf	0.052	Pf	0.9	Pn			PRV VALVE = 61PSI
		q				L		C=		Pt	**131.1**	Pt			
						F				Pe		Pv			
		Q				T		pf		Pf		Pn			