Orfalea College of Business Fire Safety Analysis

Garth Ornelas
Fire Protection Engineering Department
March 2017

Cal Poly San Luis Obispo

Statement of Disclaimer

This project report is a result of a class assignment; it has been graded and accepted as fulfillment of the course requirements. Acceptance of this report in fulfillment of the course requirements does not imply technical accuracy or reliability. Any use of information in this report is done at the risk of the user. These risks may include, but may not be limited to, catastrophic failure of the device or infringement of patent or copyright laws. California Polytechnic State University at San Luis Obispo and its staff cannot be held liable for any use or misuse of the project.

Keywords: Performance Based Design, Fire Dynamics Simulator (FDS) , RSET, Tenability, ASET

Table of Contents

List of Tables:

List of Figures:

Executive Summary:

The following report discusses the fire and life safety factors for the Orfalea College of Business Building located on the main campus of California Polytechnic State University in San Luis Obispo. The building functions are primarily administrative and academic in nature, with various lecture halls, offices, and labs located throughout the building.

The Business Building was constructed in 1989 following the 1985 Uniform Building Code (UBC). For the purposes of this report, the building will be evaluated using the 2015 International Building Code, NFPA Life Safety Code Handbook (Thirteenth Edition), SFPE Handbook (4^{th} and 5^{th} Editions), and the NFPA handbooks relevant to each individual section.

The prescriptive fire safety features that will be examined in the building will be divided into categories including egress analysis, fire detection, alarm and communication systems, water based fire suppression, structural fire protection, and tenability.

The performance-based design of the building will be carried out with the goals outlined in the Life Safety Code (13^{th} edition) including ASET >RSET with minimal loss of life and property damage.

The performance criteria of the FDS model will be based on methods 1 and 2 for performance-based design outlined in the LSC Handbook (13th edition)

The performance-based design will be carried out using Pathfinder and FDS to simulate a design fire that was selected to reflect a serious threat to the occupants in the building

Following the performance based design criteria outlined in methods 1 and 2 of the LSC (13^{th} edition), the proposed design fire ensures that incapacitation does not occur, however visibility is lost. This satisfies method 1 of the performance based design which states that no occupant shall be incapacitated by the effects of fire for the duration required for the required safe egress time. Method 2 of the design fails because this performance goal is to ensure that the toxic gas layer does not fall below 6 feet at any point during the simulation.

In order to maintain the functionality of smoke doors and barriers, doors that are not designed to be help open should be kept closed. Hallway obstructions on the third and fourth floors should be removed to ensure a clear egress route. If complete coverage of smoke detectors is a safety goal of the building, smaller offices should install smoke detection devices. Foliage between the Business and Education should be removed to maintain a safe exterior exposure separation.

Introduction:

The Orfalea College of Business is located on the main campus of Cal Poly San Luis Obispo. The Exact location of the building is shown on the campus map in Figure 1.

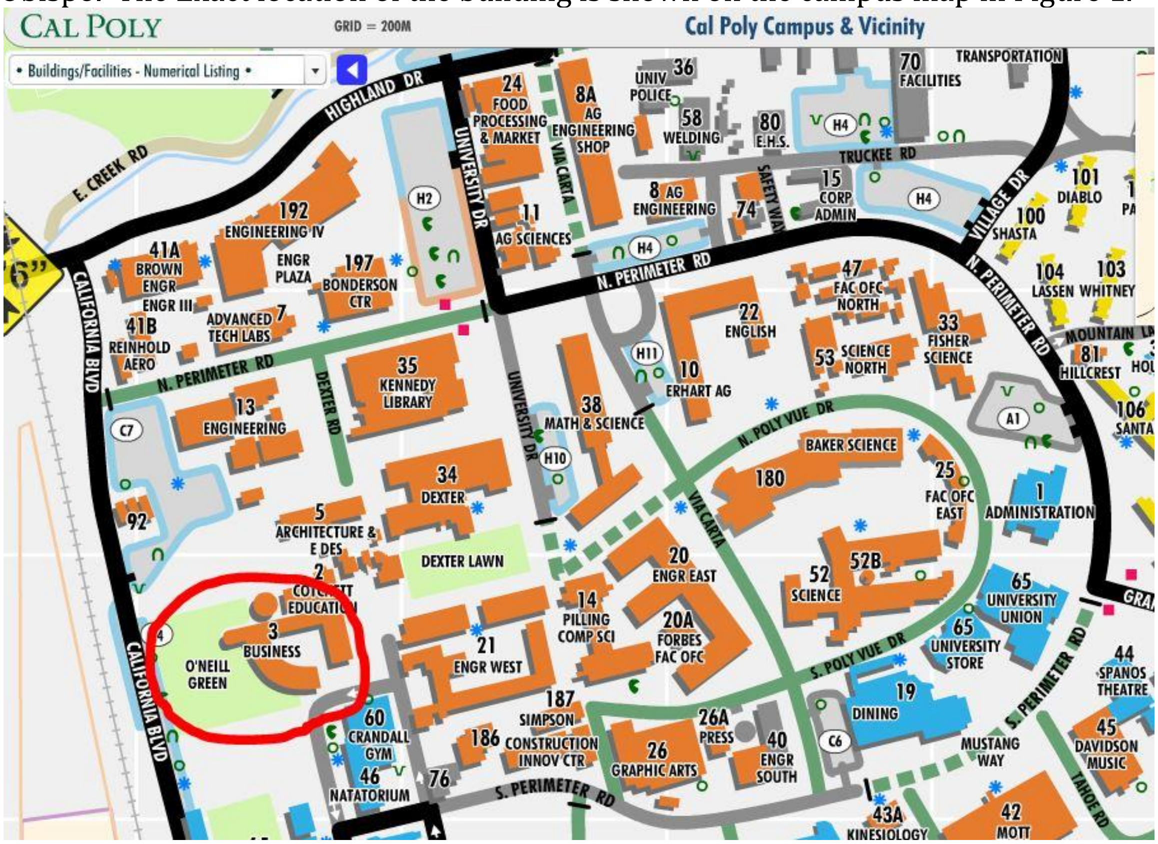


Figure 1: Location of business Building on Main Campus

A closer view of the building is shown in Figure 2. Note the small round structure next to the building, which for the entirety of the report shall be called the Business Silo. This structure, while a part of the Business Building will be analyzed as a standalone structure.

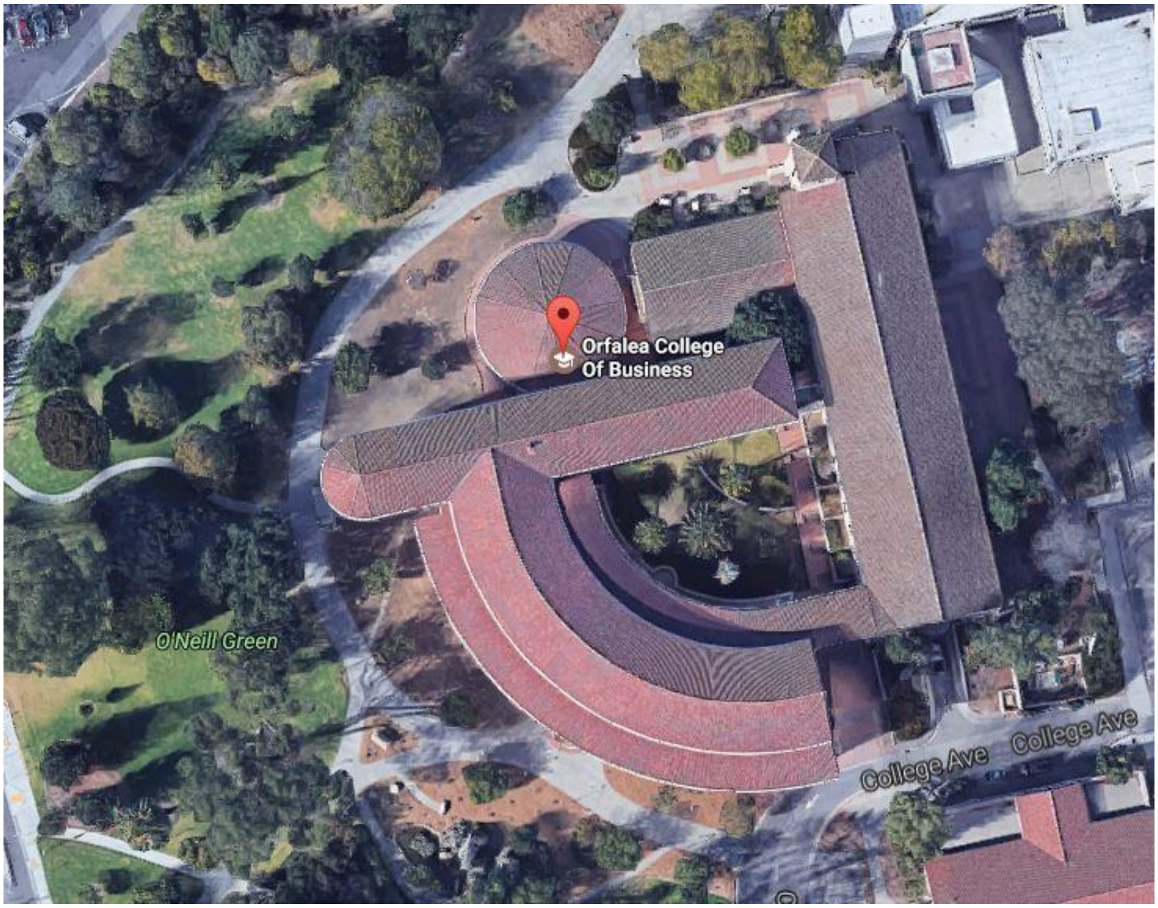


Figure 2: Ariel View of Business Building (Google Earth 2017)

The building is connected to the Education Building on the campus with the division shown in Figure 3.

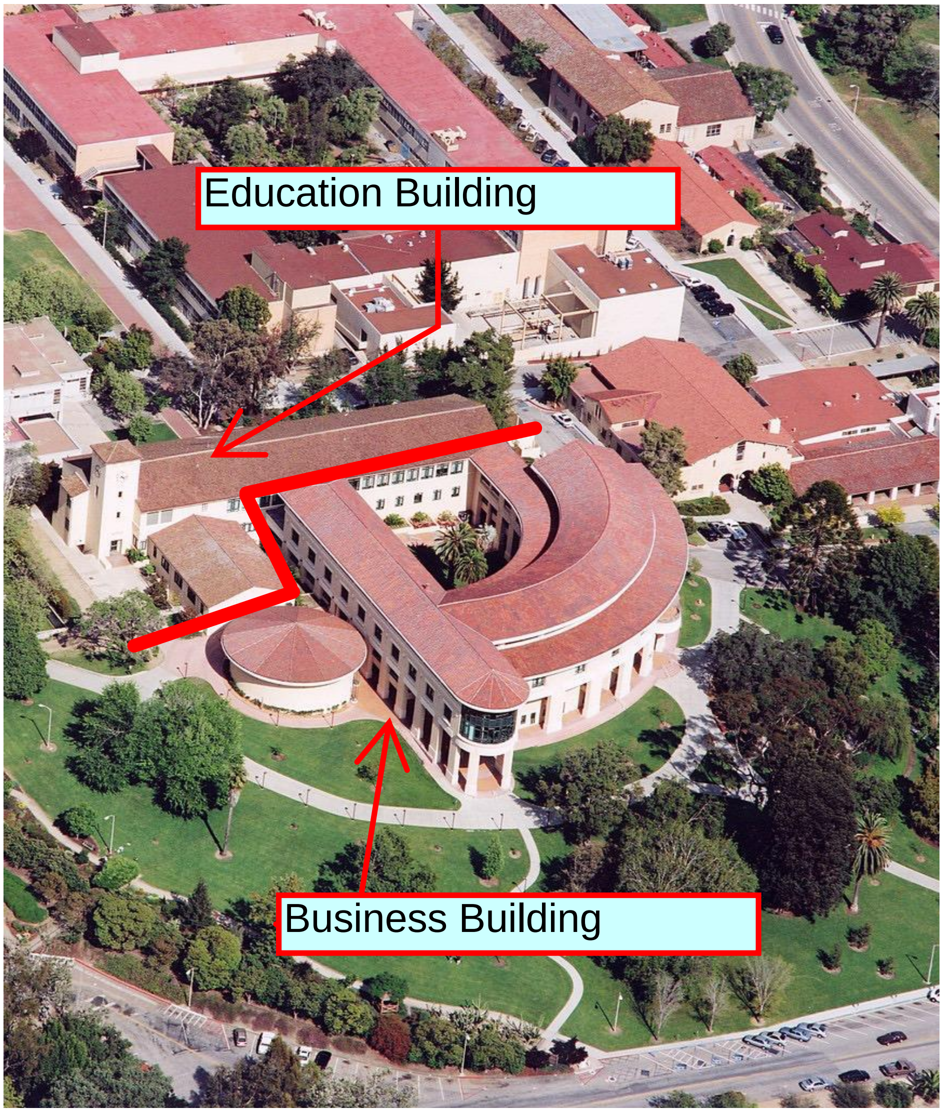


Figure 3: Division Between Business and Education Building

The business building serves as an administrative building with other areas dedicated to serve academic uses. Students have access to multiple computer labs, lecture halls, classrooms, and study areas located mainly on floors one and two of the building. There are multiple administrative offices along with lounges used by the building staff. The areas on the fourth floor are almost exclusively administrative in use while floor three is a mix of labs and offices.

This report is going to analyze the fire safety features present in the building. This analysis will include an assessment of the building's egress plan, water based fire suppression, alarm and communication systems, and structural fire protection. These elements of the building will be analyzed using a prescriptive approach in relation to the codes mentioned in the Executive Summary.

For each section of the report, the prescriptive requirements will be compared to the features of the building to determine if the protection in the building is sufficient. If alterations to the building are required, a recommendation will be made to reconcile the discrepancy.

In order to explore the safety of the building in a possible fire scenario, a performance based design approach was used. The performance based design explores the occupant characteristics, tenability conditions necessary to incapacitate occupants and affect egress, total required safe egress time (RSET), and actual safe egress time (ASET). The egress of the building was modeled in a program called Pathfinder. A fire model was created using a program called Pyrosim.

The first step in analyzing the existing building is determining if the exit capacity of each floor is adequate for the number of people present. This will require an egress analysis.

Egress Analysis:

Introduction:

In order to understand how people will react to a potential fire condition, an egress analysis is essential in determining if the building provides adequate exit capacity for occupants.

Occupancy Classification:

Under the 1985 UBC, the business building was placed in the B-2 category with some A-3 areas dispersed throughout the building. Under the 2015 IBC, the building will be considered primarily group B business occupancy with some minor A-3 rooms. Labeled occupancy use maps can be found in Appendix C.

Occupant load:

Occupant load factors were calculated using Table 7.3.1.2 in the LSC Handbook (13th edition) based on the occupancy use of each room. A summary of the total occupant loads of the building by floor are shown in Table 1. Occupant load calculations can be found in Appendix B.

Table 1: Summary of Occupant Loads

Area	Occupant Load
Floor 1	318
Floor 2	522
Floor 3	154
Floor 4	94
Total	1088
Business Silo	238

Exit Capacity:

Exit capacities were calculated using exit capacity factors found on Table 7.3.3.1 in the LSC Handbook (13th edition) and summarized in Table 2. The number and type of each exit is shown in Figures 4 -7. Exit capacity calculations can be found in Appendix D.

Table 2: Summary of Exit Capacities

	Total Exit Capacity
Floor 1	N/A
Floor 2	661
Floor 3	760
Floor 4	540
Silo	720

All single door exit widths are at least 3 feet wide, with double doors measuring 6 feet across. These door widths satisfy the width requirements presented in section 7.3.4.1 (2) of the LSC Handbook (13^{th} edition). Smaller rooms and offices have a door width of 3 feet, which is above the required width outlined in section 7.3.4.1.1 (13^{th} edition) for rooms with less than 6 people.

Exit capacities of stairs above a width of 44 inches were calculated using equation 7.3.3.2 in the LSC Handbook (13th edition).

Assessment of Exit Capacity

Floor 1 Analysis:

For the first floor of the building many rooms contain a 3-ft wide door corresponding to an exit capacity of 180 people. The occupant load from rooms that do not lead directly to an exit (100A, 100B, 100C, 177A, 101A, 101B, 114B, 107B, 107A, 108A, 111A, 119A, 119B) are well below the exit capacity of the doors that the rooms are attached to meaning that exit capacity exceeds occupant load everywhere on the first floor. For example, the combined occupant load of the cluster of rooms 100C, 100A, 100, 100B, and 101 is only 8 people and there are two possible exits from these areas with exit capacities of 360 and 180 based on the width of the doors (Factor of 0.2 in per person). Table 3 summarized the egress capacity and occupant load on the first floor of the building.

Floor 1 Egress Location Map

Table 3: Egress Summary of First Floor

Occupant Load	Exit Capacity
318	N/A

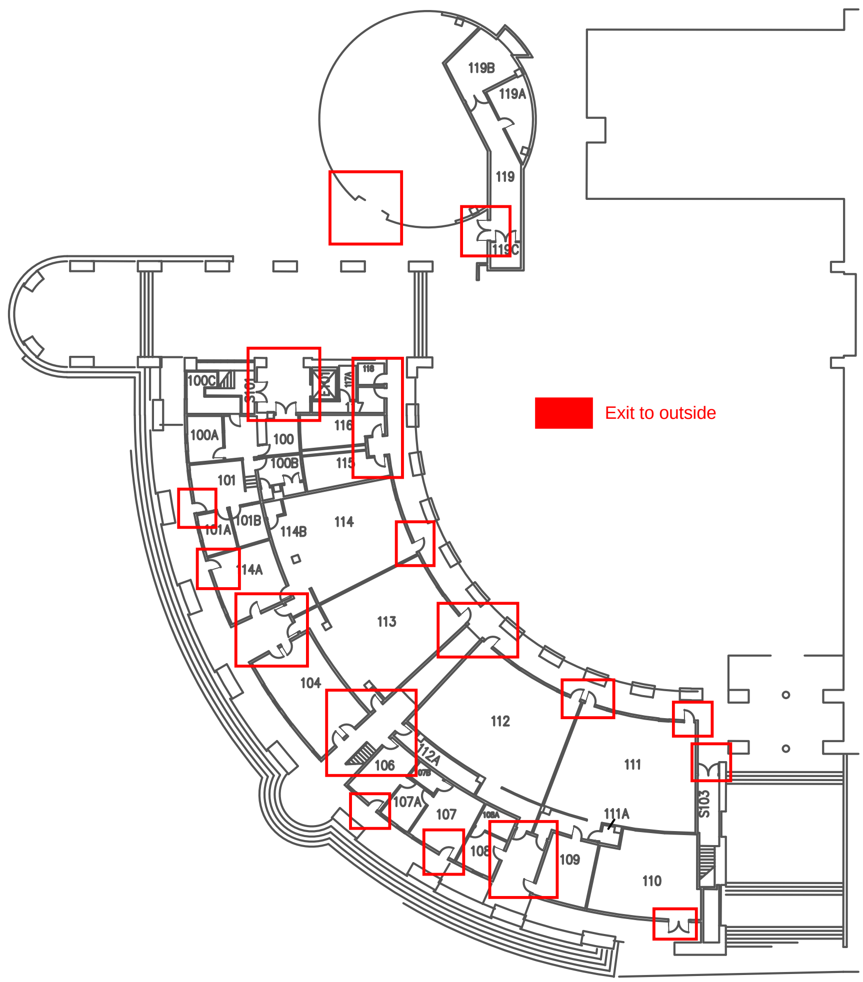


Figure 4: Labeled Egress Locations on First Floor

Floor 2 Analysis:

The exit capacity of 661 is above the occupant load of 522 as shown in Table 5. The exterior stairwell was able to be used as a means of egress due to the fact that the building is less than 6 stories in height. (IBC 2015) While the area connected to the education building in the bottom right corner of Figure 5 has adequate fire ratings to be considered a horizontal exit, the direction of the doors indicate that the walkway is used as a horizontal exit from the Education Building into the Business Building.

Silo Analysis:

The business silo is a round lecture hall located next to the main Business Building (See Figure 5). There are two exits located in the silo with a total exit capacity of 720, which well exceeds the occupant load of 238 as shown in Table 4.

Located beneath the silo are a number of isolated mechanical and storage rooms with an occupant load of 4.8 and an exit capacity of 360.

Floor 2 Egress Location Map

Table 4: Egress Summary of Business Silo

Occupant Load	Exit Capacity
238	720

Table 5: Egress Summary of Second Floor

Occupant Load	Exit Capacity
522	661

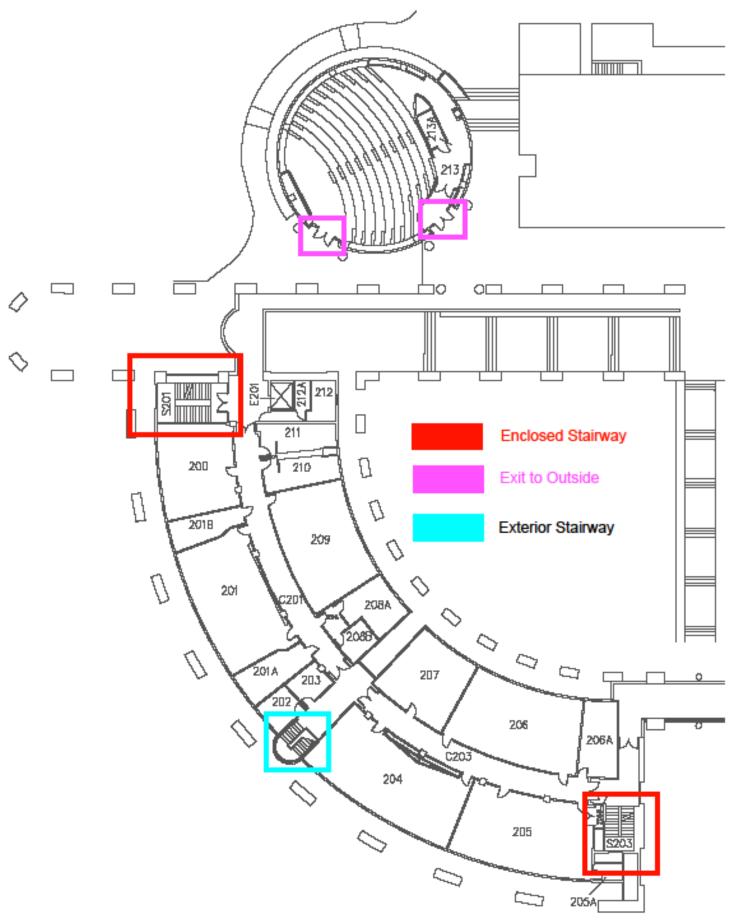


Figure 5: Labeled Egress Locations on Second Floor

Floor 3 Analysis:

The exit capacity of 760 is well above the occupant load of 154 as shown in Table 6. There is one horizontal exit on this floor under definition 3.3.83.1 of the LSC (13th edition). Figure 6 shows the location of the exits on the third floor of the building.

Floor 3 Egress Location Map

Table 6: Egress Summary of Third Floor

Occupant Load	Exit Capacity
154	760

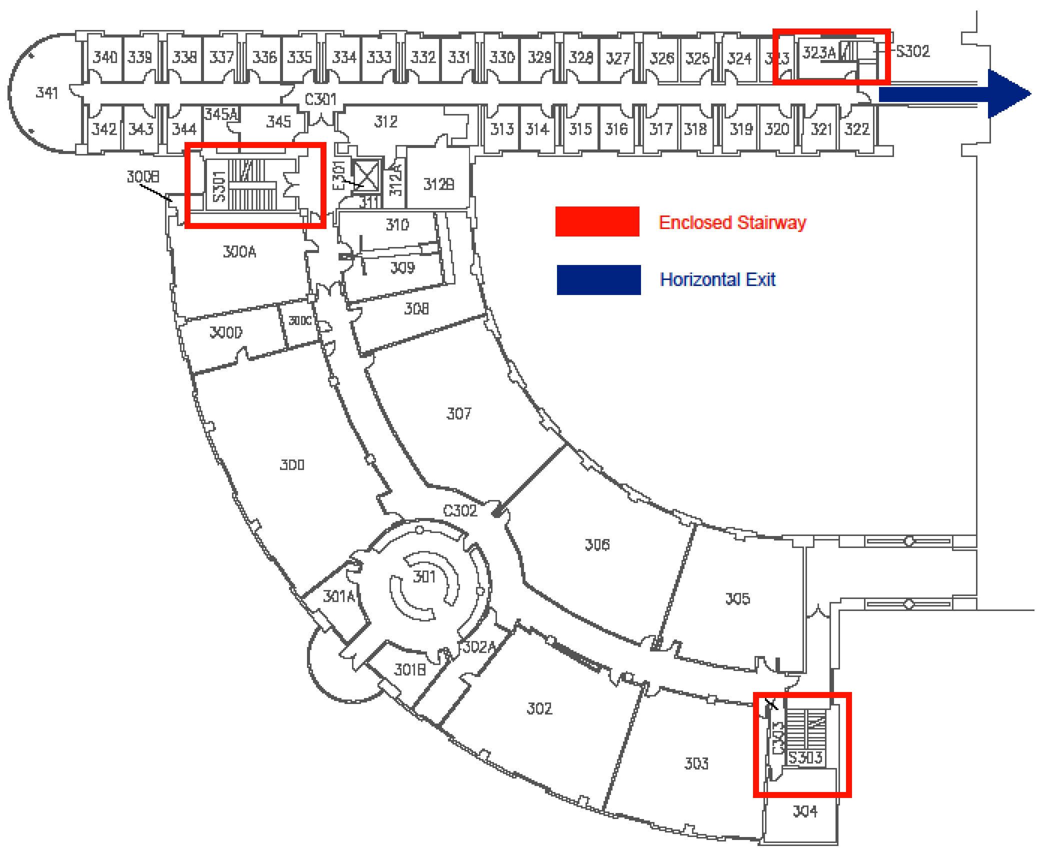


Figure 6: Labeled Egress Locations on Third Floor

Floor 4 Analysis:

From the calculations for each exit in Appendix D, the exit capacity of 540 is well above the occupant load of 94 as shown in Table 7. Figure 7 shows the location of exits on this floor.

Floor 4 Egress Location Map

Table 7: Egress Summary of Second Floor

Occupant Load	Exit Capacity
94	540

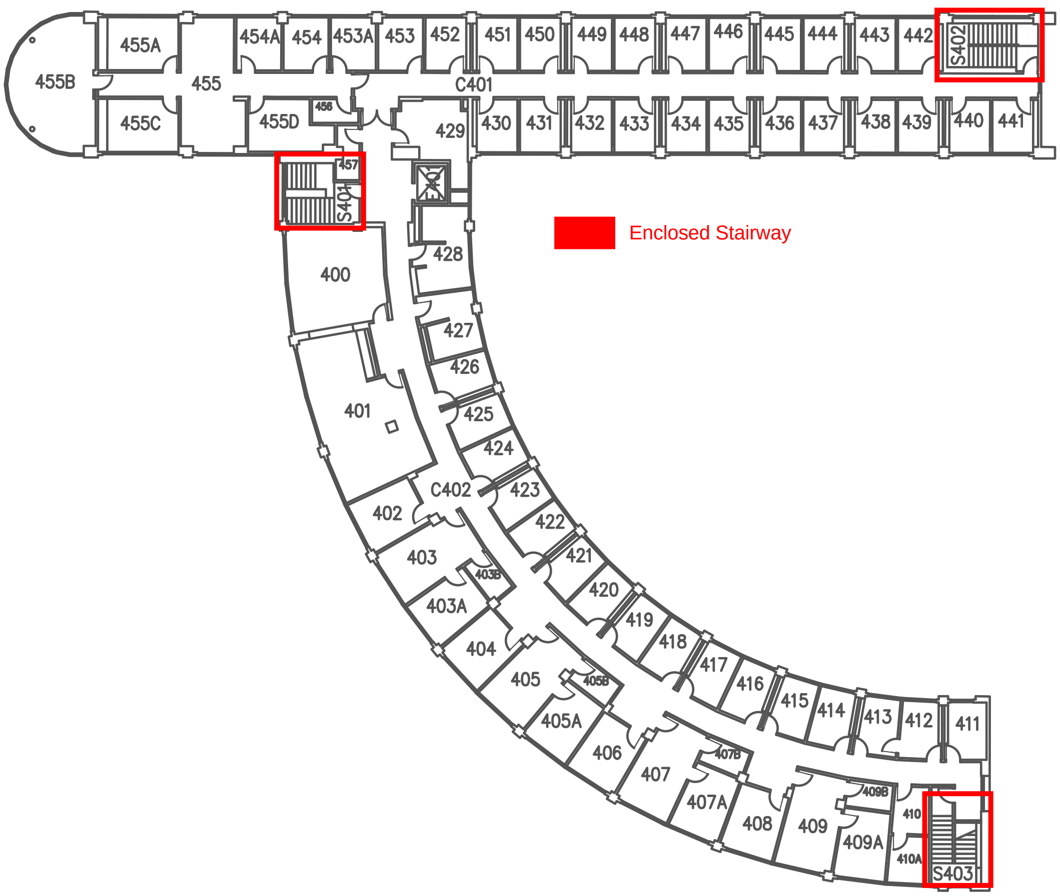


Figure 7: Labeled Egress Locations on Fourth Floor

Loss of Exit:

If one exit is lost the remaining exits should accommodate no less than 50 percent of the occupant load for that area in accordance with 7.3.1.1.2. Assuming that the largest staircase is blocked on the second floor (occupant load of 522) the remaining stairs hold an occupant load of 332, which is well above half of the occupant load for this floor. The loss of the exit is shown in Figure 8.

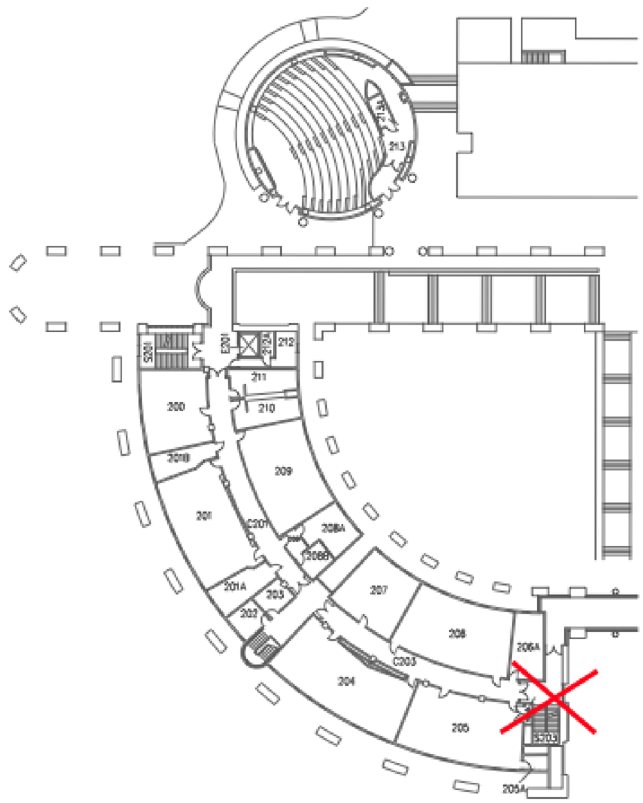


Figure 8: Loss of Exit on Second Floor

Remoteness:

Since this building does not have sprinklers, the remoteness requirement for the exits must satisfy 7.5.1.3.3 of the LSC Handbook (13th edition) which states that the exits should not be more than 1/2 the total diagonal distance of the building away from each other.

Assuming that the main diagonal is taken from the rectangular part of the building, all exit stairs will be at least 1/2 the total diagonal away from each other. This assessment was done using a scaled map of the building. The exit distances were above 1/2 the total diagonal away from each other as shown in Figure 9.

Figure 9: Remoteness Diagram of Fourth Floor

Horizontal Exits

The exits in this building are unique in that there are some areas that lead directly to an outdoor mezzanine on the second floor, and two corridors that lead to an adjacent building on the third. In accordance with definition 3.3.83.1 of the LSC Handbook (13th edition), there is only one horizontal exit in the building on the third floor leading into the Education Building as seen in Figure 6. A few other areas appear to be horizontal exits, however the direction of the doors indicate the use of the exits for the adjacent Education Building. These doors open inward in relation to the Business Building as seen in Figures 6 and 7.

Marking Means of Egress

Exit sign placement was performed in accordance with 7.10.1.2.1 of the LSC (13th edition) with exits placed in areas other than main entrances visible from the direction of travel of the hallways.

Utilizing 7.10.1.2.2 of the LSC (13th edition), exits were placed in areas where continuation of paths of egress was not obvious. This requirement is similar to 7.10.1.5.1 of the LSC (13th edition) for new buildings.

To the best of my ability, exit signs were placed within a viewing distance of 100 ft from the nearest sign in accordance with 7.10.1.5.2 of the LSC (13th edition). This was difficult due to the curved hallways in the building, but sign placement was kept to a minimum so as not to confuse people.

Given the function and open layout of the building, exit sign placement as occupancies where people do not visit the building on a daily basis as discussed in A.7.10.1.2.1 of the LSC (13th edition).

Interior Finish Requirements:

Table A.10.2.2 of the LSC Handbook (13th edition) was used to classify the interior finish requirements of exits, corridors, and other spaces for an existing business building. A summary of table A.10.2.2 LSC Handbook (13th edition) is shown in Table 8 for a business occupancy.

Table 8: Summary of Interior Finish Requirements (LSC 13th Edition)

Occupancy Type (Existing)	Exits	Exit Access Corridors	Other Spaces
Business	A or B	A or B	A, B, or C

Class A interior wall and ceiling finish- flame spread index, 0-25(new application), smoke development index, 0-450

Class B interior wall and ceiling finish- flame spread index, 26-75(new application), smoke development index, 0-450

Class C interior wall and ceiling finish- flame spread index, 76-200(new application), smoke development index, 0-450

IBC Comparison:

A comparison of the interior finish requirements from the LSC (13th edition) is compared to the 2015 IBC in Table 9.

Table 9: Summary of Interior Finish Requirements (IBC 2015)

Interior Wall and Ceiling Finish Requirements by Occupancy			
Group			
B	Interior Exit Stairways and ramps and exit passageways	Corridors and enclosure for exit access stairways and ramps	Rooms and enclosed spaces
	A	B	C

Points of Concern:

Waste bins and recycling bins left in the corridors on the third and fourth floors (Figure 10) pose egress concerns.

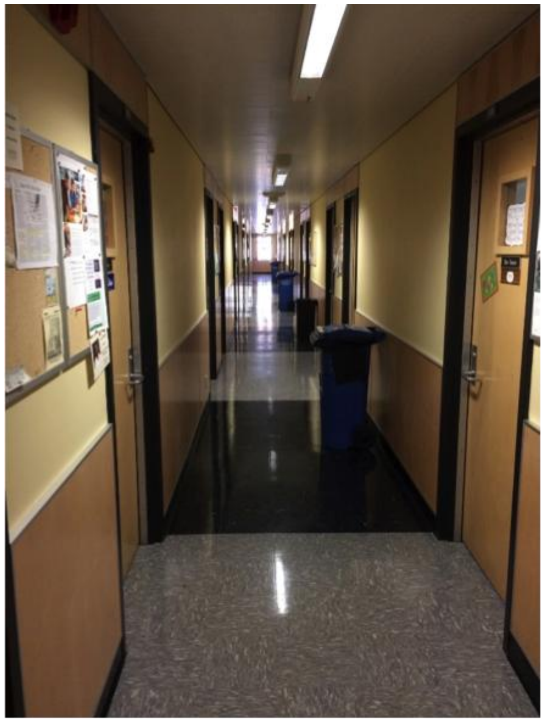


Figure 10: Waste Bin Hallway Obstructions

A rolling chair (Figure 11), and phone books (Figure 12) are also left in the corridor and pose a risk to egress by reducing exit with of the corridor.

Figure 11: Rolling Chair Hallway Obstruction

Figure 12: Textbook Hallway Obstruction

Conclusions/ Recommendations:

Each floor contains at least three exits thus complying with section 7.4.1.1 of the LSC Handbook (13^{th} edition), which states that a total of two exits are required for each floor.

None of the floors have an occupant load of above 500 meaning that section 7.4.1.2 of the LSC Handbook (13^{th} edition) is satisfied.

Each floor satisfies the requirement that each corridor will provide access to at least two exits as specified by 7.5.1.1.1 of the LSC Handbook (13^{th} edition).

The corridors in the building are at least 44 inches wide as required by section 12.2.3.8 in the LSC Handbook (13^{th} edition) for assembly occupancies.

Overall, the building complies with the prescriptive requirements present in the Life Safety Code Handbook. One point of concern is the number of obstructions that are left within the exit corridors on a daily basis. These obstructions reduce the minimum width of the corridors below the required 44 inches. This hallway reduction violates the clear width requirement of the 13^{th} edition of the LSC. These obstructions may also lead to injury or the obstruction of doorways if moved into different spaces. I would recommend removing hallway obstructions to leave the hallways clear.

In order for the successful egress of a building to occur, the occupants need to be notified about the fire as soon as possible so that they can begin to exit the building. The proper implementation of alarms, pull stations, and detection devices are discussed in the next section.

Fire Detection, Alarm, and Communication Devices

Introduction:

An important part of a fire safety analysis is the assessment of how the fire will be detected, and how long it will take the system in place to notify the occupants to begin exiting the building. A few minutes might be the difference between a safe egress and a point in which untenable conditions are reached. Proper detection and notification are essential to the safe egress of any structure.

Fire Alarm System and FACP Information

Type of fire alarm system

The type of fire alarm system installed in this building is a supervising station alarm system with a central station service in use.

Operational Matrix

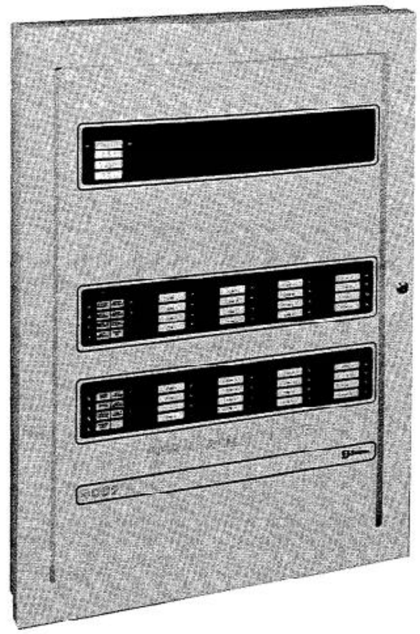
The operational matrix (Figure 13) outlines the response of the alarm system to each of the actions that will signal an abnormality in the building.

	ANNUNCIATE ALARM CONDITION AT FIRE ALARM CONTROL PANEL	ACTIVATE HORNS & STROBES THROUGHOUT BUILDING	ACTIVATE SUPERVISORY ALARM AT FIRE ALARM CONTROL PANEL	ANNUNCIATE TROUBLE CONDITION AT FIRE ALARM CONTROL PANEL	RELEASE DOOR HOLDERS THROUGHOUT BUILDING	SHUT DOWN ASSOCIATED FAN UNIT	SEND ALARM SIGNAL TO CENTRAL STATION	SEND TROUBLE SIGNAL TO CENTRAL STATION
MANUAL PULL STATION	O	O			O		O	
SMOKE DETECTOR	O	O			O		O	
DUCT DETECTOR	O	O				O		
FLOW SWITCH	O	O			O			
TAMPER SWITCH			O	O				O
SYSTEM TROUBLE				O				O

OPERATIONAL MATRIX

Figure 13: Operational Matrix

FACP Information:



FIRE ALARM CONTROL PANEL
MODEL #4002-8001
C.S.F.M. #7165-026:154

Figure 14: Fire Alarm Control Panel

Data Sheet:

http://firealarmresources.com/wp-content/uploads/2013/06/Simplex-4002+Installation++Operating+Manual.pdf

The fire alarm control panel is located on the first floor of the building as shown on the map in Appendix A.

FACP Features:

This model of FACP (Figure 14) can operate up to six notification appliance circuits and monitor up to 32 zones of initiating device circuits. The panel can automatically control equipment including fire doors, smoke dampers, and fans if a fire condition arises. If a trouble or (alarm) fire condition does arise, the panel will provide both audible and visual indications of the signal in the form of either a yellow LED (trouble signal), or a red LED (alarm signal).

Duct Detector Information

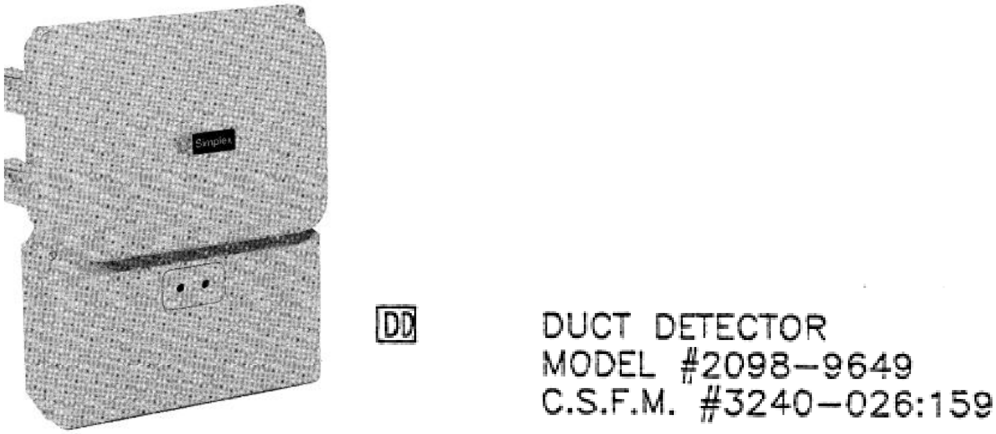


Figure 15: Duct Detector

Datasheet:

http://www.readbag.com/firealarms-pbworks-f-2098-9645ducthousinginstallationmanual

Duct Detector Features:

The 2098 -9649 air duct detector housings (Figure 15) are designed to sample air and detect smoke in an air duct. The housing contains a 2098-9201 photoelectric smoke detector. The air in the ducts is sampled via sampling tubes that extend into the duct. This housing may be used for ducts with widths from 8 to 95 inches. It may also be used on round ducts with a diameter of 24 inches or greater.

Smoke Detector Information

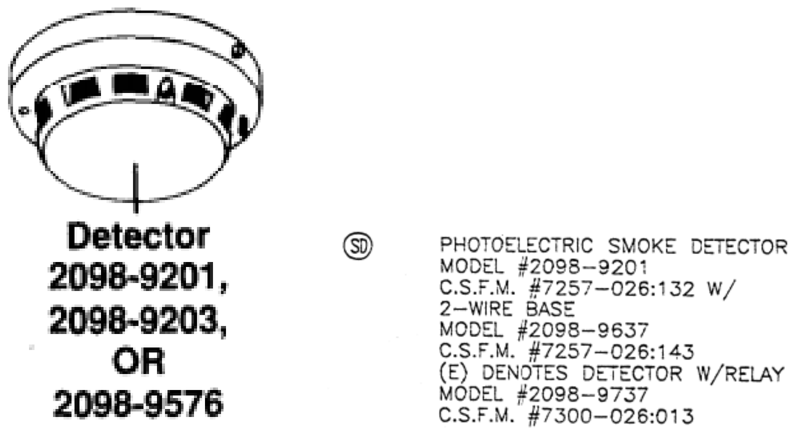


Figure 16: Smoke Detector

Datasheet:

http://firealarmresources.com/wp-content/uploads/2013/06/Simplex-2098-9201+Installation+Manual-1.pdf

Smoke Detector Features:

Each photoelectric smoke detector (Figure 16) is capable of providing 450-900 square feet of coverage, depending on codes in place in the state of instillation. In order for a photoelectric smoke detector to activate, smoke must enter the detection chamber. The air flow, air stratification, air velocity, air stagnation, and air migration will have an effect on the detector efficiency and should be taken into account during installation.

Device Locations found in Appendix A.

Spacing of Fire Detection Devices

This building does not contain sprinklers meaning that the duct, spot type smoke detectors, and manual pull stations are the only means by which the mass notification system will be activated.

From the map layout it appears that detectors were only placed in the larger rooms and areas of importance like the room containing the fire alarm control panel, and mechanical rooms that would normally not be occupied. The layout of the building is very open and many of the smaller rooms lead directly to the outdoors.

Many of the rooms do not have spot type smoke detectors meaning the floor plan does not adhere to the specification required by 17.7.3.2.3.1 of NFPA 72, which would make the minimum requirement a detector located at 0.7 times the nominal spacing of each smoke detector on all points of the ceiling.

Given the openness of the floor plan I believe a performance based design approach was created in accordance with section 17.7.3.1.2 of NFPA 72. For the rooms leading directly outside, the performance criteria dealing with compartment ventilation can be utilized to justify not having a smoke detector.

While detectors are not located in every room, the location of smoke detectors in the larger rooms adheres to a specification laid out in 17.6.3.1.2 of NFPA 72 that states the spacing of detectors cannot be more than 0.7 times the listed spacing of 30. This would make the maximum radius of operation for each detector 21 ft making the maximum distance 42 feet away from each other in the same space.

The system seems to rely on the fact that the fire will likely be noticed immediately as the building will likely be occupied when a fire occurs and one of the pull stations will be activated.

On the top two floors of the building where rooms no longer exit into the open, smoke detectors are placed in larger rooms and adhere to section 17.6.3.1.2 of NFPA 72. In the northern corridor of the building that connects multiple smaller rooms detectors were placed in the corridor as opposed to placing a detector in each of the smaller offices. The spacing of these detectors also adheres to section 17.6.3.1.2 of NFPA 72. If a fire starts in one of the smaller offices, the occupant of the office will most likely be in the room at the time, walk outside, and pull a manual pull station located by each exit. If the fire starts while an occupant is not present in the building the smoke may be detected by a hallway or duct detector, which should be obtaining a representative sample of the airstream in accordance with section 17.5.5 of NFPA 72.

Business Silo:

The business silo contains a duct detector and two manual pull stations. Given the height of the ceiling in the lecture hall, the activation time of a spot type smoke detector would be long making these measures more practical.

Duct Detectors:

Duct detectors are located in mechanical rooms on floors 1,3, and 4 to take representative samples of the air circulating throughout the building. One duct detector is located within the Business Silo to test the air circulating in this area.

Alarm Supervisory and Trouble Signals

Disposition of alarm (26.3.8 NFPA 72)

When an alarm signal is activated on the premises, the central station shall retransmit the signal to the communication center. The station must dispatch a runner or technician to the premises to reset equipment that requires a manual reset within 2 hours of receiving the signal. If a qualified technician on the premises does this, dispatching a runner or technician is not necessary. The central station is immediately required to notify the subscriber, AHJ, or both if it is required for the building.

Supervising signal (26.3.8.3 NFPA 72):

The central station must make contact immediately with the personnel designated by the subscriber and also notify the fire department, law enforcement agency, or both depending on the AHJ. The central station must dispatch a maintenance person to arrive within 2 hours unless the signal was cleared prior. If the sprinkler system or other fire suppression system or equipment has been out of service for 8 hours, the AHJ and subscriber must be notified. (No sprinkler or suppression equipment in this building). In the event that equipment was out of service for 8 hours or more, the subscriber and AHJ must be notified when power is restored, the nature of the signal, and the time of the occurrence.

Trouble Signals (26.3.8.4 NFPA 72):

When dealing with a trouble signals dealing solely with alarm system maintenance, the central station shall communicate immediately with the person designated by the subscriber. The central station must also dispatch personnel within 4 hours to perform maintenance if any is required. If an interruption lasts 8 hours or more, the central station must provide notice to the subscriber and fire department if required by the AHJ. In this notice the central station must address the nature of the interruption, the time of the occurrence, and when restoration of service can be expected.

Alarm Notification Devices

Alarm unit Information:

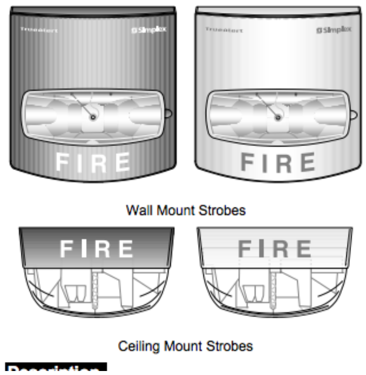


Figure 17: Audiovisual Units

Datasheet:

https://www.tycosimplexgrinnell.com/wps/wcm/connect/e99eba1e-89b1-4c2d-877f-6b5ef753ba05/4906-9101,+-9102,+-9103,+-9104.PDF?MOD=AJPERES&CACHEID=e99eba1e-89b1-4c2d-877f-6b5ef753ba05

The intensity of the strobes (Figure 17) can be set to 15, 30, 75, or 110 candela ratings.

Surface horn Information:

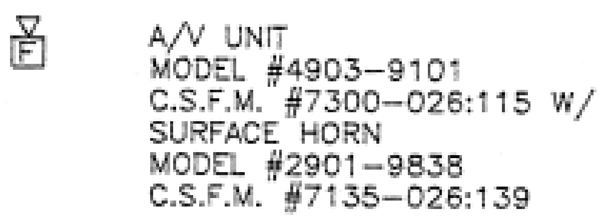


Figure 18: Surface Horn

Horn Datasheet (newer model):

The exact datasheet for the horns installed in the building were not available therefore a newer model will be used to calculate the secondary power supply https://www.tycosimplexgrinnell.com/wps/wcm/connect/9e4d85a1-6d46-4eb2-8a04-4b69b1d9cc7d/4901-9856%2C+4901-9857.PDF?MOD=AJPERES&CACHEID=9e4d85a1-6d46-4eb2-8a04-4b69b1d9cc7d

The horns (Figure 18) offer a variety of tones including horn, bell 500 Hz Horn, Canadian Horn, Slow Whoop, or Hi/Lo. For each of the tones a standard or high output level is available which ranges from 67-87 dBA in a 10ft reverberation chamber test.

Device locations are found in Appendix A.

Spacing of Alarm Notification Devices

Audible placement considerations:

Using Table A.18.4.3 in NFPA 72, the ambient sound level is 55 dBA for Business occupancies, which would be the correct occupancy classification for the business building on campus.

In accordance with the code restriction above, the sound level of the alarm should be no less that 55 + 15 = 70 dBA at all times.

Utilizing the 6 dBA rule outlined in NFPA 72:
For an open room where sound does not reflect off surfaces, the sound level decreases by about 6 dB every time the distance from the source is doubled.

The hallways in the building only have a distance of 6 feet meaning that even if the lowest setting of 77 dBA for the horn is used, a decibel loss of less than 6 will occur leaving the decibel level above 70 which would be sufficient for this area.

Visual Considerations:

All the A/V devices are placed within 100 feet of each other in the building with at least one A/V device located within15 feet from the end of the corridors in accordance with 18.5.5.5.5. Given the unique curved layout of the building, it is likely that the room spacing criteria of 18.5.5.5.1 would not cover all areas. For this reason I believe that most of the devices adhere to the lowest dBA setting which would leave the total ambient noise level well below 105 dBA. Utilizing 18.4.1.1 visual devices would not have to be present in this low noise setting.

Mass Notification System

Since this building is only installed with horns and strobes intended for use with fire emergencies without any of the components listed above, the system installed in this building is not considered a mass notification system. One reason that a mass notification system may not be necessary in such a building is the building's connection to the college campus network of emergency notification. For example, if there was an active shooter on campus alerts would be sent directly to the cell phones and emails of students and teachers on campus.

Secondary Power Supply Requirements

The calculations of the secondary power supply requirement were done by facilities, and the results of the calculations are shown below. Using the datasheets for each device, the secondary power supply is going to be calculated and then compared to the value obtained by facilities.

Facilities calculations:

BATTERY CALCULATIONS

SUPERVISORY CURRENT OF FACP	.32
SUPERVISORY CURRENT OF PERIPHERALS	+ 0
TOTAL SUPERVISORY CURRENT OF SYSTEM	= .32
HOURS OF EMERGENCY STANDBY POWER REQUIRED	x 24
TOTAL AMP HOURS STANDBY POWER REQUIRED	= 7.68
ALARM CURRENT OF FACP	.557
ALARM CURRENT OF PERIPHERALS	+ 2.82
TOTAL ALARM CURRENT OF SYSTEM	= 3.38
TOTAL HOURS EMERGENCY ALARM POWER REQUIRED	x .083
TOTAL AMP HOURS ALARM POWER REQUIRED	= .28
TOTAL AMP HOURS BATTERY BACKUP REQUIRED	= 7.96

10.0 AH BATTERIES ARE PROVIDED

Figure 19: Required Battery Power (Facilities Calculation)

Listed Currents: The listed standby current of the FACP (Figure 19) was listed as 0.32 A, and the alarm current was listed as 0.557 A.

Smoke detectors:

Figure 20 summarizes the battery power required for the smoke detectors in the building to be used in calculating the required battery capabilities.

Standby Current: 40uA
Alarm current: 86mA

TABLE 1

SPECIFICATIONS	SMOKE DETECTOR DATA				
Detector	2098-9576	2098-9201	2098-9202	2098-9203	†2098-9208
Type of Detector	Ionization	Photoelectric	Photoelectric with Heat	Photoelectric	Photoelectric
Working Voltage (2-Wire)	15-36.3 VDC	15-36.3 VDC	15-36.3 VDC	15-36.3 VDC	15-32 VDC
Rated Voltage (4-Wire)	17.7-33.0 VDC	17.7-33.0 VDC	17.7-33.0 VDC	17.7-33.0 VDC	17.7-33.0 VDC
Voltage Waveform	Filtered DC * 18V Ripple Max.	Filtered DC * 18V Ripple Max.	Filtered DC * 18V Ripple Max.	Filtered DC * 18V Ripple Max.	Filtered DC † 18V Ripple Max.
Max. Alarm Current	86 mA	86 mA	86 mA	86 mA	86 mA
Surge Current	200 uA	200 uA	200 uA	200 uA	200 uA
Standby Current	40 uA	40 uA	40 uA	40 uA	50 uA
Heat Element Rating	N/A	N/A	135 Degrees F	N/A	N/A
** Compatibility Identifier	2098-9576	2098-9201	2098-9202	2098-9203	2098-9208
Test Procedure	Magnet or 553-536	Magnet or 553-536	Magnet or 553-536	Magnet or 553-536	Magnet or 553-574
Max. Qty. Per Initiating Circuit	See Table 4	See Table 4	See Table 4	See Table 4	See Table 4

Figure 20: Battery Data for Smoke Detectors

Strobes:

Figure 21 summarizes the battery requirements for the strobes used in the building to be used in calculating the required battery capabilities.

(assuming small cd usage due to small hallway size)
Standby: none
Alarm (15cd): 60mA

Strobe Specifications

Wall Mount or Ceiling Mount, Common Specifications

Rated Voltage Range	Regulated 24 VDC; see Note 1 below
Flash Rate	1 Hz
Synchronized NAC Loading	Up to 35 synchronized strobes maximum per NAC
Temperature Range	32° to 122° F (0° to 50° C)
Humidity Range	10% to 93%, non-condensing at 100° F (38° C)
Connections	Terminal blocks for 18 AWG to 12 AWG (0.82 mm² to 3.31 mm²); two wires per terminal for in/out wiring

Wall Mount	Housing Dimensions (with lens)		5-1/8" H x 5" W x 2-3/4" D (130 mm x 127 mm x 70 mm)			
	Maximum RMS Current Rating per Strobe Setting (see Note 2 below)		**15 cd**	**30 cd**	**75 cd**	**110 cd**
			60 mA	**94 mA**	**186 mA**	**252 mA**
	Reference RMS Currents at other voltages	18 VDC	53 mA	84 mA	165 mA	224 mA
		24 VDC	40 mA	63 mA	124 mA	168 mA
Ceiling Mount	Housing Dimensions (with lens)		4-3/4" L x 2-5/16" W x 2-5/8" D (121 mm x 75 mm x 67 mm)			
	Maximum RMS Current Rating per Strobe Setting (see Note 2 below)		**15 cd**	**30 cd**	**75 cd**	**110 cd**
			75 mA	**125 mA**	**233 mA**	**316 mA**
	Reference RMS Currents at other voltages	18 VDC	67 mA	111 mA	207 mA	281 mA
		24 VDC	50 mA	83 mA	155 mA	211 mA

NOTES:

1. "Regulated 24 VDC" refers to the voltage range of 16 to 33 VDC per UL Standard 1971, Signaling Devices for the Hearing

Figure 21: Battery Data For Strobes

Horns:

Figure 22 summarizes the battery requirements for the horns used in the building to be used in calculating the required battery capabilities.

Standby: 0 mA
Alarm: 35 mA

Multi-Tone Horn Specifications

Rated Voltage Range	16 VDC to 33 VDC
Rated Current	35 mA
Temperature Range	32° to 122° F (0° to 50° C)
Humidity Range	10% to 93%, non-condensing @ 100° F (38° C)
Connections	Terminal blocks for 18 AWG to 12 AWG (0.82 mm^2 to 3.31 mm^2); two wires per terminal for in/out wiring

Multi-Tone Horn Sound Output Characteristics (see notes as indicated)

Tone	Description	Sound Output Ratings per **UL 464** Reverberant Chamber test @ 10 ft (~3 m)		Sound Output Ratings per **ULC S525** Anechoic Chamber test @ 3 m (~10 ft)	
		Standard Output	**High Output**	**Standard Output**	**High Output**
Horn[1] or Canadian Horn[1]	2400 to 3700 Hz sweep, modulated at 120 Hz rate	77 dBA	86 dBA	92 dBA	102 dBA
Bell[1]	1560 Hz modulated at 7 ms intervals	73 dBA*	87 dBA	84 dBA**	99 dBA
500 Hz Horn[1]	500 Hz tone	77 dBA	86 dBA	84 dBA**	99 dBA
Slow Whoop[2]	500 Hz to 1200 Hz sweep	73 dBA*	83 dBA	90 dBA	103 dBA
Siren[2]	600 Hz to 1200 Hz, 1 sec on then repeat	67 dBA*	79 dBA	87 dBA	100 dBA
High/Low[2]	Alternating tones of 1000 Hz and 800 Hz, 250 ms duration	77 dBA	86 dBA	91 dBA	102 dBA
Sound Dispersion per ULC S525 testing		-3 dBA at +/-30° off-axis			
		-6 dBA at +/- 50° off-axis			

* For Private Mode use only. Always test installed sound level against local requirements.

Figure 22: Battery Data For Horns

Duct Detectors:

Figure 23 summarizes the battery requirements for the duct detectors used in the building to be used in calculating the required battery capabilities.

Standby:1 mA
Alarm: 1 mA

Two-Wire MAPNET II Operation (Figure 4)

- *Input voltage* — 16.5 to 36VDC
- *Ripple tolerance* — 20% maximum
- *Standby Current* — 1 mA
- *Alarm Current* — 1 mA. Add 1 mA for remote alarm LED 2098-9744.

Figure 23: Battery Data for Duct Detectors

Manual Battery Calculations:

Tables 10-16 carry out the battery requirements of the building based on the ratings outlined in Figures 20-23.

Table 10: Standby Current Calculation

Description	Standby current per unit (amps)	Quantity	Total standby current per unit(amps)
FACP	0.32	1	0.32
Duct Detectors	0.001	7	0.007
Smoke alarms	0.00004	48	0.00192
Horns	0	30	0
Strobes	0	30	0

Table 11: Alarm Current Calculation

Description	Total alarm current per unit (amps)	Quantity	Total system alarm current (amps)
FACP	0.557	1	0.557
Duct Detectors	0.001	7	0.007
Smoke alarms	0.086	48	4.128
Horns	0.035	30	1.05
Strobes	0.06	30	1.8

Table 12: Total Standby and Alarm Current Calculation

Total system standby current (amps)	Total system alarm current (amps)
0.32892	7.542

Table 13: Required Operation Time of Standby and Alarm Signals

Required Operation Time of Secondary Power Source from NFPA 72 10.5.6.3	
Standby: 24 hours	Alarm = 5 min (1 hour/60 min) = 0.0833

Table 14: Required Standby Capacity

Required standby time (hours)	Total system standby current (amps)	Required standby capacity (amp-hours)
24	0.32892	7.89

Table 15: Required Alarm Capacity

Required alarm time (hours)	Total system alarm current (amps)	Required alarm capacity (amp-hours)
.0833 hours	7.542	0.63

Table 16: Total Required Battery Capacity (Including Safety Factor)

Standby capacity (amp-hours)	Alarm capacity (amp-hours)	Total capacity (amp-hours)	Safety factor	Battery capacity (amp hours)
7.89	0.63	8.52	1.2	10.22

When the battery calculations were done manually a battery capacity of 10.22 A-H were calculated, while in the facilities calculation yielded 7.96 A-H. This discrepancy might be explained by the fact that new detectors were added to the building, and this new layout found in Appendix A was used for these calculations. Another discrepancy might be found in the fact that there are combined A/V units in the building making it hard to distinguish if only a horn is in use. Based on this calculation the 10 A-H battery would not be sufficient, but taking the factors mentioned above into account it is likely that the 10A-H battery has been changed to accommodate the new detection devices.

Inspection Testing and maintenance

The inspection and testing requirements for the building are laid out in Tables 14.3.2 and 14.4.3.2 respectively. The relevant sections for the review of the FACP, batteries smoke and duct type detectors, and A/V devices were taken from NFPA 72 and placed below.

The maintenance of the hardware installed in the building shall be maintained in accordance with the manufacturer's instructions with the frequency of maintenance depending on the type of equipment and ambient conditions. The cleaning of equipment will also depend on the type of equipment and ambient conditions present. All apparatus items that require resetting shall be reset as soon as possible after each test and alarm signal

Detector Activation Example Fire Scenario:

An employee on the third floor of the building utilizes a coffee maker located in one of the larger classrooms that sits on a counter that is 1.5m off the ground. While working late one night the employee makes a cup of coffee and forgets to turn off the coffee maker. Before leaving the room, the employee accidentally shifts a small stack of paper closer to the coffee maker putting the paper in contact with the heating plate. The employee leaves the room and after heating up enough, the piece of paper catches on fire igniting the work area and coffee maker. The fire occurred in room 307. For this scenario we are going to assume that there was a printer, a coffee maker and a stack of paper on top of the counter in the building. The ceiling height in these large classrooms is 15ft.

The Optical Density Method Versus Temperature method outlined in B.4.8.1.1 in Annex B of NFPA 72, and the DETACT model outlined below were used to solve this problem.

The average value for temperature rise for detector response taken from Table B.4.7.5.3 from Annex B of NFPA 72 shall be used because the material that makes up the counter may vary in heat release rates. This value was 21.1, and when added to the ambient temperature of 20C the actuation temperature would be 41.1C

The RTI value for this calculation was taken to be 15-m 1/2 sec ½. A similar value was used in example B.4.8.1.3 in Annex B of NFPA 72 . When a low RTI is used for a smoke detector, it behaves as a heat detector would in the DETACT model by making the detector temperature closer to the actual gas temperature.

The maximum radial spacing was taken to be 0.707 (41) based on the configuration of the smoke detectors in the larger rooms of the building. The fire is going to be assumed to be a medium growth fire with a growth coefficient of 0.012kW/s^2.

Looking at the data corresponding to the actuation temperature of 41.4 C, we find that it will take the detector 208 seconds to activate and at this time a heat release rate of 519.2 kW. Table 26 shows the HRR, gas temperature, gas velocity, detector temperature and dT/dt for at the time of activation.

Basis of DETACT T^2 Model:

The DETACT T^2 Model is used to calculate the actuation time of heat detectors (fixed-temperature and rate of rise) and sprinklers for t^2 fires. This model assumes that the detector is located in a large compartment with an unconfined ceiling with no accumulation of hot gasses at the ceiling. The activation of a detector is only caused by the flow of hot gases along the ceiling. The DETACT T^2 model calculates the time at which the detector will activate and the heat release rate at the time of detection.

DETACT Model Results:

Table 17 summarizes the parameters that were used for the design detection room. These correspond to the furthest possible radial distance of the detector. Figure 24 shows how the gas temperature, detector temperature, and heat release rate vary as a function of time during the course of the fire. Table 18 shows the characteristics of the fire at the time of activation.

Table 17: Parameters Used in DETACT Calculations

Estimate of the response time of smoke detector in room 307				
INPUT PARAMETERS			CALC. PARAMETERS	
Ceiling height (H)	3.07	m	R/H	2.834
Radial distance (R)	8.7	m	dT(cj)/dT(pl)	0.150
Ambient temperature (To)	20	C	u(cj)/u(pl)	0.084
Actuation temperature (Td)	41.4	C	Rep. t2 coeff.	k
Response time index (RTI)	15	(m-s)1/2	Slow	0.003
Fire growth power (n)	2	-	Medium	0.012
Fire growth coefficient (k)	0.012	kW/s^n	Fast	0.047
Time step (dt)	2	s	Ultrafast	0.400

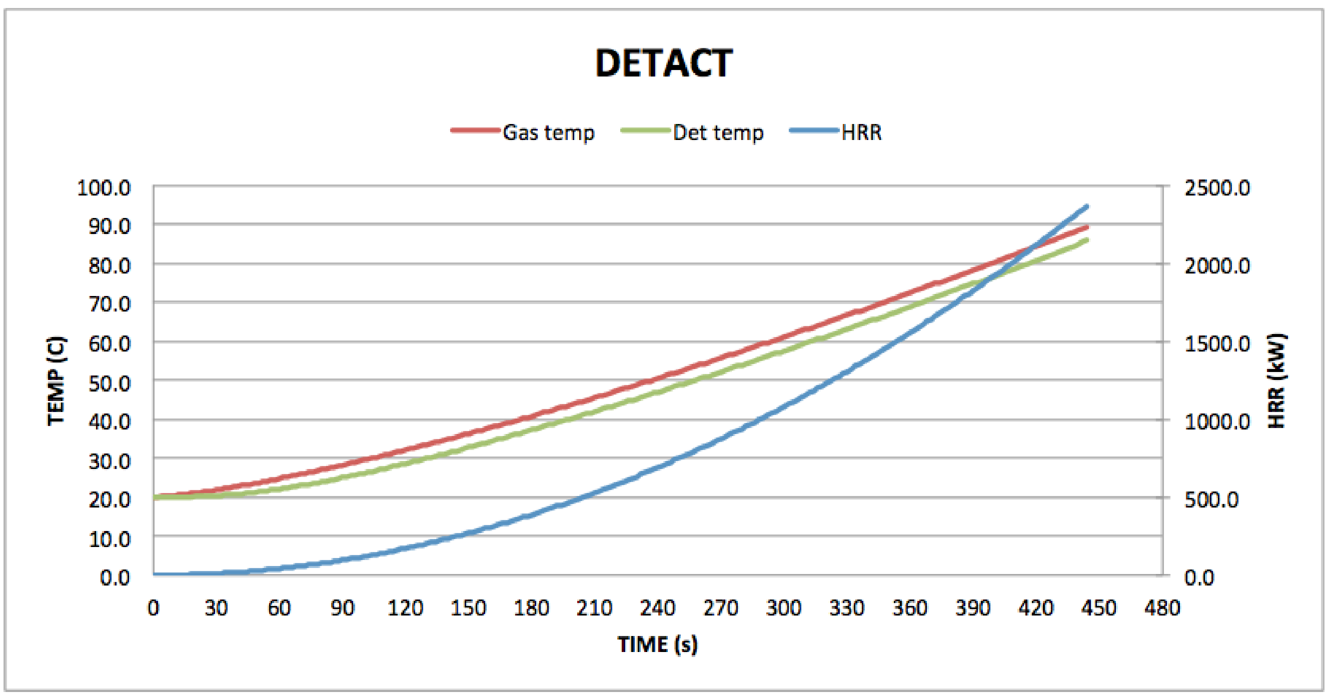


Figure 24: DETACT Curves for Gas Temperature, Detector Temperature, and Heat Release Rate of Fire

Table 18: Activation Time of Smoke Detector

Calculation time (s)	HRR	Gas Temp	Gas velocity	Detector temperature	dT/dt
208	519.2	45.2	0.46	41.66	0.1619

Conclusions/ Recommendations

The alarm and notification devices meet the prescriptive requirements of the code and provide adequate coverage to notify occupants of a potential fire scenario.

The smoke detection devices do not comply with the spacing requirements outlined in NFPA 72 if full coverage is a goal of the building design . The exceeded space requirement (above 42 feet) is especially true for the smaller offices on the third and fourth floors of the building. A new addition to the smoke detectors in 2012 along the corridors indicate that the detectors are in fact utilized for coverage purposes and not just to release doors to act as barriers. While the duct detection devices might pick up smoke from a fire in one of these areas, the risk of flashover is higher due to the size of the enclosures. Due to the small size of these areas and the fuel loads present in a typical office space (desks, books, wooden shelves, electronics, foam computer chairs), I would recommend placing a photoelectric smoke detector in each office space to comply with NFPA 72.

While detection and notification of a building is important, it is also important to ensure that physical barriers in the building provide adequate protection to ensure a safe egress.

Structural Fire Protection:

Introduction:

The structural components of a building are the first line of defense against possible damage to property or a potential loss of life. The fire rating of all building elements needs to be examined to determine how much the structural elements can handle before a failure occurs. Failure of a building component on a structural level can cause damage to property or hinder an escape. A structural failure might also allow smoke or harmful flames to spread into a new area.

Required Construction Classification:

The business building is composed of mostly small offices with lecture halls and classrooms dispersed throughout the first and second floors. For this reason, the building will be considered primarily group-B occupancy with some A-3 areas. The lecture hall detached from the main building is considered a group A-3 occupancy. In accordance with sections 508.2.2,and section 508.2.3 of the 2015 IBC, the building height and area requirements shall be determined using the main occupancy classification of B. The building has two floors above grade and a basement level that opens to the outside. The total area of the floors at and above grade in the main building is 86, 546 ft^2 with a roof height of 59.5 feet. The building is not sprinklered, and utilizes a passive fire protection system to divide the building into individual sections using fire rated walls and corridors.

Building Height:

Main Building Height: 59.5 feet (from lowest floor of Fire Department Access)

Table 19 summarizes allowable building height in feet above grade plane for a group B occupancy. (Based on Table 504.3 a in the 2015 IBC)

Table 19: Maximum Allowable Building Height (IBC 2015)

Table 504.3 a										
Occupancy Classification		Type 1		Type 2		Type 3		Type 4	Type 5	
		A	B	A	B	A	B	HT	A	B
A, B, M, F, A, S, U	Unsprinklered	UL	160	65	55	65	55	65	50	40
	Sprinklered	UL	160	85	75	85	75	85	70	60

Number of Stories:

Number of stories above grade plane: 3

Table 20 summarizes the maximum number of stories above grade plane for a group B occupancy. (Based on Table 504.4 a, b in the 2015 IBC)

Table 20: Maximum Number of Stories Above Grade Plane (IBC 2015)

Table 504.4 a,b										
Occupancy Classification		Type 1		Type 2		Type 3		Type 4	Type 5	
		A	B	A	B	A	B	HT	A	B
B	Unsprinklered	UL	11	5	3	5	3	5	3	2
	Sprinklered	UL	12	6	4	6	4	6	4	3

Area Consideration:

The classification of the building was originally listed as type II FR in the 1985 UBC, which would be a fire-resistive noncombustible classification. From the above graphs up to this point it is clear that multiple construction types are possible, but for the sake of argument type II-A construction will be used to calculate the area considerations.

Total square footage: $86,546\ ft^2$

Table 21 summarizes the maximum allowable are for a group B occupancy (Based on Table 506.2 1,b in the 2015 IBC)

Table 21: Maximum Allowable Area (IBC 2015)

Table 506.2 1,b										
Occupancy Classification		Type 1		Type 2		Type 3		Type 4	Type 5	
		A	B	A	B	A	B	HT	A	B
B	NS	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
	S1	UL	UL	150,000	92,000	114,000	76,000	144,000	72,000	36,000
	SM	UL	UL	112,500	69,000	85,500	57,000	108,000	54,000	27,000

Allowable Area Increase:

Utilizing equation 5-2 for the allowable area increase of a single-occupancy, multi-story building as found in the IBC section 506.2.3:

Note: This equation was used under the provision of 508.2.3 which (as stated in the intro) allows the area calculation for a mixed occupancy building to use the primary occupancy classification.

506.2.3 Single-occupancy, multistory buildings.
The allowable area of a single-occupancy building with more than one story above grade plane shall be determined in accordance with Equation 5-2:

$$A_a = [A_t + (NS \times I_f)] \times S_a \quad \textbf{(Equation 5-2)}$$

where:

A_a = Allowable area (square feet).
A_t = Tabular allowable area factor (NS, S13R or SM value, as applicable) in accordance with Table 506.2.
NS = Tabular allowable area factor in accordance with Table 506.2 for a nonsprinklered building (regardless of whether the building is sprinklered).
I_f = Area factor increase due to frontage (percent) as calculated in accordance with Section 506.3.
S_a = Actual number of building stories above grade plane, not to exceed three. For buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2, use the actual number of building stories above grade plane, not to exceed four.

In order to calculate I_f, the following code was used
Note: The exception listed was used due to the size of the public access ways located around half of the building's perimeter making the W value the maximum of 60 feet.

Exception: Where a building meets the requirements of Section 507, as applicable, except for compliance with the minimum 60-foot (18 288 mm) *public way* or *yard* requirement, and the value of *W* is greater than 30 feet (9144 mm), the value of *W* shall not exceed 60 feet (18 288 mm).

506.3.3 Amount of increase.
The area factor increase based on frontage shall be determined in accordance with Equation 5-5:

$$I_f = [F/P - 0.25]W/30 \quad \textbf{(Equation 5-5)}$$

where:

I_f = Area factor increase due to frontage.
F = Building perimeter that fronts on a *public way* or open space having minimum distance of 20 feet (6096 mm).
P = Perimeter of entire building (feet).
W = Width of *public way* or open space (feet) in accordance with Section 506.3.2.

I = ((585/1170) - .25) (60/30) = .5

A = (37,500 + (37,500X.5)) X 2

Allowable area = 112,500 ft^2

Separation Distance:

Perimeters were calculated using a scaled drawing in a program called BlueBeam to measure applicable distances. This drawing is shown below in Figure 25.

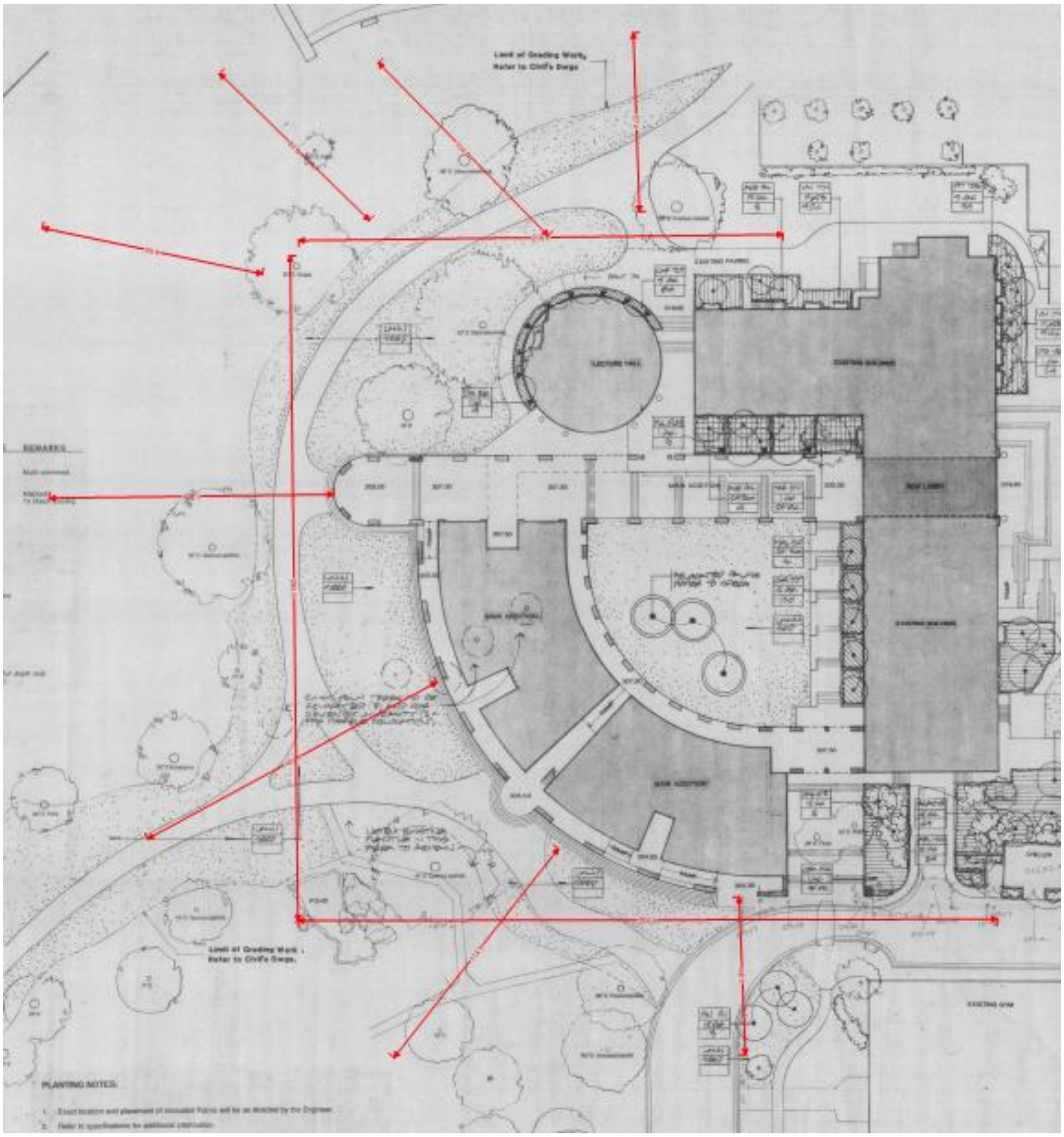


Figure 25: Fire Separation Distance around Business Building

Based on the charts above and the allowable area calculation, the building area fits into the II-A category.

Materials Used in Construction:

Columns:

All columns shall be ASTM A5-72-grade 50 steel.

Beams:

All beams for frames shall be ASTM A36 steel.

Floor Assemblies:

3” metal decking with 2-$^1/_2$” concrete topping and 6X6/ W2.9 X W2.9 welded wire fabric.

Roof Assembly:

3” metal decking with lightweight concrete topping and 6X6/ W 2.9 X W 2.9 welded wire fabric. Thickness of topping varies from 5-$^3/_4$ " maximum to 2-$^1/_2$ " minimum.

Exterior Walls:

Basement walls are solid concrete with varying thickness. Typical walls on upper floors use type R-II insulation with cement plaster over two layers of building paper and one layer of ½” gypsum sheathing.

Interior Walls and Partitions:

Noncombustible gypsum wallboard covering wooden beams construction spaced at 16” on center with type R-II.

Fire Resistance Ratings Used in Construction:

Table 22 summarizes the fire resistance ratings of different elements used within the building. When comparing fire ratings to the 2015 IBC it is important to know how each element of the building was treated in the original construction.

Table 22: Fire Resistance Rating of Elements Used in Construction

Structural Component	Fire Resistance Rating (Hours)
Primary structural frame	2
Columns	2
Beams	2
Floor Assemblies	2
Roof Assembly	1
Bearing Walls	
Exterior	1
Interior	none
Nonbearing walls and partitions	
Exterior	
With separation (0-30 feet)	1
With separation (greater than 30 feet)	0
Interior	0
Door Openings	none
Joints	2
Penetrations	Same as wall penetrating
Shaft	2
Corridor	1

Original Construction vs. Current Code Requirements:

All the fire resistance ratings present indicate a Type I-B building in accordance with Tables 601 and 602 in the 2015 IBC. The only difference between the actual building construction and a Type 1-B building is the exterior bearing walls are not rated for 2 hours. Under the 1985 UBC, the structural classification is Type II-FR. The two requirements are compared in Table 23.

Table 23: Structural Comparison of Fire Rated Elements Used in Construction vs. Required Rating Under the 2015 IBC

Structural Comparison	2015 IBC	1985 UBC
	Required	Actual Construction
	Type 1-B	Type II-FR
Primary structural frame	2	2
Bearing Walls		
Exterior	2	1
Interior	2	-
Nonbearing walls and partitions		
Exterior		
With separation (0-30 feet)	1	1
With separation (greater than 30 feet)	0	0
Interior	0	0
Floor construction and associated secondary members	2	2
Roof construction and associated secondary members	1	1

Fire Rating Requirements:

Table 24 summarizes the required fire rating of the walls and doors within a group B occupancy. Tables 25-28 show the ratings of the doors and corridors that are actually present on each floor of the building. Figures 26-29 show a color-coded depiction of the fire ratings of both the doors and the corridors.

Table 24: Fire Rating Requirements of Walls and Doors (LSC Handbook 13th Edition)

	Wall Rating (hours)	Door Rating (hours)
Horizontal Exits	2	1 1/2
Elevators/ Shafts	2	1 1/2
Exit Access Corridor	1	1/3
Smoke Barriers	1	1/3
Fire Barriers	1	3/4

Floor 1:

Table 25: Fire Resistance Rating of Doors Along Corridor and Leading to Exits on First Floor of Building

Rated Corridor	Exit
20 Minutes	90 minutes

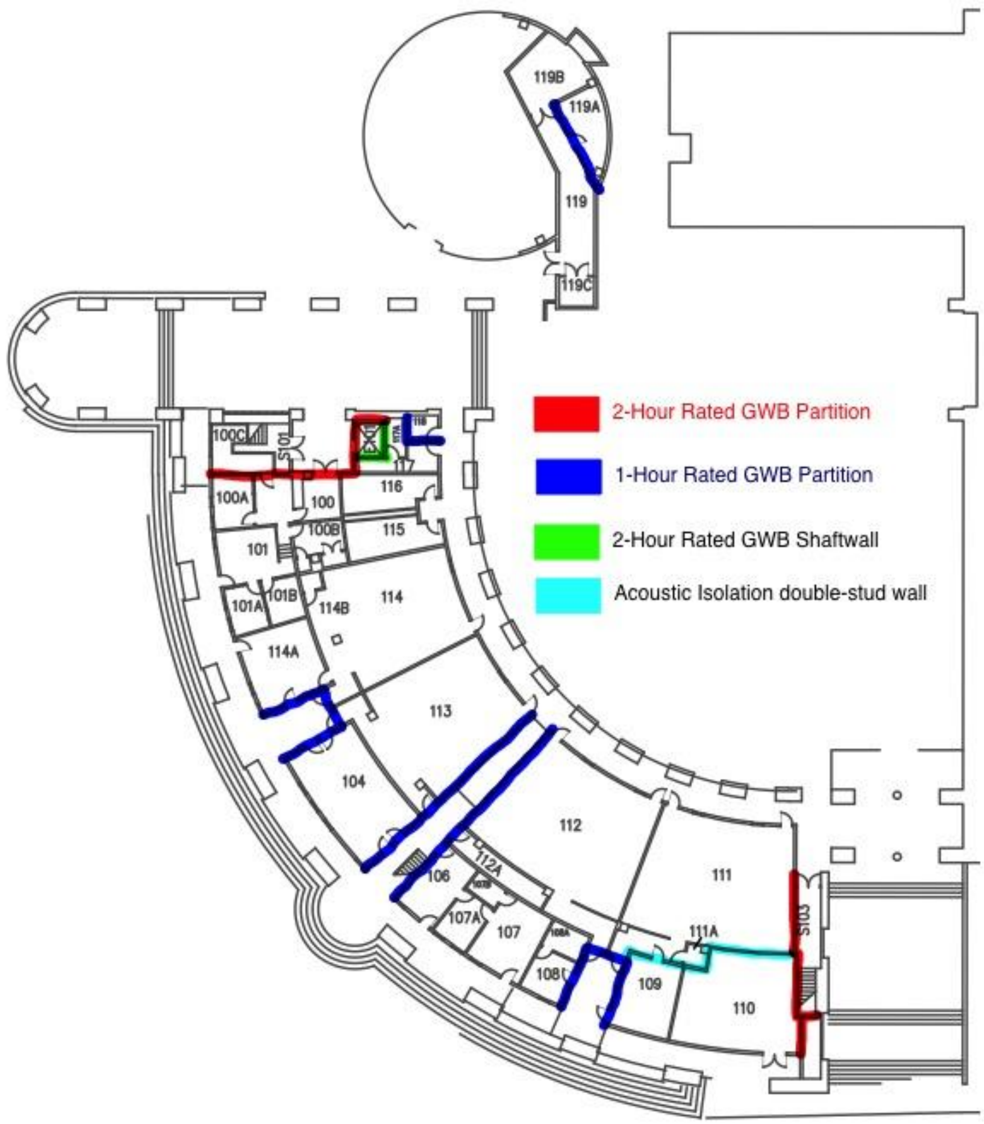


Figure 26: Fire Rating of Walls on First Floor of Building

Floor 2:

Table 26: Fire Resistance Rating of Doors along Corridor and Leading to Exits on Second Floor of Building

Rated Corridor	Exit
45 Minutes	90 minutes

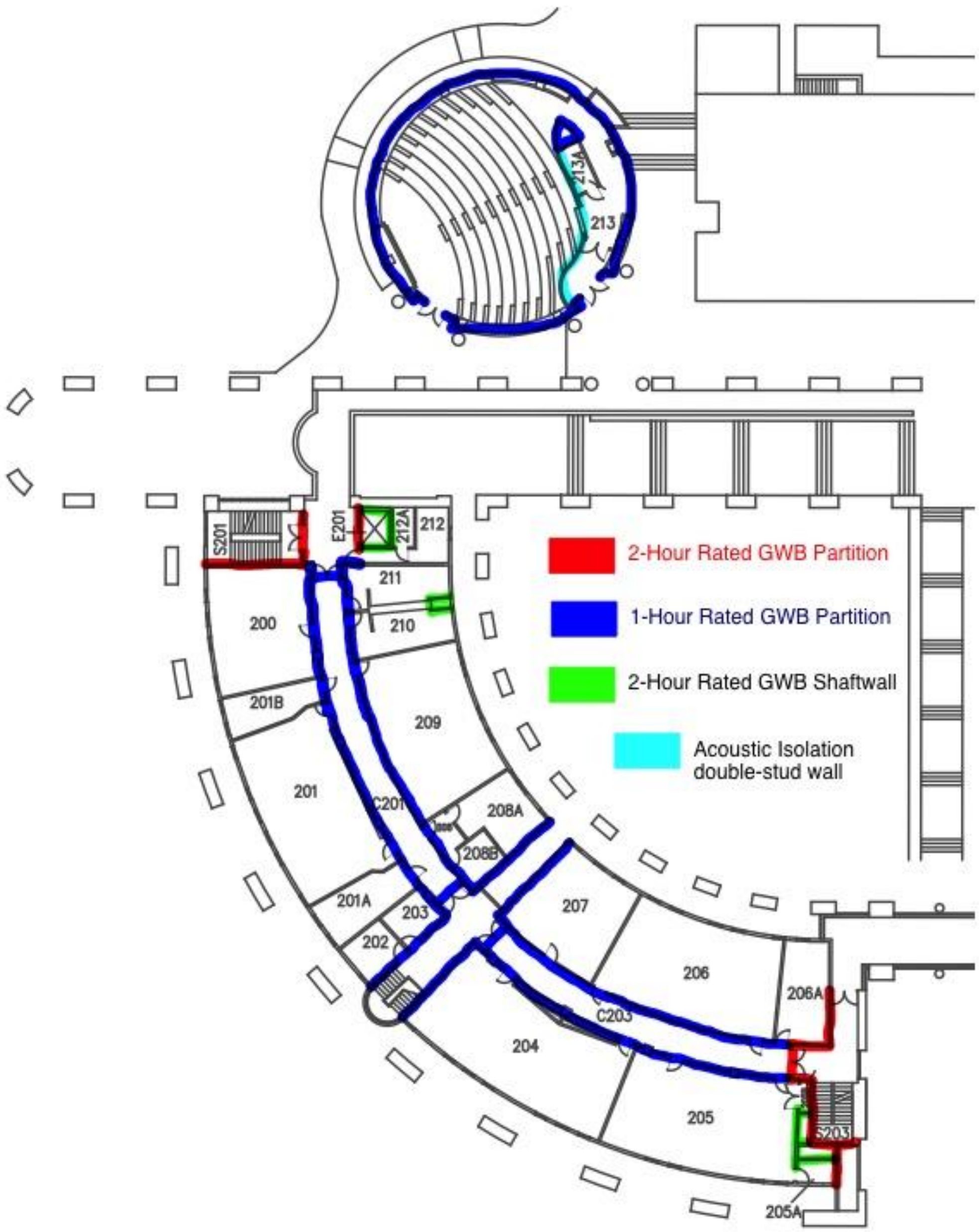


Figure 27: Fire Rating of Walls on Second Floor of Building

Floor 3:

Table 27: Fire Resistance Rating of Doors along Corridor and Leading to Exits on Third Floor of Building

Rated Corridor	Exit
20 Minutes	90 minutes

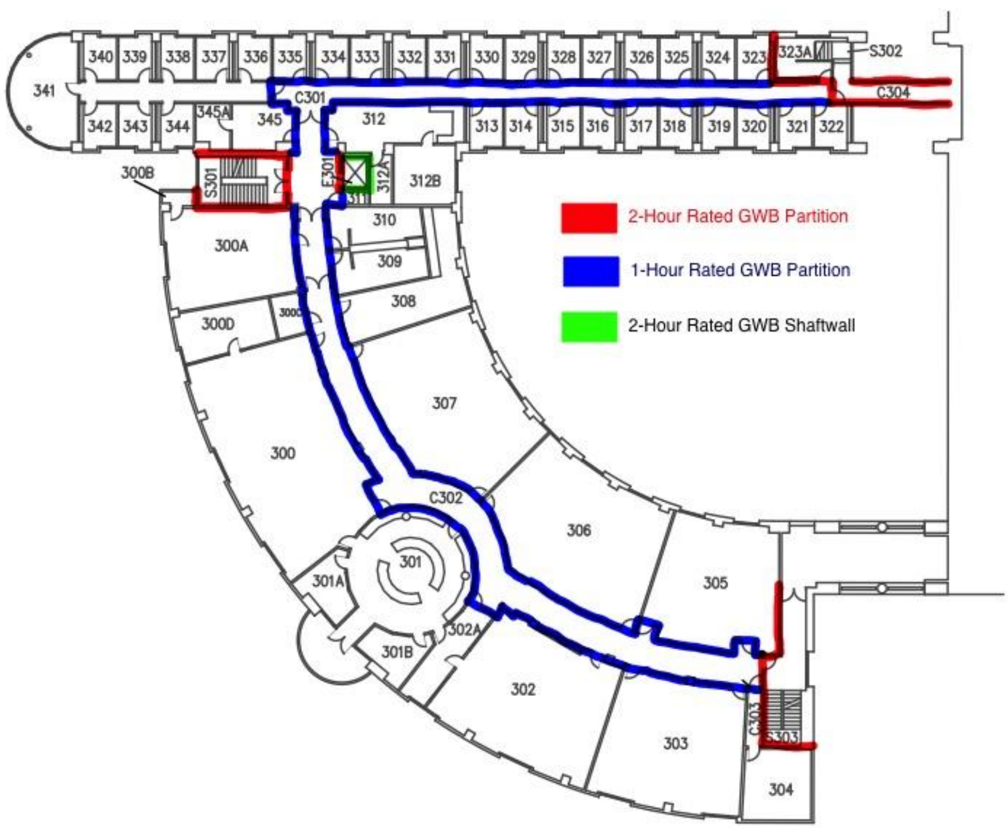


Figure 28: Fire Rating of Walls on Third Floor of Building

Floor 4:

Table 28: Fire Resistance Rating of Doors along Corridor and Leading to Exits on Forth Floor of Building

Rated Corridor	Exit
45 minutes	90 minutes

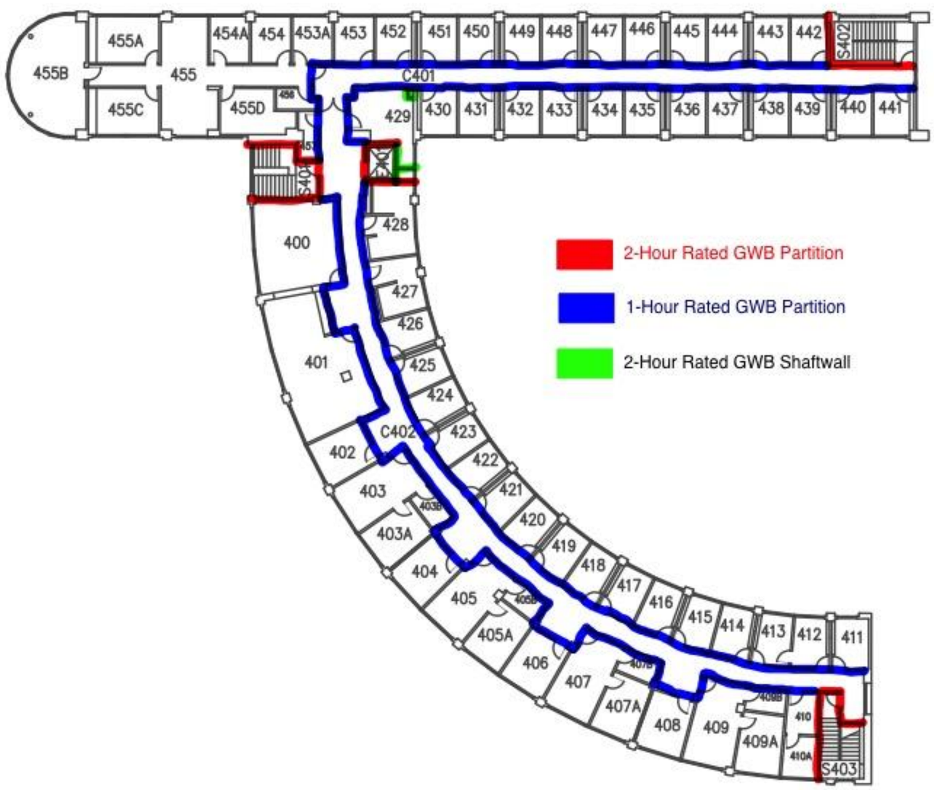


Figure 29: Fire Rating of Walls on Fourth Floor of Building

Points of Concern:

Figures 30 and 31 show areas where doors have been propped open in the building leading into an exit stairwell on the fourth and third floors respectively. Figure 32 shows a door with a magnetic door holder that appears to be disengaged. The door in Figure 32 is propped open (not pictured).

Figure 30: Propped Door Leading into Exit Stairwell

Figure 31: Wedged Door Leading into Exit Stairwell

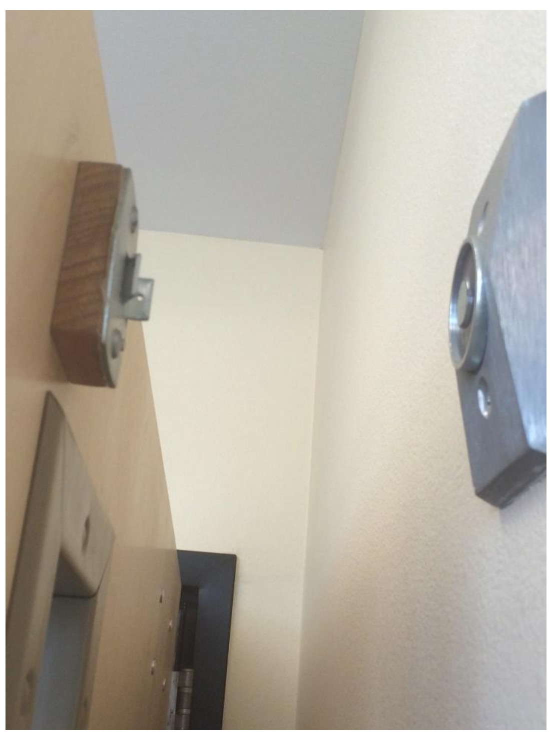


Figure 32: Broken Magnetic Door Holder (Door Wedged Open)

Conclusions/ Recommendations:

In order for the building to comply with the area requirement of a Type 1-B building, the exterior load bearing walls need to be rated for two hours as opposed to the current one hour rating. The rating of exterior openings on the building are required to be 3/4 of an hour for a 1 hour rated exterior wall. The windows in the building do not comply with this requirement. All other fire rating requirements including door and wall ratings comply with the 2015 IBC for a Type 1-B occupancy.

A number of doors leading to important egress routes are propped open with door stops. The door pictured in Figure 32 appears to have had a functioning magnetic door holder at one point, but is now propped open. Many doors in the building are equip with magnetic door holders that will release the doors when an alarm signal is activated. Doors with magnetic holders often serve as smoke or fire barriers for occupants. When a door that is not designed to be left open is wedged, the system does not behave in a predictable manner, and the egress time of the building may be altered. These doors play an important role in the compartmentalization of the building, and should not be held open.

Along with doors connected to magnetic holders, there are other smoke management techniques implemented in the building. The goal of smoke management is to compartmentalize the building so that smoke is contained in the area of origin of the fire. It is also important that the HVAC system does not circulate the smoke to other areas, or cause the smoke layer to behave in a way that would cause harm to occupants.

Smoke Management:

Introduction:

Often the detrimental effects of the movement of smoke within a building are more harmful that the effects of heat coming from a fire. Smoke both inhibits an occupant's visibility and physical ability to safely exit a building.

Smoke Control Features:

In order to address this issue, the Business Building is equipped with fusible link smoke dampers, duct type smoke detectors, and a number of passive fire barriers throughout the corridors.

The smoke barriers are located along the main corridors and contain a wall assembly rating of 1 hour, and a fire door rating of at least 1/3 of an hour as outlined in table 716.5 of the IBC (2015 Edition).

When the duct type smoke detectors activate, the fan associated with the duct containing the detector will automatically be shut down.

The fusible link smoke dampers will close and prevent the movement of smoke through the ductwork if the fusible link associated with the damper in question is activated.

Exterior Exposure:

The area pictured in Figure 33 has a fire separation distance of 20 feet (measures 10 feet on each side from the line dividing the Business and Education Buildings). The courtyard area contains some foliage that provides both a potential fuel source and a reduction in the separation distance present in between the two buildings.

Figure 33: Foliage in Courtyard Between Business and Education Building

Figure 34: Open Window Located in Exit Stairwell

In accordance with Table 602 in the IBC (2015 Edition), an area with a fire separation distance of 10-30 feet shall have outdoor walls rated for 1 hour. The exterior walls of the building comply with this requirement with a 1 hour fire rating for exterior load bearing walls.

Following Table 716.6 in the IBC (2015 edition), windows in exterior walls with a required fire rating of 1 hour are required to have a minimum fire window assembly rating of 3/4 of an hour and are required to have a fire-rated glazing of OH-45, or W-60. The window assemblies in the building do not contain a fire resistance rating. Figure 34 shows a window leading into the courtyard shown in Figure 33.

Conclusions/ Recommendations:

The presence of the trees in the courtyard provides an increased risk to a potential fire scenario directly outside the building. Coupled with the fact that the windows are not rated adequately this provides an increased risk to outdoor exposure fires. Despite the aesthetic appeal of the foliage present in the courtyard, I would recommend removing it completely to retain the separation distance the building was originally intended to maintain.

Water Based Fire Suppression Systems:

Introduction

The safety features of the building including the smoke control systems and structural fire protection are considered passive in that they do not actively work to suppress a fire. A passive approach often makes compartmentalization of smoke and separating the occupants from the effects of a fire the main goal of the design. A sprinkler system actively works to suppress a fire by releasing water in the area of activation. This active approach is beneficial in that the fire can be contained and loss of life will be minimized.

Building Features:

The Business Building does not currently have a sprinkler system installed. There are dry standpipes located in each of the stairwells with 2 ½ in. connections (Figure 35). Many fire hose cabinets have been replaced with fire extinguishers, but still contain 1 ½ in. fire hose connections (Figures 37 and 38). A wet and dry fire hose connection is located on the outside of the building (Figure 36).

Figure 35: Dry Standpipe Located in Stairwell

Figure 36: Wet and Dry Standpipe Connections Located on Outside of Building

Figure 37: Fire Hose Cabinet Containing a Fire Extinguisher


Figure 38: 1 ½ in. Fire Hose Connection in Fire Hose Cabinet (Hose Removed)

Proposed Sprinkler System:

General Description – The building selected is a four-story business facility that is composed of lecture halls, classrooms, and offices. The sprinkler system shall be designed for the 4th floor of the building.

Applicable Code – The applicable sprinkler standards for this project include NFPA 13 (2016 Edition) for sprinkler design criteria and NFPA 25 (2014 Edition) for the review of installation and maintenance.

Purpose of Report – The business building does not currently have a sprinkler system in place. The purpose of this report is to provide a design for a sprinkler system for the 4th floor of the building that satisfies the requirements outlined in NFPA 13.

Water Supply

A flow test has not been performed on the hydrants located near the building recently. Pressures from another building on campus called Bakers were used. The information from these flow tests is shown below. A safety factor of 10% was not used because the building is higher in elevation meaning that the actual pressures at the Business building should be higher.

Bakers Elevation (Ground floor)= 351.0 ft
Business Building Elevation (Ground floor) = 303.50 ft

Static Pressure: 60 psi
Residual Pressure: 55 psi
Flow Pressure: 914 gpm

47.5 ft $(0.433\,\frac{psi}{ft})$ = 80.57 (static pressure with elevation taken into account)

Available Water Pressure Summary

A summary of the available water pressure after the height consideration is shown in Table 29.

Table 29: Water Pressure Available to Building

Static	80.57 PSI
Residual	55 PSI
Flow	914 GPM

Automatic Sprinkler Design Criteria

Occupancy Classification: Light Hazard

In accordance with section A.5.2 of NFPA 13, buildings used for Educational, and Office use, including data processing are considered light hazard occupancy. Most of the business building is composed of offices and lecture rooms making the building a light hazard occupancy.

Summary of Occupancy Classifications:

These elements are the required design attributes of a light hazard occupancy when utilizing the room design method.

1. Light hazard occupancy
2. Density of 0.10 gpm/ft^2
3. Wet system
4. Wet Standpipe
5. Quick Response sprinklers (k=5.6)
6. Largest room size = 625 ft^2

Room Design Method:

In order to test for the highest hydraulic demand (Figure 39), the room design method was selected. The 4th floor of the business building is composed of many smaller offices. In this case the most remote area would be a one-room office that only requires one sprinkler. For this reason, the properties of the largest room will be selected for hydraulic analysis as opposed to the Density/ Area Method, which would require the calculation to be based on remoteness.

11.2.3.3.1* The water supply requirements for sprinklers only shall be based upon the room that creates the greatest demand.

The area of the largest room in the building is 625 sq ft. This is room 401 located on the floor plan attached.

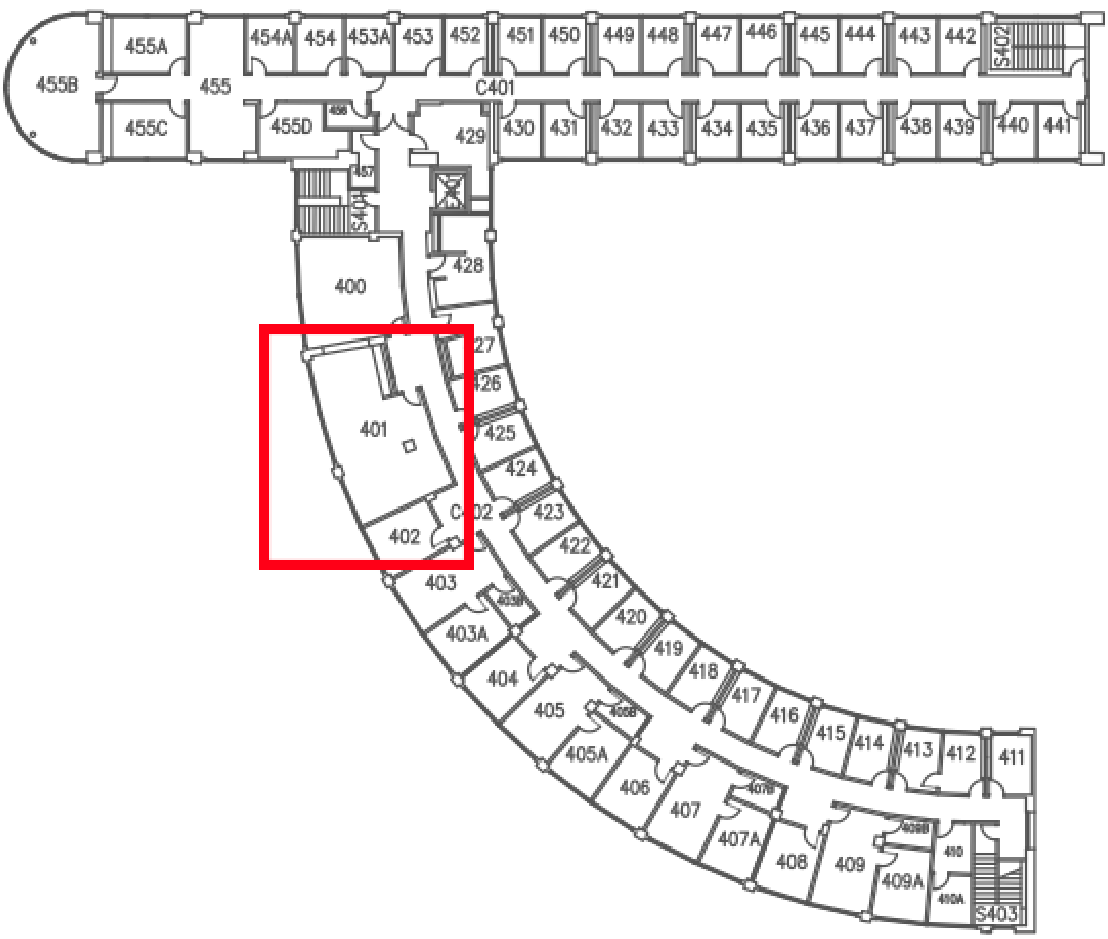


Figure 39: Location of Room with Highest Hydraulic Demand

11.2.3.3.2: The density selected shall be that from Figure 11.2.3.1.1 corresponding to the occupancy hazard classification and room size.

From Figure 11.2.3.1.1 taken from NFPA 13, we see that the minimum flow rate is 0.10 gpm/ft^2 for an area of operation of 1500 ft^2 for light hazard occupancies.

Quick response sprinklers in a wet pipe system are going to be used for this sprinkler system meaning that the area of operation reduction outlined in Figure 11.2.3.2.3.1 of NFPA 13.

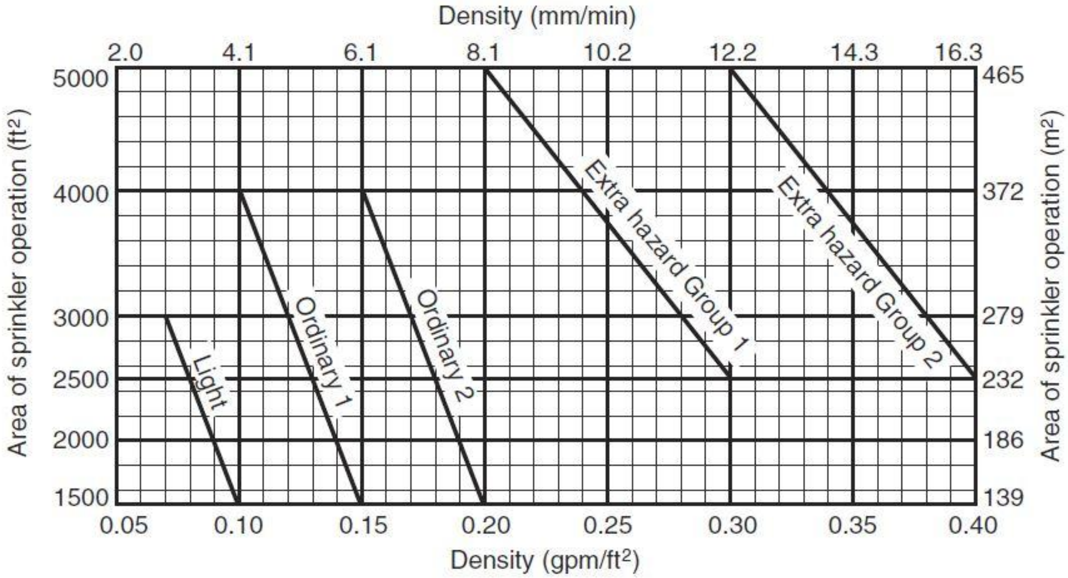


FIGURE 11.2.3.1.1 Density/Area Curves.

Y = -3x/2 + 55
Y = percent reduction to design area
X = ceiling height (15 feet)
Y = 32.5 %

The area of the largest room in which the highest sprinkler demand will occur is 625 ft^2. Implementing the reduction for quick response sprinklers we can reduce this area by 32.5 percent to get a maximum area of 421.87 ft^2.

Following Table 11.2.3.1.2, the total hose stream allowance for light hazard occupancies is 100 gpm for a duration of 30 minutes.

Multiplying the flow rate per unit area by the area of the largest room we obtain a flow rate

0 .10 gpm/ft^2 (421.88 ft^2) = 42.19 gpm

Adding the hose stream allowance of 100gpm we can get an ideal total flow rate of 142.19 gpm.

Multiplying this flow rate by the minimum duration of the system we can get a nominal water requirement without the losses from friction taken into account.

42.19 gpm (30 min) = 1265.7 gallons of water

Sprinkler Spacing

Sprinklers were spaced in accordance with Table 8.6.2.2.1 (A) for the Protection Areas and Maximum Spacing of Standard Pendant and Upright Spray Sprinklers for Light Hazard. The layout of the sprinklers is shown in Figure 40.

Maximum Protection Area: 225 ft^2
Maximum Spacing: 15 ft
Sprinklers were kept within 7.5ft of the walls in accordance with 8.6.3.2.1

Sprinkler Layout

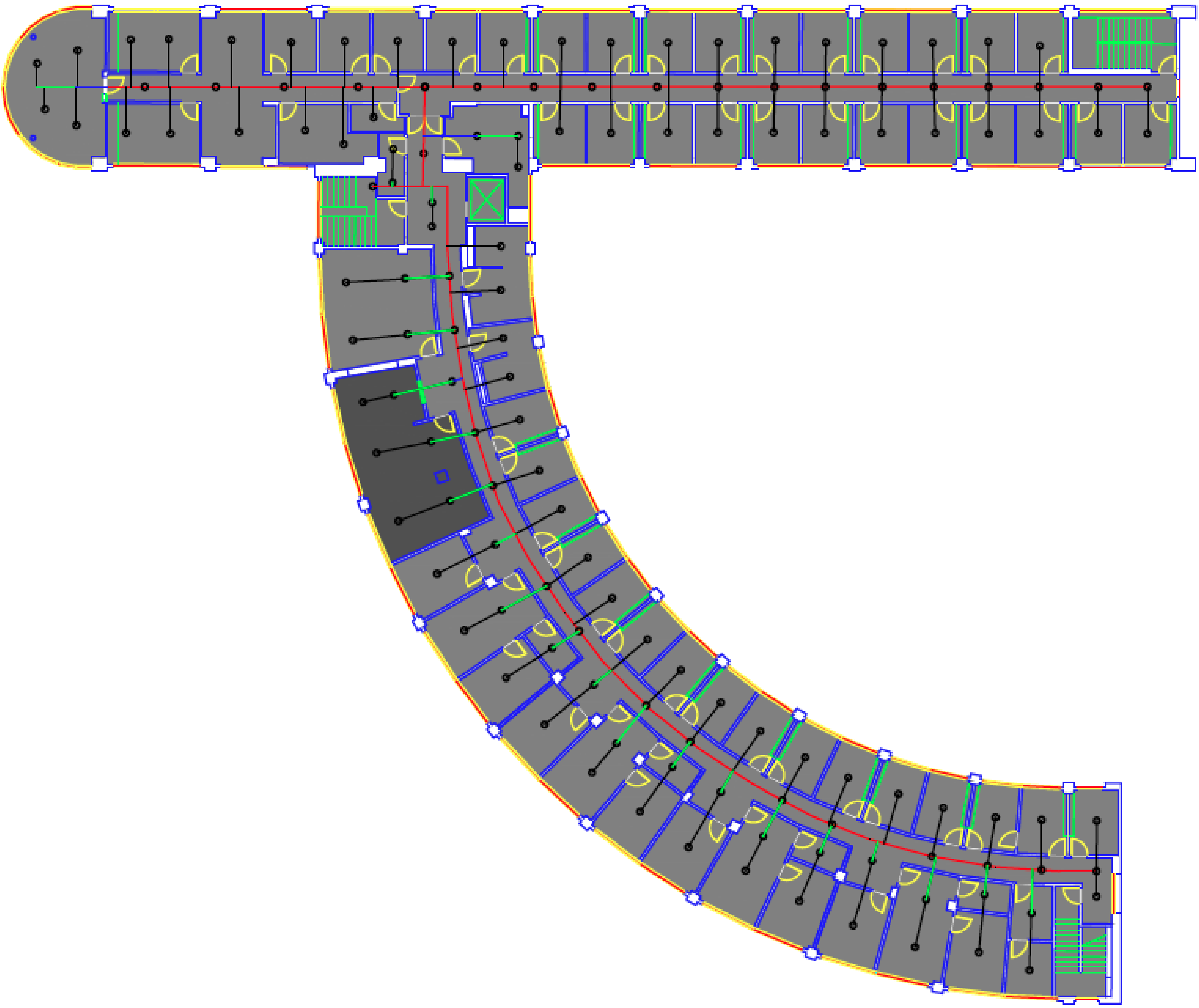


Figure 40: Layout of Designed Sprinkler System

Legend
Black pipes = 1 in. Schedule-40 Black Steel pipe (C=120)
Green pipes = 1.25 in. Schedule-40 Black Steel pipe (C=120)
Blue Pipes = 1.5 in. Schedule-40 Black Steel pipe (C=120)
Red Pipes = 3 in. Schedule-40 Black Steel pipe (C=120)

System Riser

The sprinkler design is new meaning that there are currently dry standpipes in place, but no sprinkler risers. Dry standpipes are located in each of the three exit stairwells; however, the riser in Figure 41 below was selected to reduce the travel distance to each end of the building. For the purposes of the design of the sprinkler system, this standpipe is going to be treated as a wet standpipe.

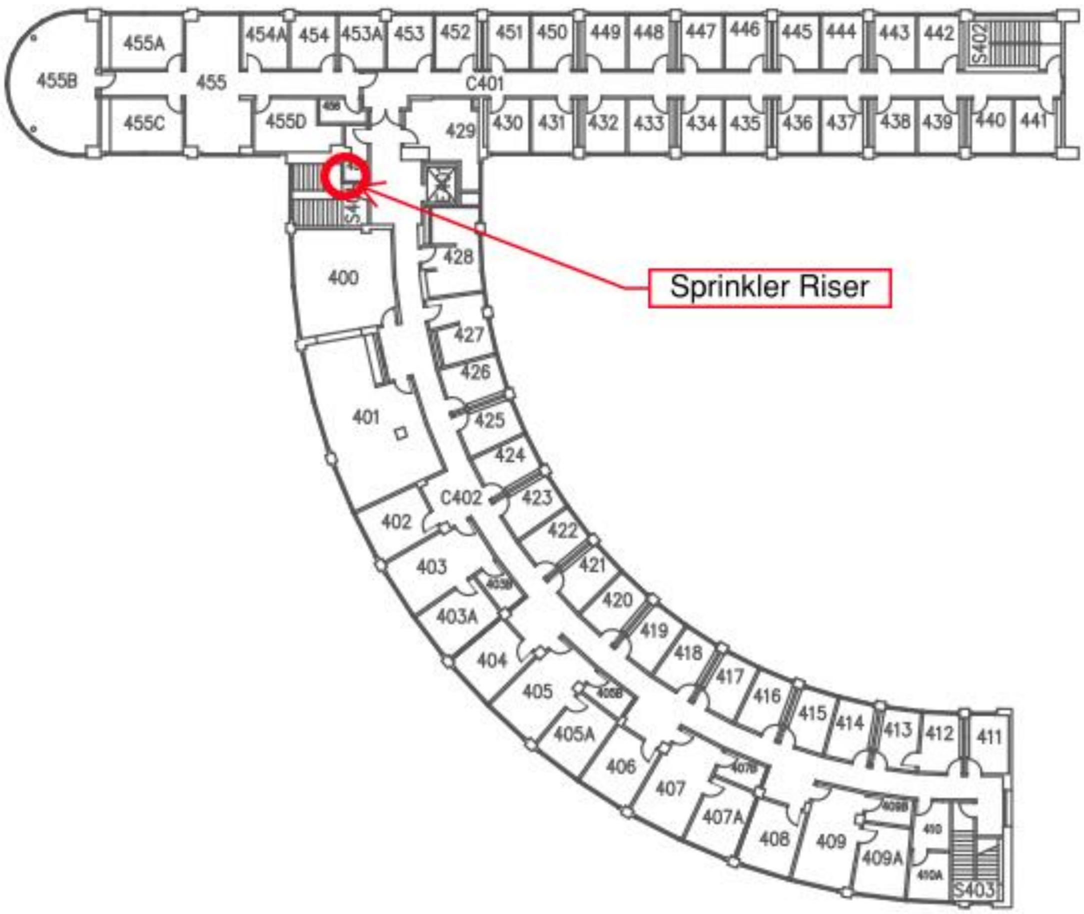


Figure 41: Location of Selected Dry Standpipe to be used as Sprinkler Riser

System Component Information

The risers present in the building are 4 in. in diameter with 2 ½ in. water hose connection on each floor. Cross-main and branch line sizes were designed using the pipe schedule method using Table 23.7.2.2.1 from NFPA 13. Cross-mains were designed to be 3 in. Schedule-40 Black Steel. Branch lines were designed to be Schedule-40 Black Steel Piping with diameters varying between 1-2 in. The diameter of the branch line varied due to the number of sprinklers present on the individual branch lines.

Color Coded AutoCAD file with pipe sizes are included in Figure 40.

Sprinkler Head Information:

The sprinkler heads chosen are Tyco TY-FRB Pendent Quick response sprinkler heads with standard coverage. The sprinkler heads have a K factor of 5.6 and a NPT of ½ an inch.

Sprinkler Data sheet:

https://www.tyco-fire.com/TD_TFP/TFP/TFP172_02_2014.pdf

Summary of Hydraulic Calculations

Starting with the largest room outlined in Figure 42, the pressure was calculated along each branch line back to the point of connection circled on the site map below. For the fittings present in the system, Table 23.4.3.1.1 from NFPA 13 was used.

Design Area

Figure 42: Sprinklers Located in Area of Hydraulic Demand to be used in Hydraulic Calculations

Legend:
White pipes = 1 in. Schedule-40 Black Steel pipe (C=120)
Green pipes = 1.25 in. Schedule-40 Black Steel pipe (C=120)
Blue Pipes = 1.5 in. Schedule-40 Black Steel pipe (C=120)
Red Pipes = 3 in. Schedule-40 Black Steel pipe (C=120)

City Water Supply

Figure 43 shows the city water main locations in light blue and the location of fire hydrants in red. The circled fire hydrant was used in the hydraulic calculations because it leads to the selected standpipe to be used as a sprinkler riser.

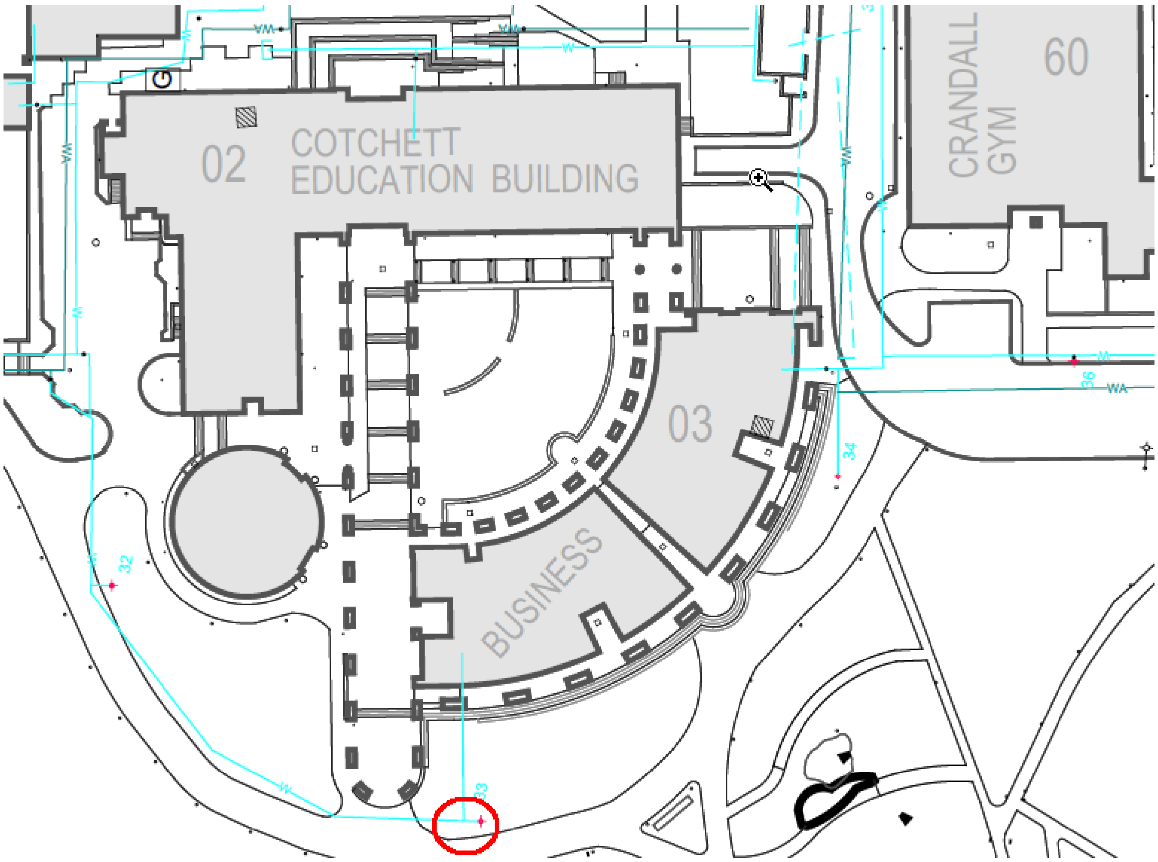


Figure 43: Location of City Water Mains (Closest Hydrant Circled)

Hydraulic Calculations:

Table 30: Total Hydraulic Calculations

Project name:		Buisness Building						Date: May 8 2016					
Step No.	Nozzle Ident and Location		Flow in gpm	Pipe size	Pipe Fittings and Devices		Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary	Notes:	
1	1 BL-1	q		1.049		L	10.33	C=	120	Pt	16.1	k=5.6	
	to					F				Pe		225	q = k * (Pt)^1/2
	2	Q	22.5			T	10.33	pf	0.162	Pf	1.7	Pt=	
	2	q	23.6	1.38	T	L	8.42	C=	120	Pt	17.8	k=	q=
	to					F	7			Pe			23.6361845
	CM	Q	46.1			T	15.42	pf	0.161	Pf	2.5		
	Cm	q		3.068		L	10.42	C=	120	Pt	20.3	k=	
	to					F				Pe		10.232	
	BL 2	Q	46.1			T	10.42	pf	0.003	Pf	0.0		
	BL2 (CM)	q	46.1	3.068		L	9.17	C=	120	Pt	20.3	k=	q =
	to					F				Pe			46.1
	BL 3	Q	92.2			T	9.17	pf	0.012	Pf	0.1		
		q				L		C=	120	Pt	20.4	k=	
						F				Pe			
		Q				T		pf		Pf			
	Bl1+2+3	q				L		C=	120	Pt	41.0	k=	
						F				Pe		25.488	
		Q	163.2			T		pf		Pf			
	BL1/2/3 (CM)	q		3.068	45 Elbow	L	49.92	C=	120	Pt	41.0		
	to					F	3			Pe		25.488	
	Riser	Q	163.2			T	52.92	pf	0.034	Pf	1.8		
	Riser	q		4.26	6- 45 Elbow	L	122.17	C=	120	Pt	42.8		
	to					F	20			Pe	17.0		Pe = 39.33*0.433=17.03
	city main	Q	163.2			T	142.17	pf	0.007	Pf	1.0		
		q				L		C=	120	Pt	60.8		
						F				Pe			
		Q				T		pf		Pf			

Table 31: Hydraulic Calculations For Branch Line 3

Project name:		Buisness Building											
Step No.	Nozzle Ident and Location		Flow in gpm	Pipe size	Pipe Fittings and Devices		Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary	Notes:	
1	1 BL-3	q		1.049		L	5.92	C=	120	Pt	16.1	k=5.6	
	to					F				Pe		225	q = k * (Pt)^1/2
	2	Q	22.5			T	5.92	pf	0.162	Pf	1.0	Pt=	
	2	q	23.2	1.38	T	L	11.17	C=	120	Pt	17.1	k=	
	to					F	0			Pe			23.15795392
	3	Q	45.7			T	11.17	pf	0.158	Pf	1.8		
	3	q	25.2	1.61		L	2.08	C=	120	Pt	20.3	k=	
	to					F				Pe		15.736	25.23109193
	CM	Q	70.9			T	2.08	pf	0.168	Pf	0.3		
		q				L		C=		Pt	20.6	k=	
						F				Pe			
		Q				T		pf		Pf			

Notes:

A density of 0.10 gpm/ ft^2 was used for these calculations. In Table 30, the first two branch lines were calculated to the point where the cross main connects to the third branch line. This calculation was cumulative because the branch lines are equivalent in length. The third branch line was calculated separately on Table 31. The flow and pressure required from branch line 3 were added to the first two branch lines to obtain the total flow and pressure at the point where the cross main meets branch line 3. A map of the labeled branch lines and sprinkler heads leading from the largest room to the riser can be found in Figure 40. Sprinkler 3 in branch line 3 was included to provide a more conservative estimate. Table 32 summarizes the required demand pressure for the area shown in Figure 40

Table 32: Required Pressure for Design Area

Total Pressure Required for highest demand area
61 PSI

Water Supply – Demand Curves

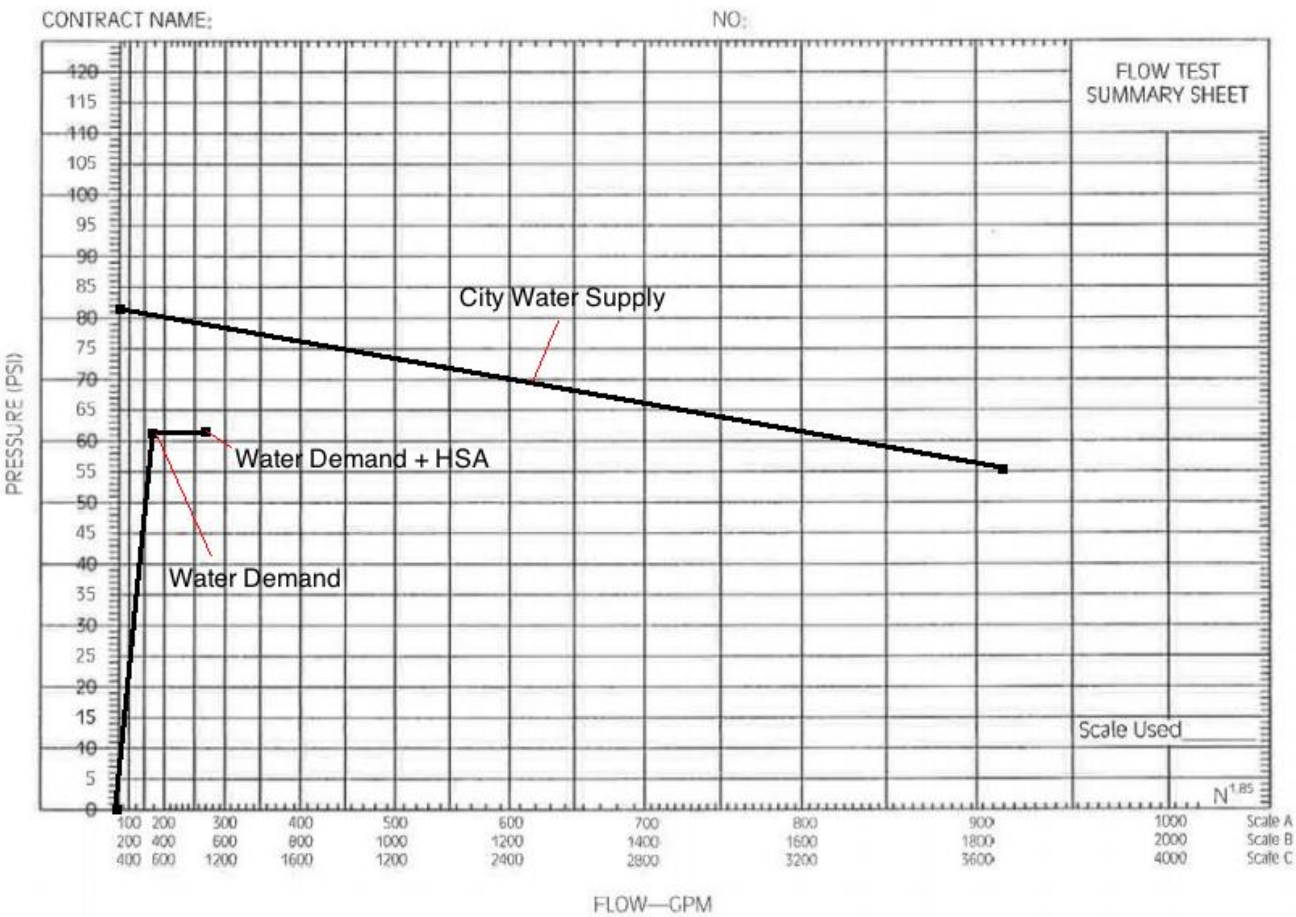


Figure 44: Required Water Pressure and Flow vs. City Water Supply Availability

The total pressure required for the system in the most hydraulically demanding area is 61 psi. The calculated flow for the building was found to be 163 gpm with 100 gpm added for the hose stream allowance for the fire department for a light hazard occupancy. The city water supply curve is based on the altered supply from the Bakers Science Building. The demand curves are shown in Figure 44.

Inspection, Testing, and Maintenance

This system shall be maintained in accordance with Table 5.1.1.2 in NFPA 13.

Sprinkler Design Conclusions:

The calculated pressure was found to be 60.8 psi for a flow rate of 163.2 gpm for the designed system. Adding a hose stream allowance of 100gpm we get a total flow rate of 263.2 gpm. Given the measurements from Bakers and the difference in elevation increasing static pressure to 80.57 psi, the pressure in the system should be more than sufficient to support this system. A flow rate of 914 gpm should also be more than enough to reach the most hydraulically demanding area. These values can be seen on the hydraulic demand curve in the hydraulic calculation section of the report.

The hydraulic flow rate is slightly higher than the flow rate calculated when the area reduction was used for quick response sprinklers in the most hydraulically demanding area, which was 142.19 gpm meaning that the flow and pressures found in the hydraulic calculations are conservative.

Looking at the demand and available water curves, the flow rate and residual flows were taken to be those of the original static pressure. In reality, at a higher elevation the residual pressure and flow rate would also be higher adding another safety factor to the calculations.

Results/ Conclusions:

The sprinkler system has an adequate water supply for the most hydraulically demanding area making the installation of sprinklers possible. In order to ensure that the egress of the building is efficient and occupants of the building know how to react to different scenarios, a fire safety management plan may be implemented.

Fire Safety Management Plan

Introduction

The following outline is based on the current evacuation procedures of Cal Poly's main campus. The plan also includes other potential threats to the occupants and the procedures to follow in such an event. All staff members should be familiar with the safety management plan in order to make sure they know how to act in a potentially life threatening situation.

Outline

The following Fire Safety Plan is based on the 2015 IBC sections pertaining to a group A-3 facility. These codes include sections 403.2 for Group A occupancies, section 403.2.1 for the details of seating plans, section 403.2.2 for announcements in a fire scenario, section 403.2.3 for fire watch personnel, and section 403.2.4 for crowd management. The details of the fire safety, evacuation and lockdown plans were developed using section 404 of the 2015 IBC. The maintenance standards and inspection schedules were taken from the corresponding NFPA standards to be referenced after each use.

The construction and demolition precautions pertain to Chapter 33 of the 2015 IBC.

Descriptions of the fire safety equipment functions and the general layout of this fire safety plan were created using the template found below with the codes for the United States taking the place of those used for the Canadian report.

http://www.cambridge.ca/relatedDocs/10%20pt%20tuneup-9.5%20SAMPLE%20Fire%20Safety%20Plan1.pdf

The building management procedures and evacuation plans are consistent with those for all of the Cal Poly campus (found on the Cal Poly fire safety page below).

https://afd.calpoly.edu/ehs/docs/campus%20building%20evacuation%20procedure.pdf

Human Resources Audit

Business Name: Orfalea College of Business

Address: Cal Poly State University
1 Grand Avenue
San Luis Obispo, CA 93407

Management, HR, and Information Systems:

Title: Administrative Coordinator

Name: Sandy Edar

Email: sedar@calpoly.edu

Telephone: 805-756-2012

Supervisory Staff: Professors, and designated fire floor wardens

Fire Safety Equipment Audit

General Description:

Table 33 summarizes building elements that are important to consider when creating the fire safety management plan. Important information regarding the safety equipment of the building is summarized in Table 34.

Table 33: Summary of Building Features

BLDG AREA (m^2): 115,854	**CONSTRUCTION (date):** 1989	**BUILDING HEIGHT (storeys):** 3
NUMBER OF ROOMS: 457		
NO. OF EXITS/TYPICAL FLOOR: 3	**ELECTRICAL RM LOCATIONS:** 117A, 109, 212A, 205A, 410	
CLOSEST HYDRANT: In front of building next to the O'Neil Green	**STORAGE/UTILITY/ ROOM LOCATIONS:** 118, 117, 110, 212, 205B, 311, 312A, 312B, 304, 429, 456, 119B, 119A, 301B	

Fire Safety Equipment:

Table 34: Fire Safety Equipment Present in Business Building

FIRE ALARM SYSTEM: *Single-stage*	**SMOKE DETECTION:** *photoelectric smoke detectors*
LOCATION OF MAIN PANEL:	*room 109 on first floor of building*
PORTABLE FIRE EXTINGUISHERS:	*located at the end of each corridor on each floor*
SPRINKLER SYSTEMS:	*N/A (no sprinkler system)*
STANDPIPE AND HOSE SYSTEM:	dry standpipes located in the west and south staircases
EMERGENCY LIGHTING:	*battery backup emergency lighting units in all corridors & exit stair shafts*
EXIT SIGNS:	*battery backup installed over all exit doors*

Emergency Procedures

Purpose:

This procedure has been prepared to ensure the orderly and complete evacuation of campus buildings in the event of an emergency and/or the activation of alarm system.

The primary objectives of this evacuation plan are to ensure:

1. everyone leaves the building safely;
2. a procedure is in place to safely evacuate individuals who cannot negotiate stairs;
3. building occupants are accounted for after an emergency evacuation, and
4. personnel (Building Coordinators) are selected from among building occupants, with functions to ensure plan objectives are met.

Policy:

The following are emergencies for which a total or partial evacuation of a building may become necessary:

a. Fire

b. Explosion

c. Bomb threats

d. Release of hazardous chemical substance, in quantities or toxicity, which threatens human life

e. Building air contamination

f. Weather related emergencies (flood, severe storm, severe wind)

g. Earthquake. An earthquake alone is not necessarily a reason to evacuate. Evacuation is indicated if the earthquake causes apparent structural damage or creates a secondary hazard such as flooding, hazardous materials release, exposed electrical conductors, etc.

The Plan will be updated and exercised by conducting evacuation drills of selected administrative and academic buildings on an annual basis. Evacuation drills of all residence buildings will be conducted twice a year; once in fall quarter and once in spring quarter

Emergency Evacuation Personnel

1. For the purpose of this Plan, Building Coordinators and their alternates are regular employees, who have been selected and trained to ensure that building evacuation is carried out as planned, evacuated building occupants are directed to assigned assembly points where they will be accounted for, and persons needing assistance to evacuate are accommodated.

2. Building Coordinators and their alternates shall be selected among building occupants, and on a voluntary basis.

3. The following is a list of Building Emergency Evacuation personnel and their corresponding duties.

Supervisory Staff Responsibilities

Building Coordinators:

- Maintain a current list of all occupants, including part time and student employees in their immediate work area.

- Ensure that all employees in your immediate work area are familiar with the emergency evacuation plan for their work area and for their building

- Assist and encourage your work area occupants to leave the building in cases where there may be an alternative form emergency notification, other than the sound of building fire alarms

- Inform occupants of their duty to immediately report to their designated assembly point.

- Assist occupants with limited mobility, down stairs if able to negotiate stairways

- Never put yourself in danger. Leave the building as soon as possible and go directly to your assigned assembly area.

- Check off co-workers who safely reported to assembly area from occupant list.

- Collect information on missing personnel known, or suspected to still be in the building, and report to responding University Police representatives.

- Complete Building Assessment Form, if applicable

University Police / SLO City Fire:

- Collect information on building occupants known or suspected to still be in the building from Building Coordinators
- Meet off-campus emergency responders (fire, medical, etc.) and assist with directions to the building/area as needed.
- Report information on occupants needing assistance to evacuate and other personnel suspected to still be in the building to fire and rescue response personnel.
- Assist with securing the building/area and preventing re-entry.

Fire Drills

General Building Evacuation Procedures:

1. At the sound of the Emergency Alarm, it is the responsibility of all building occupants to evacuate immediately and proceed to the predetermined assembly points, away from the building.
2. Building occupants are also responsible for ensuring that their visitors follow the evacuation procedures described herein, and leave the building along with all other occupants.
3. Faculty members are responsible for dismissing their classes and directing students to leave the building by the nearest building exit upon hearing the building alarm or upon being notified of an emergency.
4. Designated essential personnel needed to continue or shut down critical operations, while an evacuation is underway, are responsible for recognizing and determining when to abandon the operation and evacuate themselves safely.
5. Contract workers will be made familiar with the procedures outlined herein, and are expected to leave the building when the alarm sounds.

Evacuation Instructions:

Whenever you hear the Emergency Alarm (Fire Alarm) or are informed of a general building emergency:

1. Remain calm at all times
2. Do not ignore alarm
3. Leave the building immediately, in an orderly fashion
4. Exit the building utilizing stairways, not elevators
5. Dismiss classes in session and instruct students to exit the building immediately
6. Follow quickest evacuation route from where you are (see posted floor evacuation diagram/map near exit doors)
7. Do not go back to your office or classroom for any reason
8. Proceed to an emergency assembly point.
9. Report to a Building Coordinator if you have any knowledge of missing persons or specific building conditions which might be helpful to responders.
10. Return to the building only after emergency personnel have given the all-clear signal. Silencing the alarm does not mean the emergency is over.

Maintenance Procedures for Fire Protection

Portable Fire extinguishers

Portable fire extinguishers shall be maintained in accordance with the maintenance schedule in place in NFPA 10 (2013 Edition).

Fire Alarm and Voice Communication Systems

Fire alarm and voice communication systems shall be maintained in accordance with the maintenance schedule in place in NFPA 72 (2016 Edition).

Standpipe and Hose Systems

Standpipe and hose systems shall be maintained in accordance with the maintenance schedule in place in NFPA 25 (2014 Edition).

Fire Protection Measures

Water Supply

The total water supplies required for firefighting purposes may be supplied from various sources such as a municipal water supply, storage tanks (elevated or underground), lakes, rivers, wells, swimming pools or a combination of sources, and should be obtained within practical distances. Water supplies must be accessible to firefighting equipment.

Emergency Power

Emergency power is required to ensure the continued operation of fire and life safety equipment and systems in case of loss of normal hydroelectric power.

Emergency Lighting

Emergency lighting ensures that exits, corridors and principal routes providing access to exits are illuminated in the event of loss of power.

Voice Communication Systems

A voice communication system is used primarily to provide information and instructions for occupants during an emergency.

Smoke Control Measures

Smoke control measures consist of special construction and equipment to limit the volume of contaminated air on all floor areas from the fire floor.

Elevators

All elevators should be returned to and kept at street level in fire emergency situations. Chapter 30 of the 2015 IBC specifies detailed size, capacity and operation regulations for fire fighters elevators.

Conclusions/ Recommendations:

The campus Fire Safety Management plan is extensive in its analysis of how the occupants of the building should act in different situations. This plan should be updated periodically to reflect changes in the building and campus policies, but for the time being the plan is comprehensive. In order to analyze one potential fire scenario for the building, a performance based design approach will be discussed to analyze how all of the fire safety measures will function in a fire scenario. This analysis will include a summary of occupant characteristics and movement times associated with different events in the fire scenario.

Occupant Characteristics:

Introduction:

The occupant characteristics will affect how long it will take people to analyze a potential fire situation and begin to react. These characteristics will vary based on the type of occupancy and are summarized for the business building below.

The occupant characteristics that follow are similar to those outlined on page 362 of the SFPE Handbook of Fire Protection of Engineering (4^{th} Edition)

Familiarity: The majority of the building is composed of offices, lecture halls, and computer labs. The occupants that use the building are likely regular visitors that are familiar with the layout.

Responsibility: Occupants will likely not feel responsible for an alarm going off and may wait for further instruction to decide whether there is an actual threat to them.

Social Affiliation: Given that this is a place of business it is unlikely that there are many (if any) social affiliations that will make people feel responsible for others before exiting themselves.

Commitment: People working in this building may be involved in work related activities at the time of the alarm and may take a few moments to wrap up a work related activity.

Alertness and limitation: The occupants of a lecture or place of business will most likely be alert and awake at the time the alarm is triggered. The occupants will most likely not be under the influence of any substance that would otherwise impair their egress of the building.

Staff or Warden: For the areas where business is conducted there is likely an appointed floor warden with the training required to facilitate a safe evacuation. For lecture halls or classrooms, the professor will likely take this place and provide similar guidance. (See Fire Safety Management Plan)

Movement Times:

Factors that influence Evacuation time (Fire Protection Handbook volume 1 20th edition)

Time to notification:

The time to notification for the building will depend on how the occupants are first alerted to the fire. For this building this might include the use of a manual pull station, the activation of a smoke detector, or the operation of a duct detector.

Reaction Time:

The reaction time of the occupants should be relatively efficient. A short reaction time assumes that there is little reason for the occupants to linger in passageways or rooms. The occupants should be professional and rational in their decision-making.

Pre-evacuation activity time:

The pre evacuation activities of business dwellings will most likely include shutting down computers, gathering belongings, and locking office doors. This may also include grabbing a coat if it is cold outside. For the lecture halls, students may grab book bags and materials before exiting if they do not intend on returning into the building upon exiting. An outline of pre-evacuation activities can be found in the pre-movement section of the report.

Travel time:

The density of the occupants in the building and the complexity of the building layout will affect the travel time of the occupants. However, with appropriate exit sign locations and the guidance of wardens and professors, these travel times should be minimal. A summary of modeled evacuation time was calculated using the Pathfinder model discussed later in the report.

Pre-Movement Considerations:

Utilizing an approach outlined by The International Association for Fire Safety Science in "A Stochastic Approach to Occupant Pre-Movement in Fires," [1] the following table was created based on individual actions of students and staff within the building. This approach provides times associated with activities that may be added together to obtain a total pre movement time. Breakdowns of the actions that go into the chart are located in Table 35. The chosen delay times are summarized for students and staff in Table 36.

Table 35: Summary of Pre-Movement Actions taken from [1]

Table 2. Parameters for time constant distributions.

Action ID Number	Delay Action	Mean (s)	Standard Deviation (s)
1	Notify others	10	3
2	Call Fire Brigade	30	9
3	Inaction	60	18
4	Collect belongings	30	9
5	Telephoned others	30	9
6	Close/open doors/windows	5	1.5
7	Shut down equipment	20	6
8	Rescue	30	9
9	Got dressed	60	18
10	Woke up	60	18

Students: Will perform actions 1, 4, and 7
Staff: Will perform actions 7, 6, 4, 2, and 1

Table 36: Pre-movement Times of Students and Staff

Stochastic Approach (IAFSS)	Pre-movement time (seconds)
Students	60
Staff	95

The International Association for Fire Safety Science performed a pre movement time analysis on the Dreadnought building located at the University of Greenwich and cataloged the results in a paper entitled "The Collection of Pre-Evacuation Times From Evacuation Trials Involving a Hospital Outpatient Area and a University Library Facility". [2]

Dreadnought Building Description:

The Dreadnought building is a three-storey structure utilized for a variety of different purposes in providing library services, student computing facilities and a small canteen. Both the ground and first floor house the library services with the computing facilities on the second floor. Lectures are currently held within the computer laboratories on the second floor.

Given the similarity of the building use and relative size to the business building, the stochastic approach will be compared to the pre movement times found for this building. the pre-movement times found in the Dreatnought building are summarized in Table 37.

Table 37: Pre-movement times found in [2]

Dreadnought Building (IAFSS)	Pre-movement time (seconds)
Students	73.7
Staff	70.8

Averaging the two values found in the stochastic approach yields a pre movement time of 78 seconds. This value is similar to the experimental values above making this a viable pre movement time for this building.

Evacuation Time Model (Pathfinder):

I used a Pathfinder model constructed from the Autocad files available for the office building. A screenshot of the completed model can be found in Figure 45.

Assumptions made in model:

- The occupant load for each room was rounded up regardless of the minuteness of the decimal place.

Example: An office with an occupant load of 1.04 would be given 2 people in the model. For this reason, the number of people in the model is much higher than the actual occupant load.

- The stairs in the lecture hall were filled to the spaces provided meaning that the width of the stairs is similar, but not exact. Connecting the staircases in this way means that the stairs are not as wide as they are in the actual building meaning the time calculation is more conservative than an actual egress time. However, given that the model does not include the fixed seating, this safety factor is necessary.

-The speed of occupants was based on the steering mode in Pathfinder which allows agents to proceed independently to their goal while avoiding other occupants and obstacles. Door flow rates depend on interaction of occupants with each other and with the object boundaries.

Travel Time (main building):

The total evacuation time of the model was found to be 2.6 minutes. The evacuation time does not include time to detection or pre movement activities, which will be added to the calculation in the performance based design scenario.

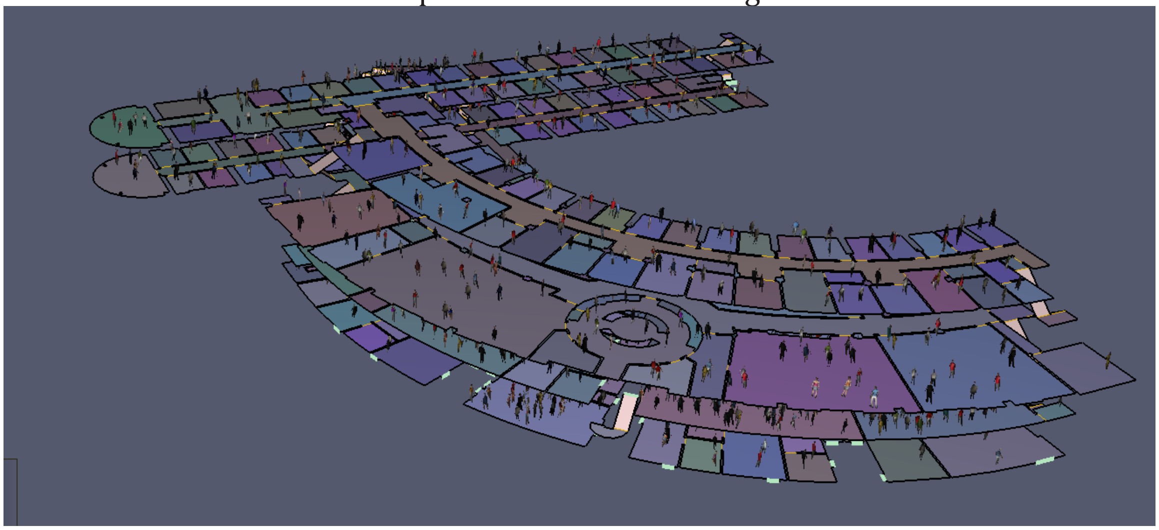


Figure 45: Pathfinder Model Screenshot

Pinch Points:

Figure 46 shows some queuing on the third and fourth floors outside the staircases. Figure 47 shows similar queuing on the second and third floors.

Figure 46: Queuing on Third and Fourth Floors in Pathfinder Model

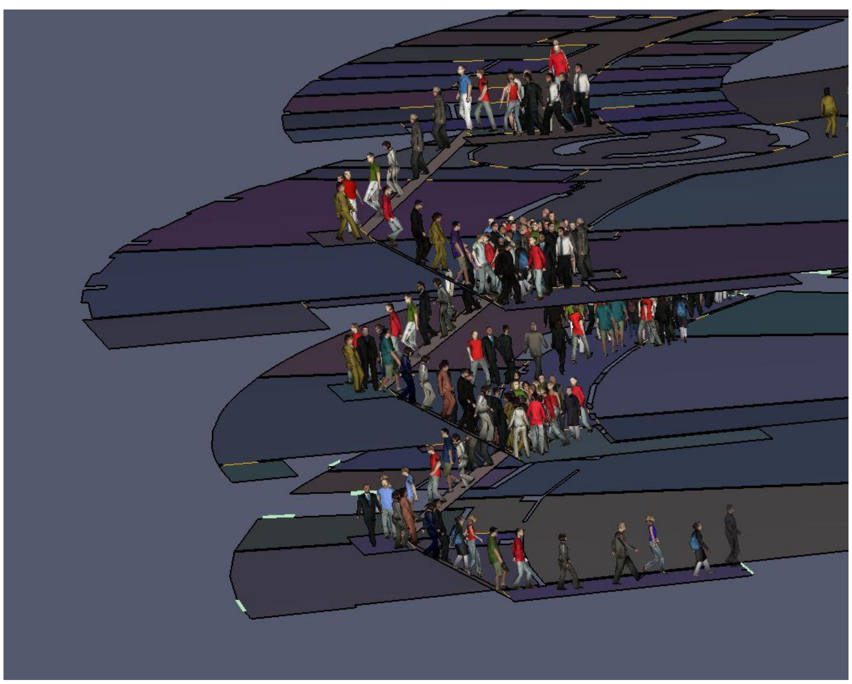


Figure 47: Queuing on Second and Third Floors in Pathfinder Model

Horizontal Exit:

Figure 48 shows how the horizontal exit helps to reduce to total egress time on the third floor.

Figure 48: Use of Horizontal Exit on Third Floor

Travel Time (Business Silo):

The business silo is evacuated in a total of 1.1 minutes with occupant loads based on fixed seating and a stage occupant load factor to represent a full presentation. Figure 49 shows the full Business Silo before egress begins. Figure 50 shows the Business Silo after 1.1 minutes of evacuation.

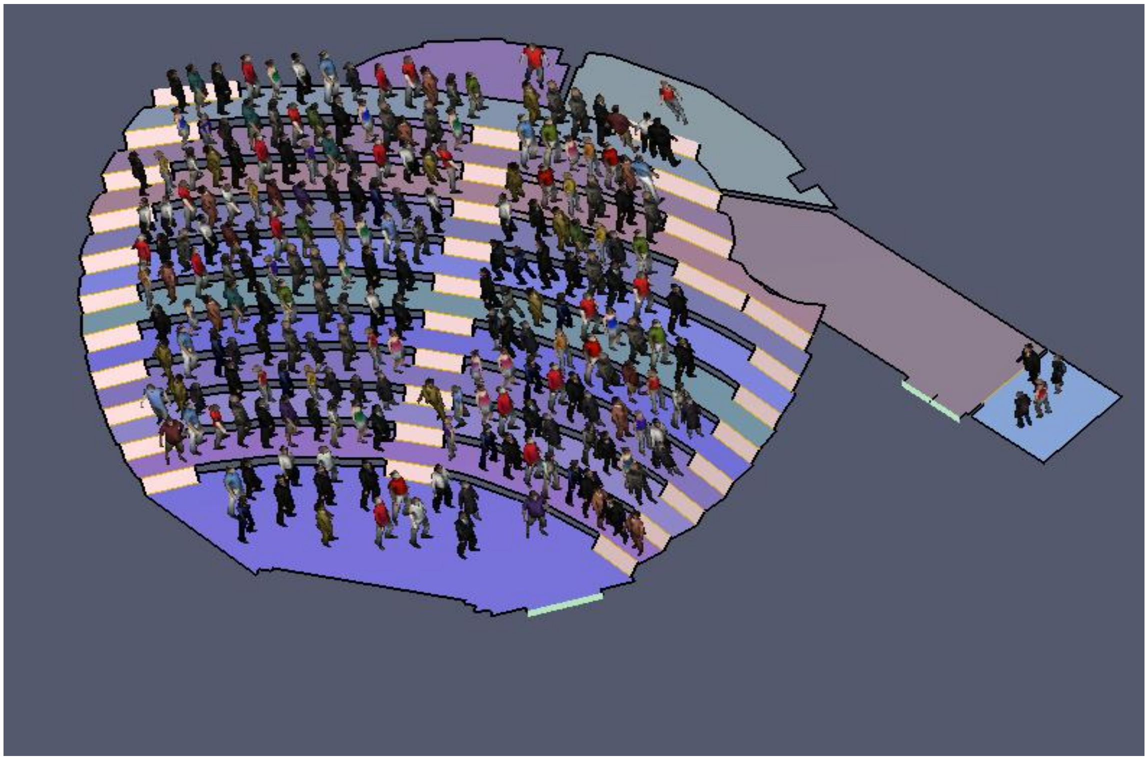


Figure 49: Business Silo Before Start of Egress

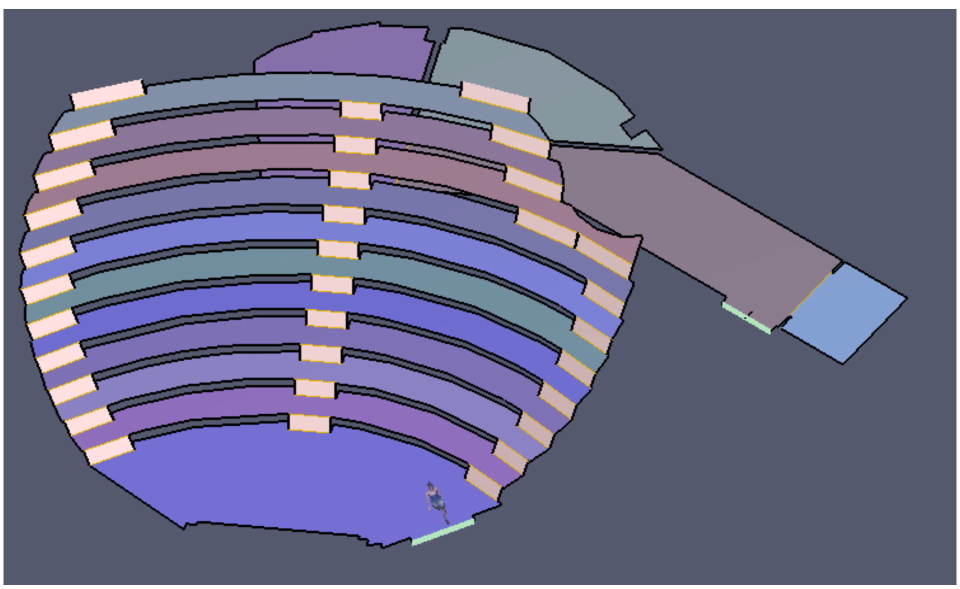


Figure 50: Business Silo after 1.1 minutes of Egress

Tenability:

Smoke Obscuration:

Table 63.5 on page 2339 of the SFPE handbook of fire protection engineering (5th edition) outlines suggested tenability limits for smoke obscuration based on enclosure size and travel distances.

Given the large size of the offices throughout the building and the open floor plan leading to multiple horizontal exits and stairways, the tenability limit for large enclosures and travel distances will be used. This limit is set at an optical density of smoke at OD/m 0.08 (visibility of 10m). This criteria is summarized in Table 38.

Table 38: Smoke Obscuration Tenability

Room size and travel distance	Optical density (OD/m)	Visibility Criteria
Large	0.08	10 m

Irritant Concentration/ doses:

The ASET impairment values for the most common irritants HCL, HBr, and Hf were found in Table 63.6 in the SFPE Handbook 5th edition. These were values found to seriously impair escape capability and movement speeds. The irritant tenability criteria are summarized in Table 39.

Table 39: Irritant Concentration Tenability

Irritant	SFPE Escape impairment (ppm)
HCl	200
HBr	200
HF	200

Asphixiant Concentration:

CO

Utilizing Table 63.9 in the SFPE Handbook 5th edition, a C · t exposure time of 35,000-ppm · min is required to incapacitate a 70kg human exerting light to moderate activity. Due to the complexity of COHb concentrations in humans, the tenability analysis for this building will assume a total evacuation time of 30 minutes. The CO tenability limits are summarized in Table 40.

Table 40: CO Concentration Tenability

C · t Exposure time (ppm · min)	Total Evacuation Time (min)	Instantaneous Concentration (ppm)
35,000	30	1,167

HCN

Utilizing Table 62.12 in the SFPE Handbook 5th edition, a loss of consciousness will occur in humans after 23-30 minutes at a HCN concentration of 100 ppm. The HCN tenability limits are summarized in Table 41.

Table 41: HCN Concentration Tenability

HCN (ppm)	Effect	Exposure time (minutes)
100	Loss of consciousness	23 - 30

Heat Tenability

Table 63.20 on page 2383 of the SFPE handbook of fire protection engineering (5th edition) outlines suggested tenability limits for convective heat exposure. The heat tenability limits are summarized in Table 42.

Table 42: Temperature Exposure Tenability

Intensity (°C)	Tolerance time (minutes)
60	> 30 min

Performance Based Design:

Introduction:

The objective of this performance-based design is to show that occupants of the building will be able to exit the area affected by the effects of a design fire before the effects of the fire cause an untenable condition that will affect egress. This goal ensures that the available safe egress time is greater than the required safe egress time (ASET>RSET).

Possible Fire Scenarios:

The sizes of the smaller offices on the third and fourth floors pose a risk of reaching flashover faster than larger compartments in the building. If a fire were to occur in one of these smaller areas, the lack of smoke detection would allow the fire to grow to a potentially hazardous size.

The area on the third and fourth floors where the corridors for an intersection would be a potentially devastating fire in terms of preventing a proper egress from each side of the corridor and trapping people in the office suite.

There is a lounge located in room 400 that contains multiple couches, coffee makers, copiers, and other electronic devices. The door to this room is frequently propped open making smoke movement into the corridor a possible effect of a fire in this room. The ceiling of the room is also higher than most in the building and contains a sloped ceiling making detection time longer due to the amount of time necessary for smoke to reach a detector.

Room 300 of the Business building has been converted to a student lounge with multiple couches and workstations. Due to the high fuel load and number of electronics, a fire in this area would be hard to control.

Chosen Fire Scenario:

The corridor on the 4th floor of the building contains multiple small alcoves in which furniture is present. Given the narrowness of the corridor and the low ceiling, a fire in the corridor could pose a real problem with egress and maintaining tenable conditions.

The alcove chosen contains two detachable sofas and a small end table. The sofas are composed of 100% polyester batting and are compliant with California bulletins 117 and 133.

Design Fire Location:

Figure 51 shows the selected design fire location in the alcove located on the fourth floor of the building. Figure 52 shows the fuel load present in this alcove.

Figure 51: Design Fire Location in Alcove

Figure 52: Available Fuel Load in Design Fire Alcove

Fuel Characteristics:

A study entitled "Heat Release Rates of Burning Items in Fires" (Kim et al.) was carried out by The American Institute of Aeronautics and Astrophysics. [3] This paper explores the burning characteristics of multiple pieces of furniture and summarizes the results of each burn test. Data from a similar sofa was used to determine the fire growth rate.

Couch Description:

A wood framed chair with urethane foam, a layer of polyester bating and then covered with a cotton fabric. (Chair 11 from [3]) Figure 53 shows the heat release rate of this chair vs. time.

Heat Release Rate Curve:

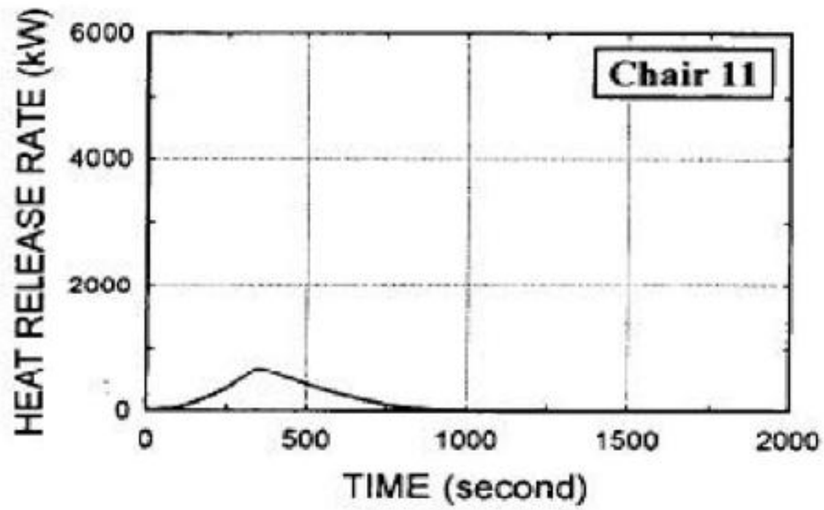


Figure 53: Heat Release Rate Curve of Similar Couch [3]

Summary of Heat Release Rate Data:

The University of Maryland created a database with the burning characteristics of multiple items [4] including the chair referenced from Kim et. al. The heat release rate data for this chair is summarized in Table 43.

Table 43: Heat Release Rate data for Chair 11 [4]

Chair 11	
Time (s)	**HRR (kW)**
42	30
80	31
125	61
167	167
212	272
253	378
291	498
319	589
350	634
378	634
423	545
469	450
507	380
552	335
604	245
646	200
691	141
740	111
778	36
823	21

Calculation of Growth Coefficient Based on Maximum Heat Release Rate:

Q= 634.440 kW
t= 378.212 seconds (Time to reach max HRR from experimental data [Table 43])

$$Q = \propto t^2$$

$\propto$ = 0.004435

In accordance with California Bulletin 133, the maximum heat release rate of the furniture in question must not reach a Heat release rate above 80kW. For the purposes of this model the assumption was made that the maximum heat release rate of 80kW was reached for each couch. With two couches the maximum heat release rate will be set at 160kW.

Summary of Fuel Characteristics:

Q= 160kW
$\propto$ = 0.004435
CO Yield: 0.080
Heat of combustion= 32500 KJ/kg

Co/ soot yields = SFPE handbook 5th edition Table A.39
Heat of combustion = SFPE Handbook 5th edition Table A.38

FDS Model Layout:

Modeled Corridor:

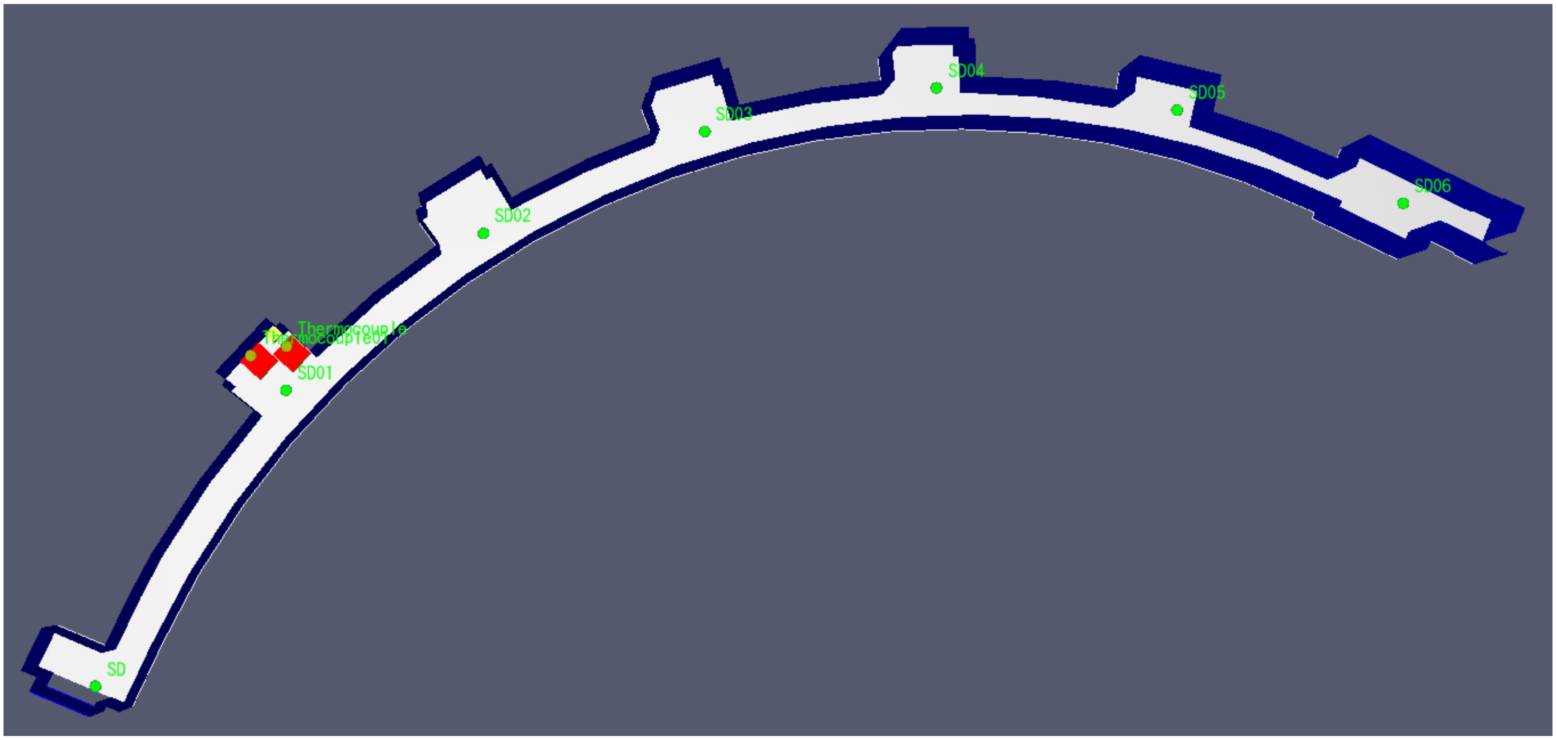


Figure 54: Pyrosim Layout of Corridor

The 4th floor corridor was modeled with the two couches set up as burners (Figure 54). One door at the end of the hallway was left open to emulate a propped door, but all other doors in the corridor were left closed to emulate the worst-case scenario for formation of smoke and tenability conditions.

Location of Burners in Hallway:

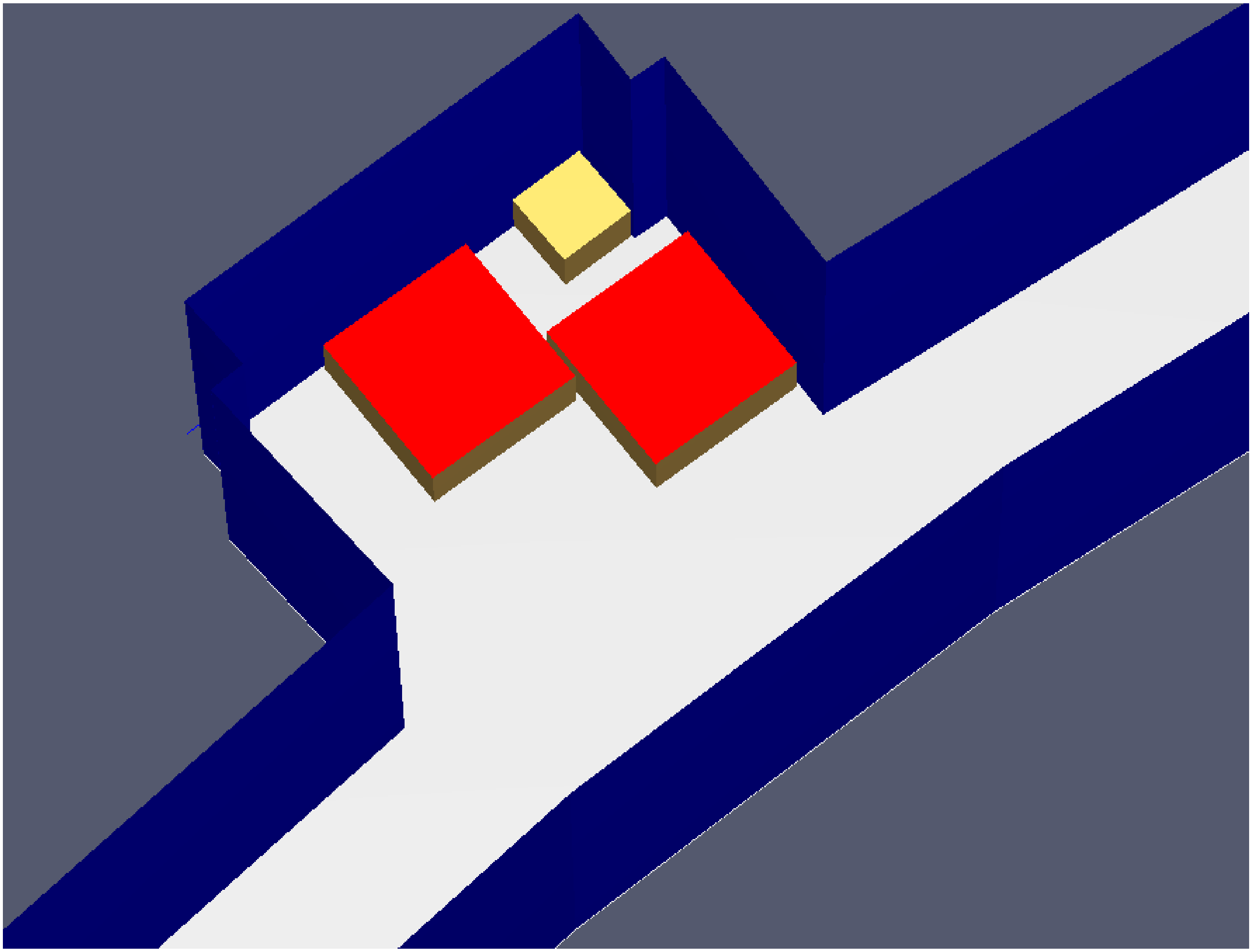


Figure 55: Pyrosim Screenshot of Modeled Fuel Loads

The burners were assumed to be 1m X 1m in order to make the HRRPUA of 160 kW into a maximum HRR of 160kW. The burners are shown in Figure 55.

Tenability Thresholds:

The three tenability criteria requirements chosen for the model are based on the smoke obscuration, CO concentration, and temperature of the fire as discussed in the tenability section of the report. Table 44 summarizes the selected visibility threshold based on Table 63.5 of the SFPE Handbook (5th edition). Table 45 summarizes the selected CO concentration threshold based on Table 63.9 of the SFPE Handbook (5th edition). Table 46 summarizes the selected heat threshold based on Table 63.20 of the SFPE Handbook (5th edition).

Smoke Obscuration:

Table 44: Visibility Criteria for Smoke Obscuration

Room size and travel distance	Optical density (OD/m)	Visibility Criteria
Large	0.08	10 m

CO Concentration:

Table 45: Tenability Criteria for Maximum CO concentration

C · t Exposure time (ppm · min)	Total Evacuation Time (min)	Instantaneous Concentration (ppm)
35,000	30	1,167

Heat:

Table 46: Tenability Criteria for Maximum Temperature

Intensity (°C)	Tolerance time (minutes)
60	> 30 min

Performance goal:

The main goal of the model is show that the design of the building will minimize fire-related injuries and prevent undue loss of life. (SFPE engineering guide to Performance-Based Fire Protection second edition)

Performance Criterion:

Any occupant who is not intimate with ignition shall not be exposed to instantaneous or cumulative untenable conditions.
(5.2.2 LSC 13 edition)

These performance criteria will be met utilizing methods 1 and 2 from the LCS Handbook (13th edition).

Method 1: The design team can set detailed performance criteria that ensure that occupants are not incapacitated by fire effects. (LCS Handbook 13th edition)

Method 2: For each design fire scenario and the design specifications, conditions, and assumptions, the design team can demonstrate that each room or area will be fully evacuated before the smoke and toxic gas layer in the room descends to a level lower than 6 feet (1830 mm) above the floor. (LCS Handbook 13th edition)

Results (ASET):

Visibility:

The visibility in the corridor drops below 10m and becomes an egress concern at 100 seconds into the model. Figure 56 shows the exact time (110 seconds) when the visibility drops below 10m all the way to the end of the corridor where the nearest exit is present. Figure 57 shows an enlarged picture of the same point in the simulation.

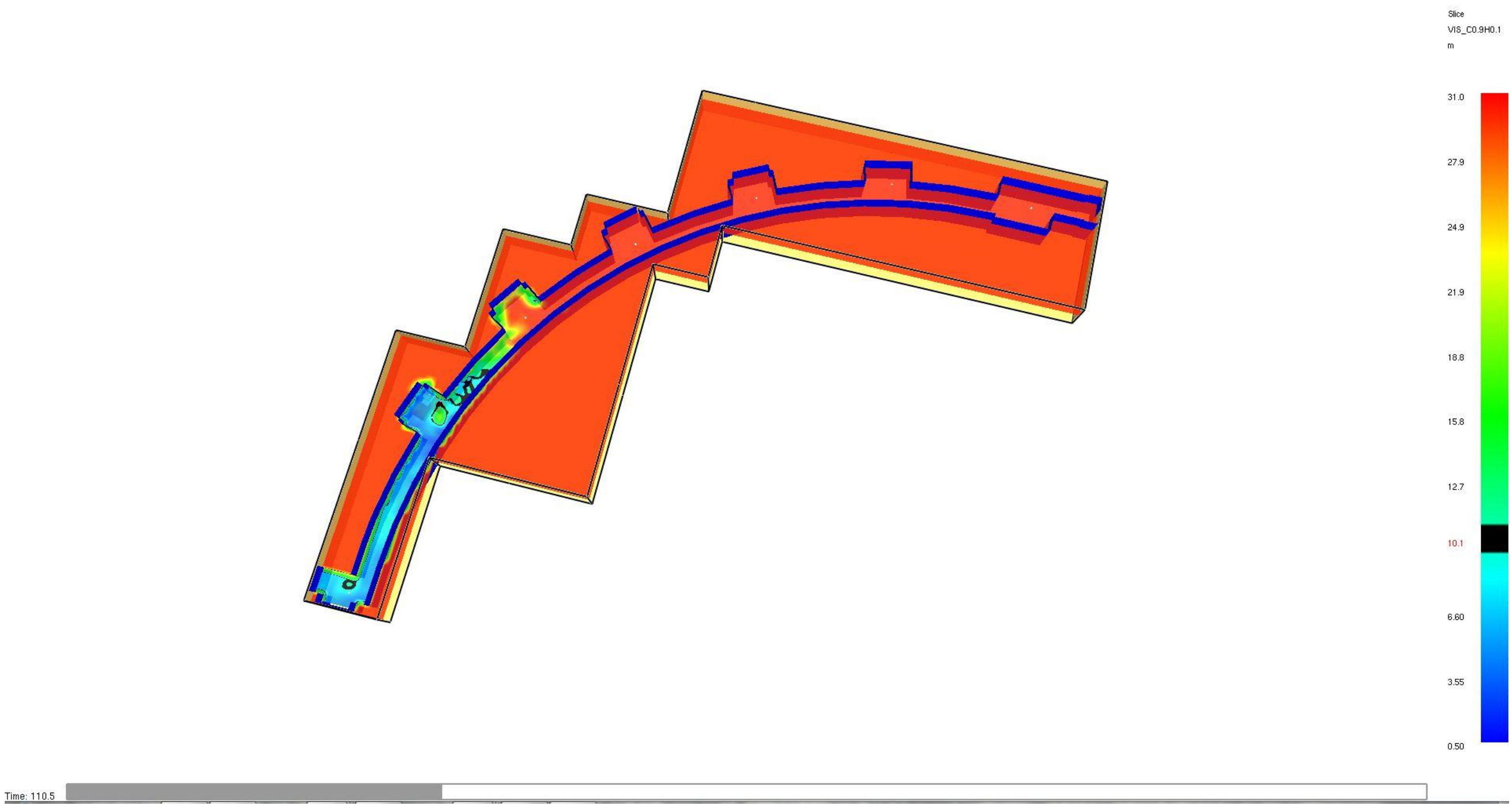


Figure 56: Smokeview Screenshot of Visibility Conditions 110 seconds into Simulation (Black Scale Bar Set to 10m visibility)

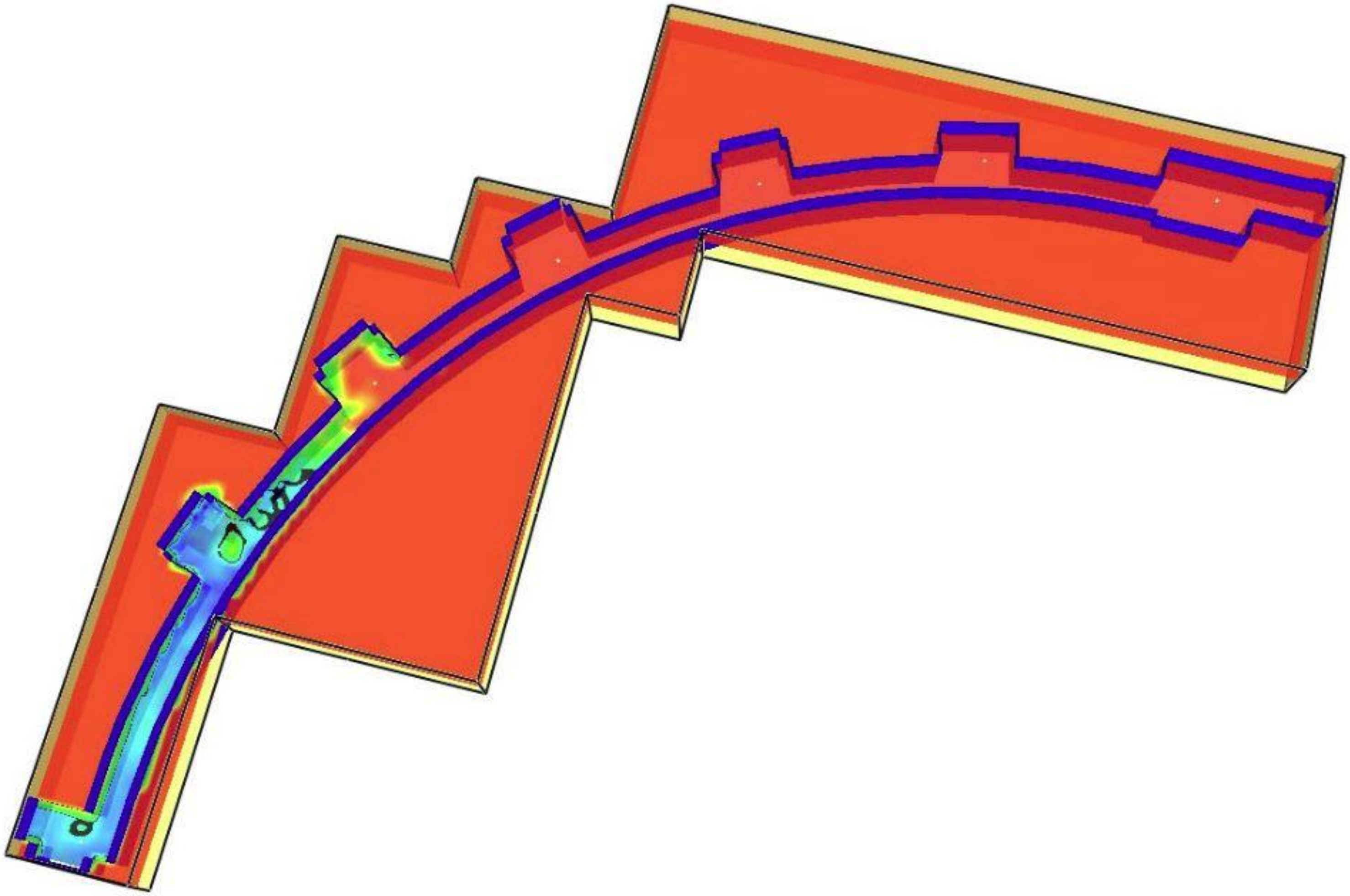


Figure 57: Zoom in of Smokeview Screenshot of Visibility Conditions 110 seconds into Simulation (Black Scale Bar Set to 10m visibility)

CO concentration (ppm):

The CO concentration of the corridor remains below 550 ppm for all 400 seconds (6.67 minutes) of the simulation. Figure 58 shows the CO concentration in ppm 400 seconds into the simulation. Figure 59 shows an enlarged picture of the same point in the simulation.

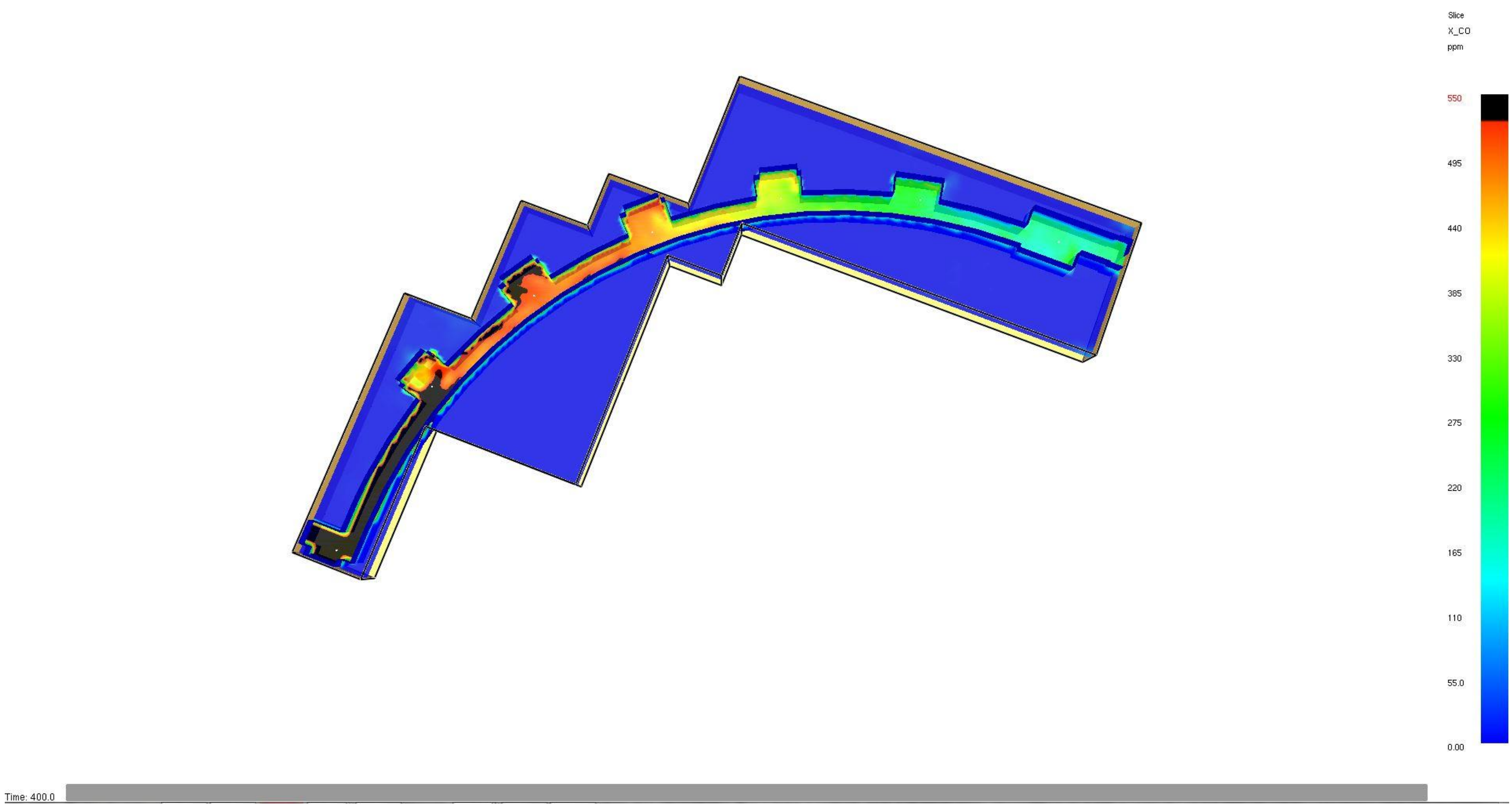


Figure 58: Smokeview Screenshot of CO Concentrations 400 seconds into Simulation (Black Scale Bar Set to Maximum Reached CO Concentration of 550 ppm)

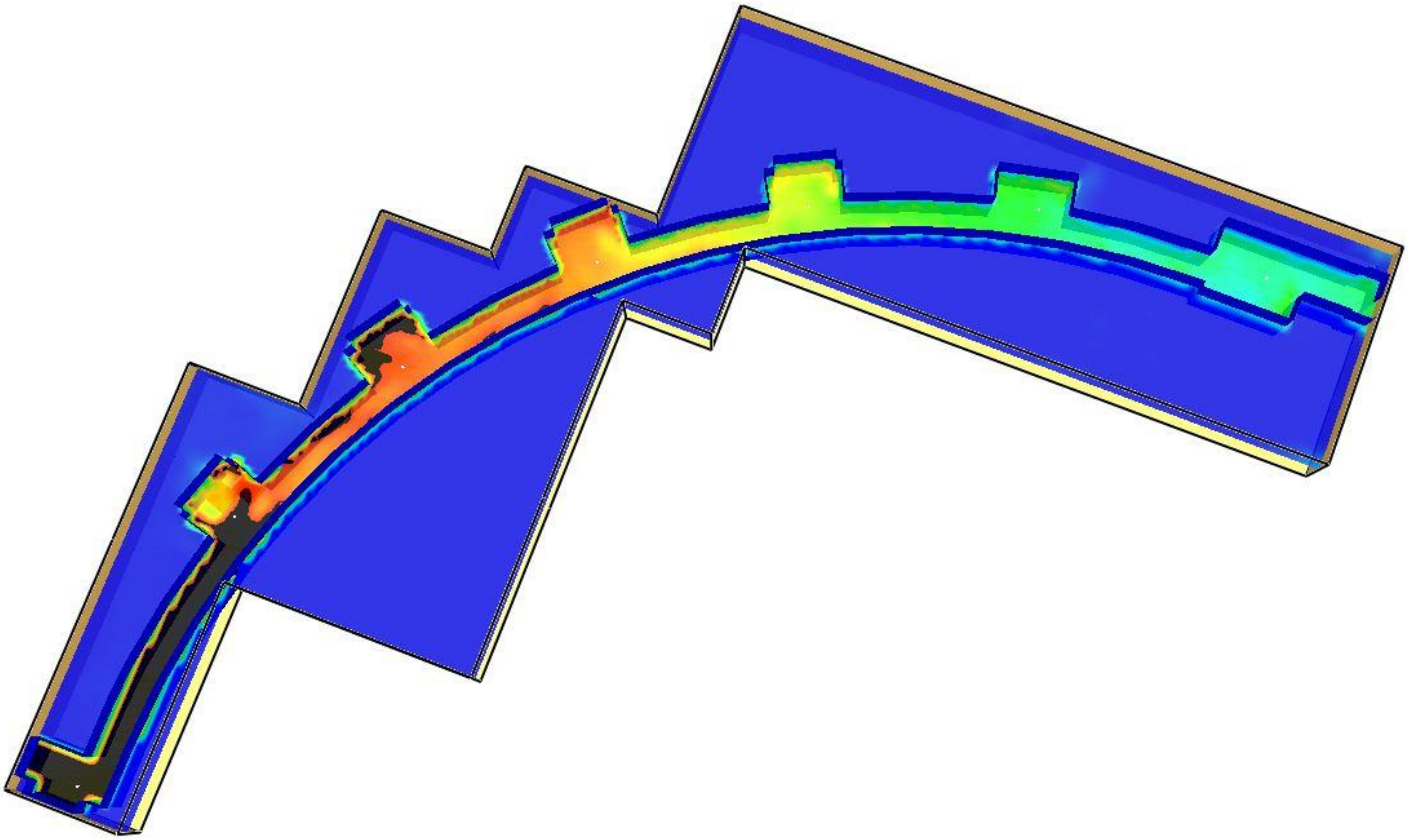


Figure 59: Zoom in of Smokeview Screenshot of CO Concentrations 400 seconds into Simulation (Black Scale Bar Set to Maximum Reached CO Concentration of 550 ppm)

Temperature:

The temperature in the corridor remains close to 60 ℃ in the area leading to the nearest exit at the end of the corridor after 400 seconds. Figure 60 shows the temperature in the simulation after 400 seconds. Figure 61 shows an enlarged picture of the same point in the simulation.

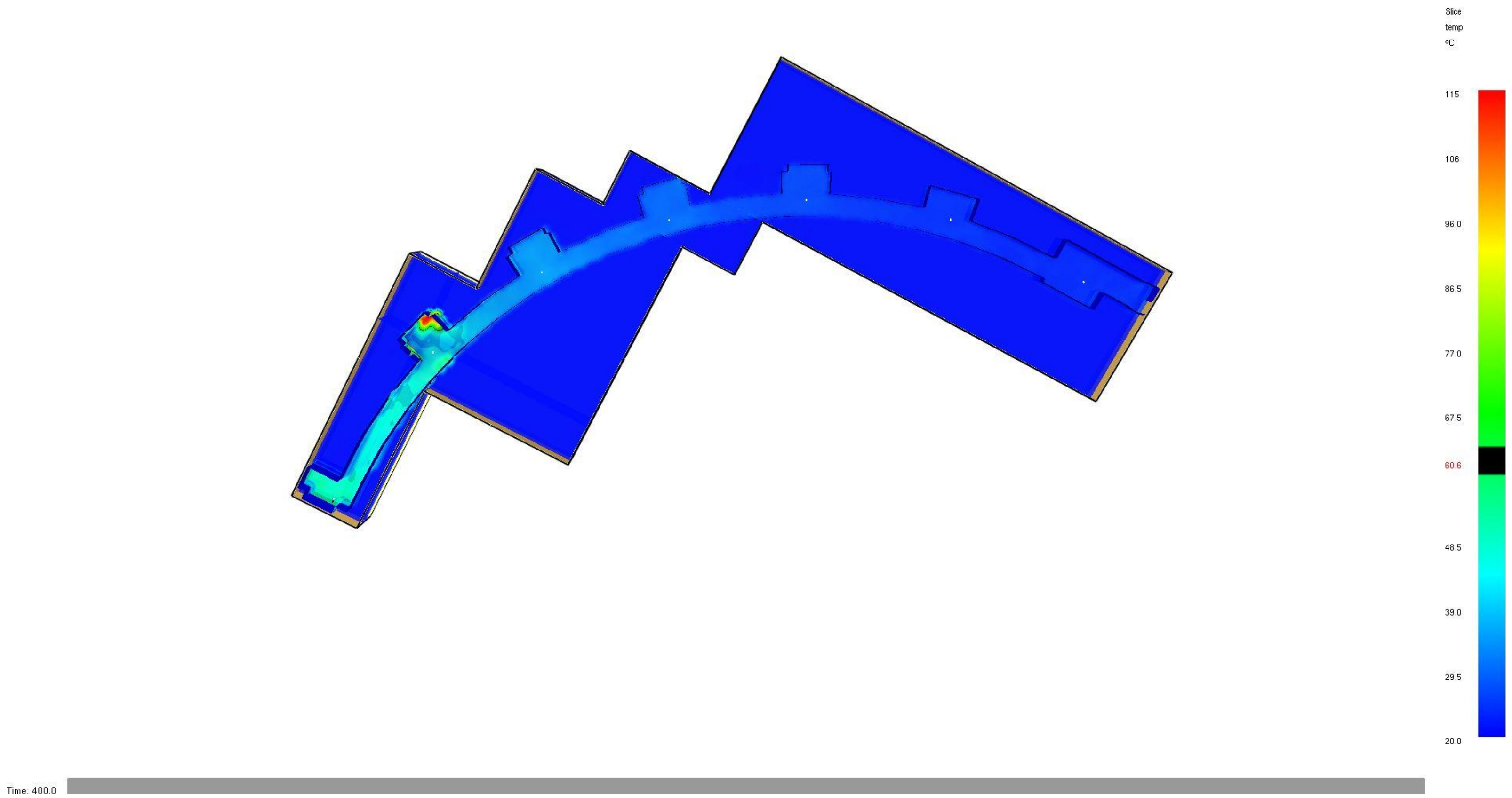


Figure 60: Smokeview Screenshot of Temperature Conditions 400 seconds into Simulation (Black Scale Bar Set to 60℃)

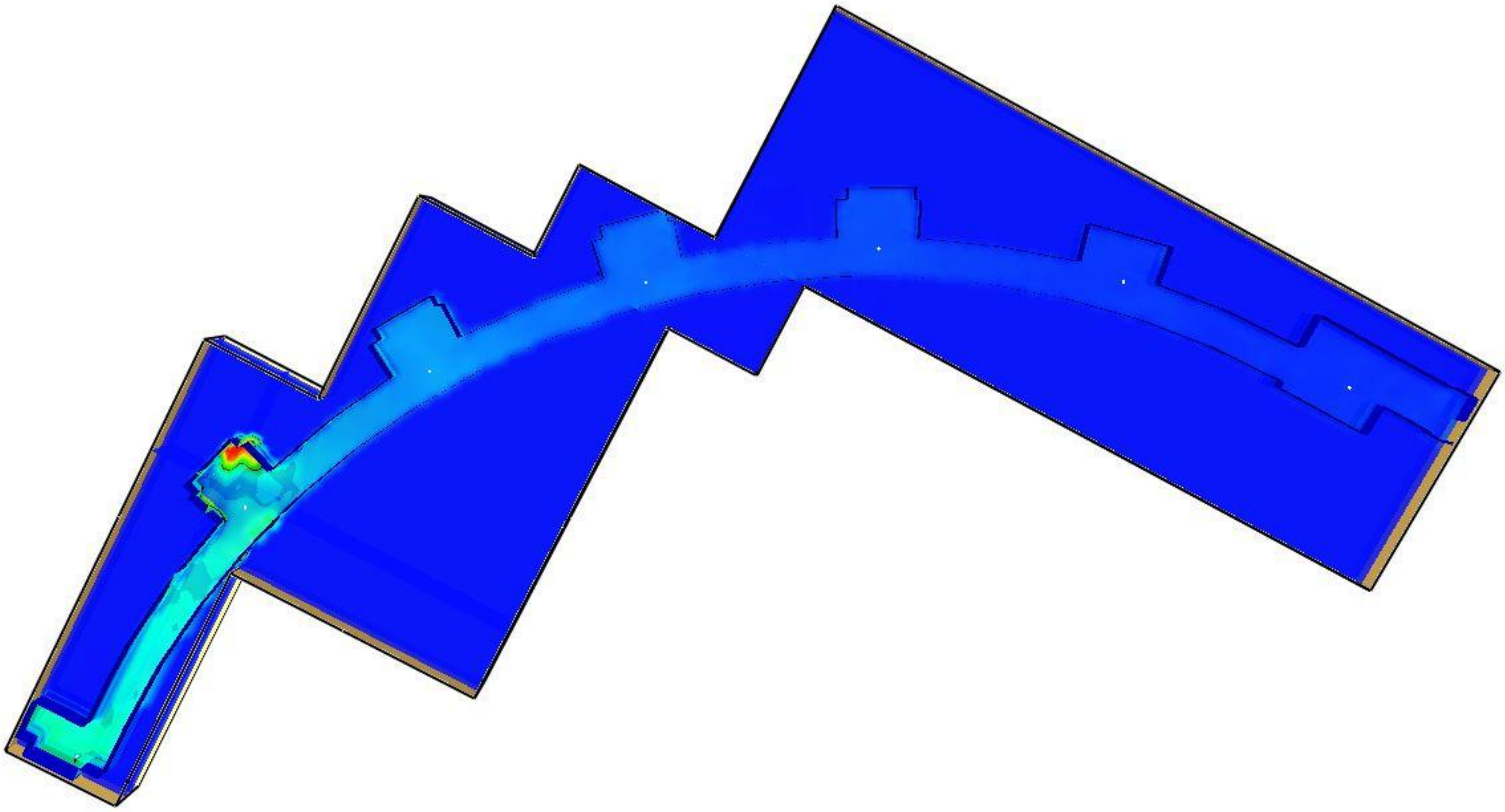


Figure 61: Zoom in of Smokeview Screenshot of Temperature Conditions 400 seconds into Simulation (Black Scale Bar Set to 60℃)

RSET:

Table 47 shows the total required safe egress time of the fourth floor of the building. The detector activation time is based on the time in the simulation when the smoke detector closest to the fire activated. The location of the detectors was based on the actual location of the detectors in the building. The pre-movement times are based on the pre-movement average discussed in the Pre-movement Considerations section of the report. The start of movement is the time it takes for both detection and pre movement to occur. Required movement time was based on the movement time to evacuate the entire fourth floor of the building. In order to obtain the total required safe egress time, the start of movement and total movement time were combined.

Table 47: Summary of RSET Events

Event	Time
Activation of First Smoke Detector	34 seconds
Pre-movement Time	78 seconds
Start of Movement	112 seconds
Required Movement Time (From Pathfinder Model)	94 seconds
Total RSET	3.4 minutes

Conclusions:

The Visibility criteria fail first after only 110 seconds. If the smoke detector is the only means by which the occupants can be notified of the fire's presence, the movement of the occupants will not begin until 117 seconds into the simulation using the pre-movement assumptions from the (IAFSS). The failure of the visibility criteria means that the requirements of method 2 for performance based design in the LSC Handbook (13^{th} edition) will fail.

Despite the loss of visibility, the occupants in the building will not be incapacitated by the effects of CO, which remains below 550 ppm 6.7 minutes into the simulation. The performance criterion of 1000 ppm was established to be the concentration necessary to incapacitate an occupant if exposure lasts for 30 minutes or more. The concentration of 550 ppm will not cause incapacitation for the occupants in this building in the span of 3.4 minutes (RSET).

The maximum temperature in the corridor remains close to 60 °C for 6.7 minutes into the simulation. In the SFPE Handbook (5th edition) this temperature is listed as being bearable to humans for 30 minutes. By this criterion, the temperature in this model will not cause injury or incapacitation to occupants evacuating the area.

While visibility may slow down the egress of occupants, the CO concentration and temperature of the fire will not cause incapacitation in the RSET meaning that method 1 of the performance based criteria in the LSC (13th edition) is satisfied.

Conclusions/ Recommendations:

Overall, the building complies with the prescriptive requirements present in the Life Safety Code Handbook in terms of egress. One point of concern is the number of obstructions that are left within the exit corridors on a daily basis. These obstructions reduce the minimum width of the corridors below the required 44 inches. This hallway reduction violates the clear width requirement of the 13th edition of the LSC. These obstructions may also lead to injury or the obstruction of doorways if moved into different spaces. I would recommend removing hallway obstructions to leave the hallways clear.

The alarm and notification devices meet the prescriptive requirements of the code and provide adequate coverage to notify occupants of a potential fire scenario. The smoke detection devices do not comply with the spacing requirements outlined in NFPA 72 for full coverage of the building. I would recommend placing a photoelectric smoke detector in each office space to provide full coverage of the building.

All fire rating and structural requirements of a Type 1-B (2015 IBC) occupancy are met aside from the ratings of the exterior load bearing walls and rated openings. These walls are rated for one hour where a two hour rating is required. A 3/4 hour rating is required for windows in exterior walls with a 1 hour rating. The windows in the exterior walls to the building are not fire rated accordingly. A number of doors leading to important egress routes are propped open with door stops. The door stops should be removed so the doors can function as barriers as designed.

The presence of the trees in the courtyard provides an increased risk to a potential fire scenario directly outside the building. Coupled with the fact that the windows are not rated adequately this provides an increased risk to outdoor exposure fires. Despite the aesthetic appeal of the foliage present in the courtyard, I would recommend removing it completely to retain the separation distance the building was originally intended to maintain.

The campus Fire Safety Management plan is extensive in its analysis of how the occupants of the building should act in different situations. This plan should be updated periodically to reflect changes in the building and campus policies, but for the time being the plan is comprehensive.

While adequate water is present for a sprinkler system, I would recommend focusing on detection to alert occupants of a fire risk sooner. This point is

highlighted well by the modeled fire results in the way that time to detection was the most important factor in exiting before tenable conditions were lost.

The modeled fire scenario did provide adequate time for occupants to egress, however visibility was lost in the simulation before egress was complete.

References:

[1]

Vistnes, Jamie, Stephen J. Grubits, and Yaping He. "A Stochastic Approach to Occupant Pre-movement in Fires." International Association for Fire Safety Science (n.d.): n. pag. Web.

[2]

S. Gwynne, E.R. Galea, J. Parke, and J. Hickson. "The Collection of Pre-evacuation times from Evacuation Trials Involving a Hospital Outpatient Area and a University Library Facility." International Association for Fire Safety Science (n.d.): n. pag. Web.

[3]

Kim, Hyeong-Jin, and David G. Lilley. "Heat Release Rates of Burning Items in Fires."American Institute of Aeronautics and Astronautics (2000): n. pag. Web.

[4]

University of Maryland Fire Burning Item Database
http://www.firebid.umd.edu/database-chairs_1.php

Appendix A - Detection Device Locations

Floor 1:

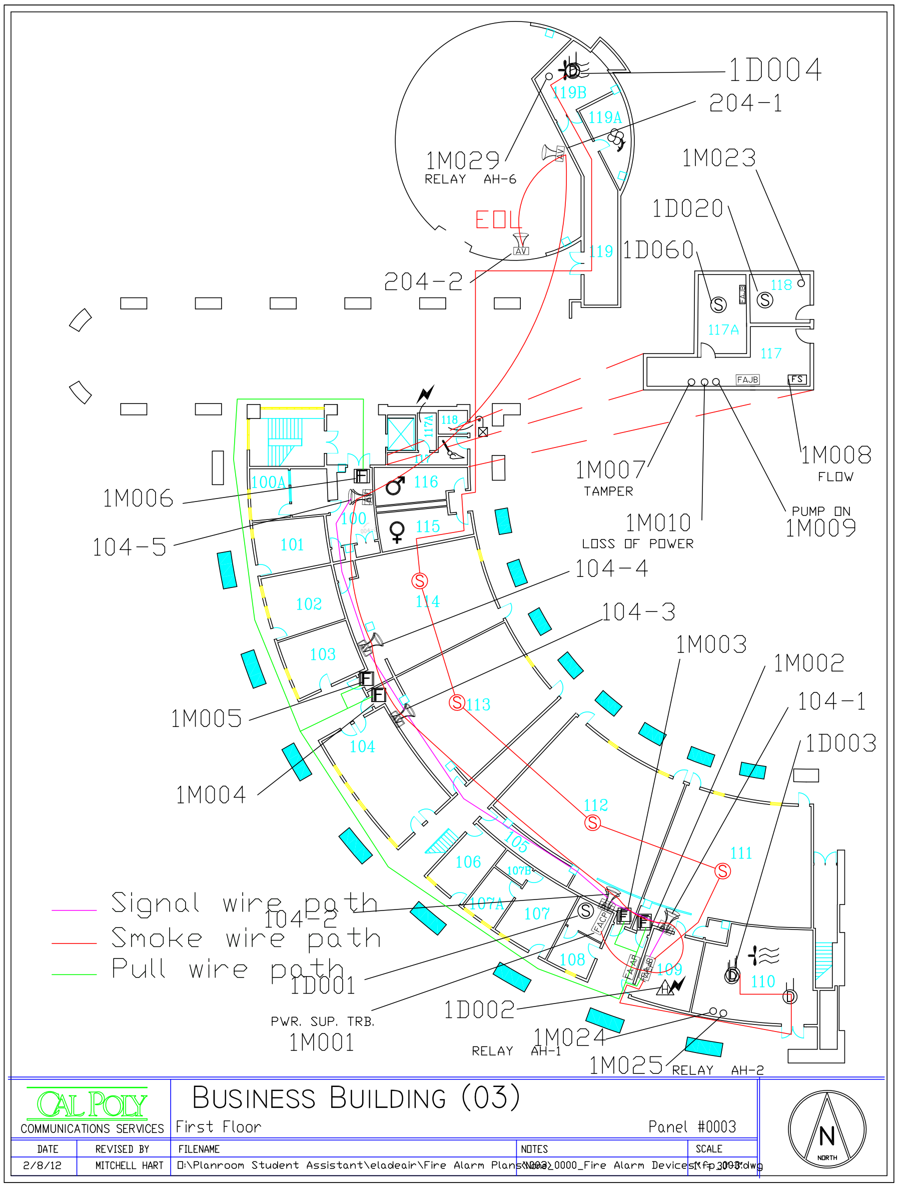


Figure 62: Detector Locations on First Floor

Floor 2:

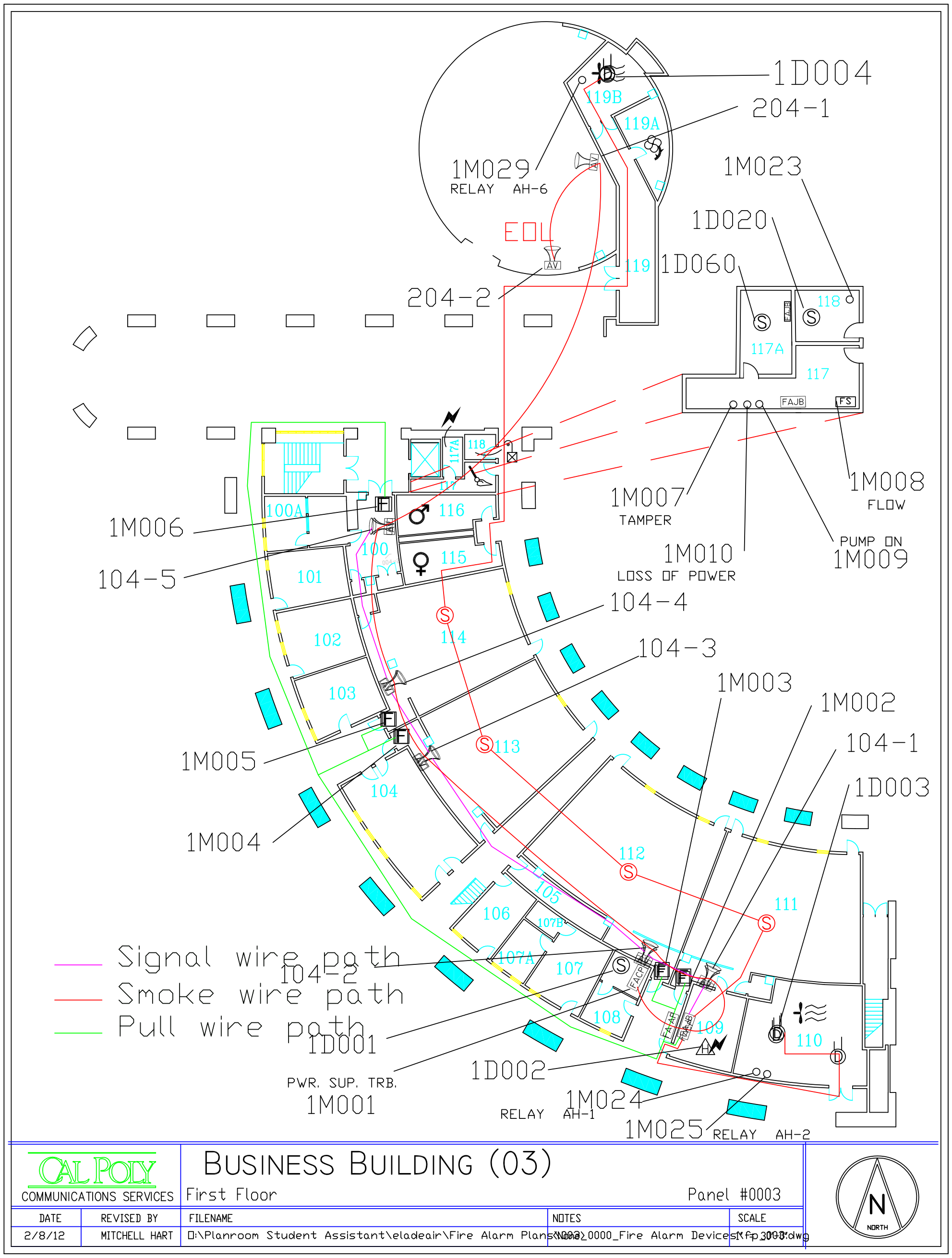


Figure 63: Detector Locations on Second Floor

Floor 3:

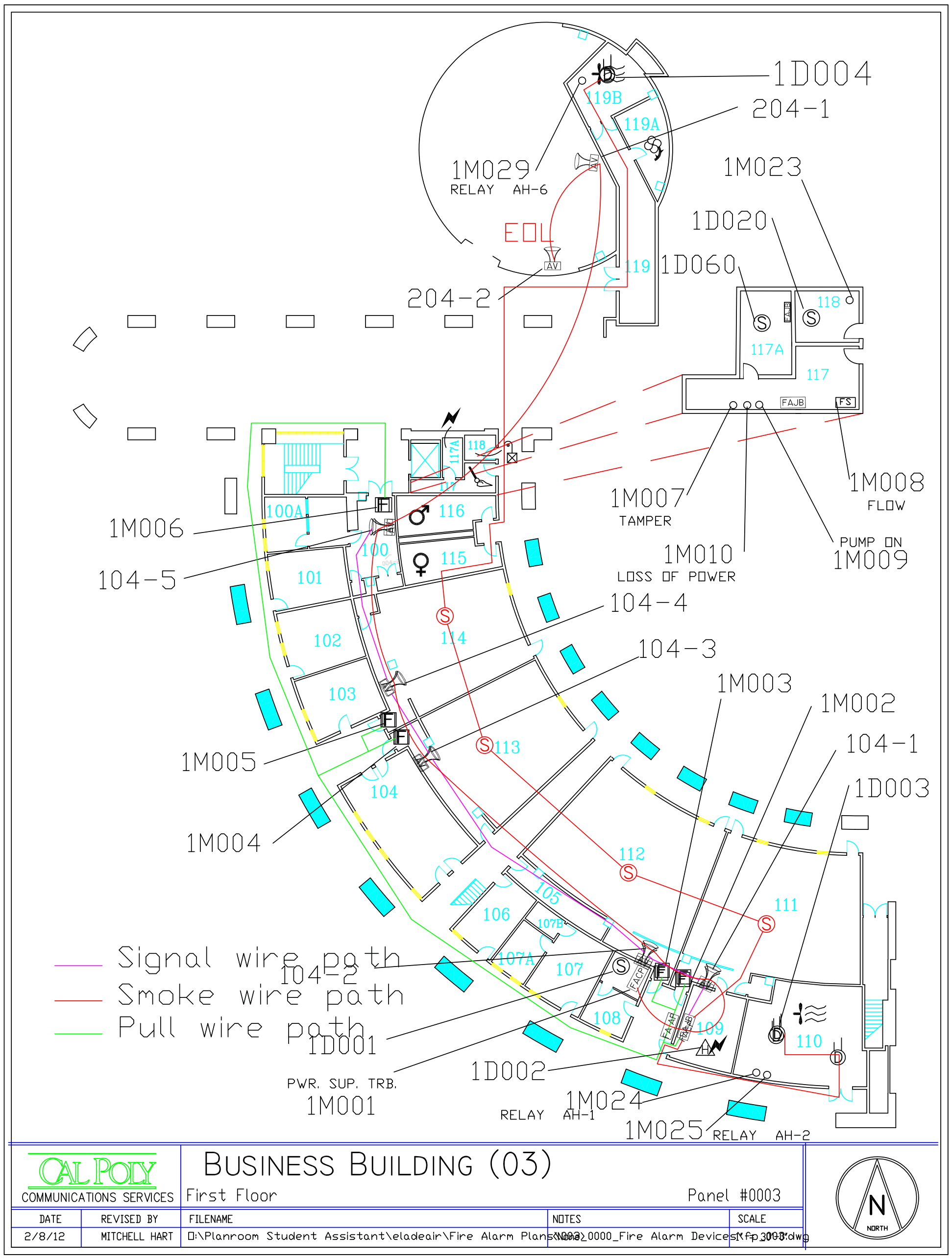


Figure 64: Detector Locations on Third Floor

Floor 4:

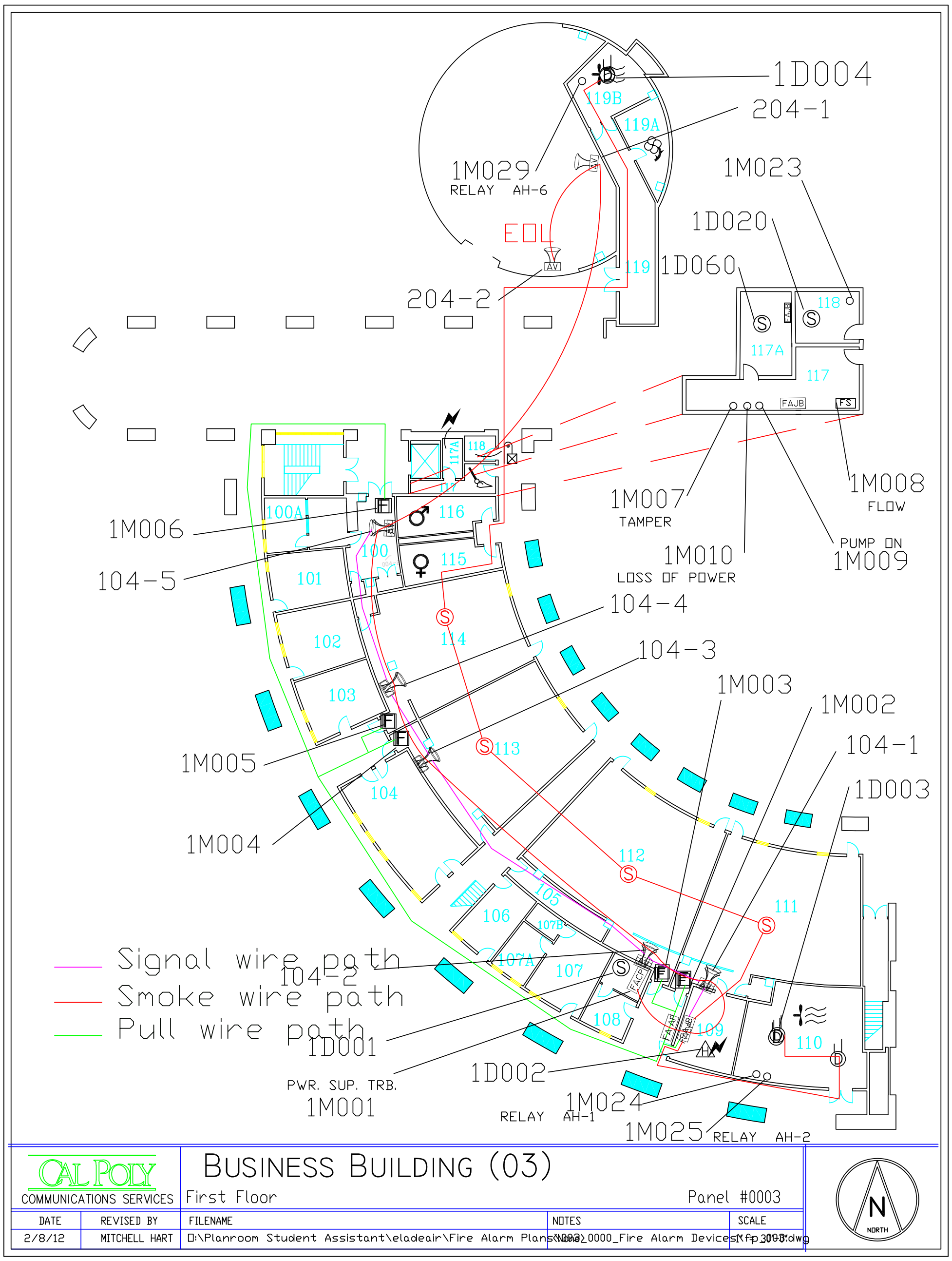


Figure 65: Detector Locations on Fourth Floor

Appendix B – Occupant Load Calculations

Table 48: Occupant Load Calculations

Room	Room Type	Area	Lvl	Occupancy type	Occupant load factor (ft^2/ person)	Occupant load
0100-00	Staff Office	237	1	Business	100	2.37
0100-A0	Admin Office	140	1	Business	100	1.4
0100-B0	Admin Office	142	1	Business	100	1.42
0100-C0	Gen Storage	136	1	Storage (mot merc/ storage)	500	0.272
0101-00	Admin Office	257	1	Business	100	2.57
0101-A0		113	1			
0101-B0		104	1			
0104-00	Lecture	624	1	Classroom	20	31.2
0106-00	Spec Instruction	217	1	Business	100	2.17
0107-00	Staff Office	280	1	Business	100	2.8
0107-A0	Conf Room	126	1	Business	100	1.26
0107-B0	Gen Storage	46	1	Storage (mot merc/ storage)	500	0.092
0108-00	Admin Office	130	1	Business	100	1.3
0108-A0	Mechanical/Elect	73	1	Storage (mot merc/ storage)	500	0.146
0109-00	Mechanical/Elect	288	1	Storage (mot merc/ storage)	500	0.576
0110-00	Mechanical/Elect	740	1	Storage (mot merc/ storage)	500	1.48
0111-00	Lecture	1414	1	Classroom	20	70.7
0111-A0	Lecture Serv	27	1	Classroom	20	1.35
0112-00	Lecture	1457	1	Classroom	20	72.85
0112-A0	Gen Storage	147	1	Storage (mot merc/ storage)	500	0.294
0113-00	Lecture	1159	1	Classroom	20	57.95
0114-00	Lecture	1106	1	Classroom	20	55.3
0114-A0	Spec Instruction	371	1	Business	100	3.71
0114-B0	Lecture Serv	23	1	Classroom	20	1.15
0115-00	Restroom	217	1			
0116-00	Restroom	215	1			
0117-00	Custodial	104	1	Storage (mot merc/ storage)	500	0.208
0117-A0	Mechanical/Elect	51	1	Storage (mot merc/ storage)	500	0.102

0118-00	Mechanical/Elect	49	1	Storage (mot merc/ storage)	500	0.098
0119-00	Circulation	348	1			
0119-A0	Mechanical/Elect	196	1	Storage (mot merc/ storage)	500	0.392
0119-B0	Mechanical/Elect	294	1	Storage (mot merc/ storage)	500	0.588
0119-C0	Lecture Serv	68	1	Classroom	20	3.4
0200-00	UpDiv Teach Lab	714	2	Business	100	7.14
0201-00	Lecture	1025	2	Classroom	20	51.25
0201-A0	Spec Inst Sup	242	2	Business	100	2.42
0201-B0	Spec Inst Sup	195	2	Business	100	1.95
0202-00	Spec Instruction	129	2	Business	100	1.29
0203-00	Spec Instruction	116	2	Business	100	1.16
0204-00	Lecture	1183	2	Classroom	20	59.15
0205-00	Lecture	1074	2	Classroom	20	53.7
0205-A0	Mechanical/Elect	51	2	Storage (mot merc/ storage)	500	0.102
0205-B0	Gen Storage	20	2	Storage (mot merc/ storage)	500	0.04
0206-00	Lecture	1017	2	Classroom	20	50.85
0206-A0	Conf Room	291	2	Business	100	2.91
0207-00	Spec Inst Sup	601	2	Business	100	6.01
0208-A0	Staff Office	257	2	Business	100	2.57
0208-B0	Admin Office	107	2	Business	100	1.07
0209-00	Lecture	934	2	Classroom	20	46.7
0210-00	Restroom	229	2			
0211-00	Restroom	228	2			
0212-00	Custodial	149	2	Storage (mot merc/ storage)	500	0.298
0212-A0	Mechanical/Elect	48	2	Storage (mot merc/ storage)	500	0.096
0213-00	Lecture	2616	2	Assembly (fixed seating)	use number of seats	230
0213-A0	Lecture Serv	63	2	Classroom	20	3.15
0300-00	Slf Inst Lab	1844	3	Business	100	18.44
0300-A0	Spec Instruction	808	3	Business	100	8.08
0300-B0	Gen Storage	30	3	Storage (mot merc/ storage)	500	0.06
0300-C0	Gen Storage	85	3	Storage (mot merc/ storage)	500	0.17
0300-D0	Spec Inst Sup	304	3	Business	100	3.04
0301-00	Spec Inst Sup	896	3	Business	100	8.96

0301-A0	Admin Office	168	3	Business	100	1.68
0302-00	Slf Inst Lab	1328	3	Business	100	13.28
0302-A0	Slf Inst Lab	228	3	Business	100	2.28
0303-00	UpDiv Teach Lab	1208	3	Business	100	12.08
0304-00	Mechanical/Elect	320	3	Storage (mot merc/ storage)	500	0.64
0305-00	UpDiv Teach Lab	1021	3	Business	100	10.21
0306-00	UpDiv Teach Lab	1423	3	Business	100	14.23
0307-00	UpDiv Teach Lab	1425	3	Business	100	14.25
0308-00	Gen Storage	501	3	Storage (mot merc/ storage)	500	1.002
0309-00	Restroom	227	3			
0310-00	Restroom	220	3			
0311-00	Custodial	23	3	Storage (mot merc/ storage)	500	0.046
0312-00	Maint Rpr Sp	388	3	Business	100	3.88
0312-A0	Mechanical/Elect	72	3	Storage (mot merc/ storage)	500	0.144
0312-B0	Mechanical/Elect	246	3	Storage (mot merc/ storage)	500	0.492
0313-00	Faculty Office	107	3	Business	100	1.07
0314-00	Faculty Office	107	3	Business	100	1.07
0315-00	Faculty Office	107	3	Business	100	1.07
0316-00	Faculty Office	107	3	Business	100	1.07
0317-00	Faculty Office	107	3	Business	100	1.07
0318-00	Faculty Office	107	3	Business	100	1.07
0319-00	Faculty Office	107	3	Business	100	1.07
0320-00	Faculty Office	107	3	Business	100	1.07
0321-00	Faculty Office	107	3	Business	100	1.07
0322-00	Faculty Office	107	3	Business	100	1.07
0323-00	Faculty Office	107	3	Business	100	1.07
0323-A0	Gen Storage	120	3	Storage (mot merc/ storage)	500	0.24
0324-00	Faculty Office	107	3	Business	100	1.07
0325-00	Faculty Office	107	3	Business	100	1.07
0326-00	Faculty Office	107	3	Business	100	1.07
0327-00	Faculty Office	107	3	Business	100	1.07
0328-00	Faculty Office	107	3	Business	100	1.07
0329-00	Faculty Office	107	3	Business	100	1.07
0330-00	Faculty Office	107	3	Business	100	1.07
0331-00	Faculty Office	107	3	Business	100	1.07
0332-00	Faculty Office	107	3	Business	100	1.07

0333-00	Faculty Office	107	3	Business	100	1.07
0334-00	Faculty Office	107	3	Business	100	1.07
0335-00	Faculty Office	107	3	Business	100	1.07
0336-00	Faculty Office	107	3	Business	100	1.07
0337-00	Faculty Office	107	3	Business	100	1.07
0338-00	Faculty Office	107	3	Business	100	1.07
0339-00	Faculty Office	107	3	Business	100	1.07
0340-00	Faculty Office	107	3	Business	100	1.07
0341-00	Conf Room	425	3	Business	100	4.25
0342-00	Faculty Office	107	3	Business	100	1.07
0343-00	Faculty Office	107	3	Business	100	1.07
0344-00	Faculty Office	107	3	Business	100	1.07
0345-00	Faculty Use	182	3	Business	100	1.82
0345-A0	Faculty Use	99	3	Business	100	0.99
0400-00	Support Office	428	4	Business	100	4.28
0401-00	Staff Office	625	4	Business	100	6.25
0402-00	Admin Office	152	4	Business	100	1.52
0403-00	Staff Office	226	4	Business	100	2.26
0403-A0	Admin Office	150	4	Business	100	1.5
0403-B0	Gen Storage	51	4	Storage (mot merc/ storage)	500	0.102
0404-00	Admin Office	153	4	Business	100	1.53
0405-00	Staff Office	223	4	Business	100	2.23
0405-A0	Admin Office	151	4	Business	100	1.51
0405-B0	Gen Storage	52	4	Storage (mot merc/ storage)	500	0.104
0406-00	Admin Office	153	4	Business	100	1.53
0407-00	Staff Office	226	4	Business	100	2.26
0407-A0	Admin Office	150	4	Business	100	1.5
0407-B0	Gen Storage	51	4	Storage (mot merc/ storage)	500	0.102
0408-00	Support Office	153	4	Business	100	1.53
0409-00	Staff Office	228	4	Business	100	2.28
0409-A0	Admin Office	151	4	Business	100	1.51
0409-B0	Gen Storage	52	4	Storage (mot merc/ storage)	500	0.104
0410-00	Mechanical/Elect	75	4	Storage (mot merc/ storage)	500	0.15
0410-A0	Mechanical/Elect	84	4	Storage (mot merc/ storage)	500	0.168
0411-00	Faculty Office	107	4	Business	100	1.07
0412-00	Faculty Office	106	4	Business	100	1.06

0413-00	Faculty Office	106	4	Business	100	1.06
0414-00	Faculty Office	106	4	Business	100	1.06
0415-00	Faculty Office	106	4	Business	100	1.06
0416-00	Faculty Office	106	4	Business	100	1.06
0417-00	Faculty Office	106	4	Business	100	1.06
0418-00	Faculty Office	106	4	Business	100	1.06
0419-00	Faculty Office	106	4	Business	100	1.06
0420-00	Faculty Office	106	4	Business	100	1.06
0421-00	Faculty Office	106	4	Business	100	1.06
0422-00	Faculty Office	106	4	Business	100	1.06
0423-00	Faculty Office	106	4	Business	100	1.06
0424-00	Faculty Office	106	4	Business	100	1.06
0425-00	Faculty Office	106	4	Business	100	1.06
0426-00	Faculty Office	106	4	Business	100	1.06
0427-00	Restroom	149	4			
0428-00	Restroom	191	4			
0429-00	Mechanical/Elect	199	4	Storage (mot merc/ storage)	500	0.398
0430-00	Faculty Office	105	4	Business	100	1.05
0431-00	Faculty Office	105	4	Business	100	1.05
0432-00	Faculty Office	105	4	Business	100	1.05
0433-00	Faculty Office	105	4	Business	100	1.05
0434-00	Faculty Office	105	4	Business	100	1.05
0435-00	Faculty Office	105	4	Business	100	1.05
0436-00	Faculty Office	105	4	Business	100	1.05
0437-00	Faculty Office	105	4	Business	100	1.05
0438-00	Faculty Office	105	4	Business	100	1.05
0439-00	Faculty Office	105	4	Business	100	1.05
0440-00	Faculty Office	105	4	Business	100	1.05
0441-00	Faculty Office	107	4	Business	100	1.07
0442-00	Faculty Office	105	4	Business	100	1.05
0443-00	Faculty Office	105	4	Business	100	1.05
0444-00	Faculty Office	105	4	Business	100	1.05
0445-00	Faculty Office	105	4	Business	100	1.05
0446-00	Faculty Office	105	4	Business	100	1.05
0447-00	Faculty Office	105	4	Business	100	1.05
0448-00	Faculty Office	105	4	Business	100	1.05
0449-00	Faculty Office	105	4	Business	100	1.05
0450-00	Faculty Office	105	4	Business	100	1.05
0451-00	Faculty Office	105	4	Business	100	1.05
0452-00	Faculty Office	105	4	Business	100	1.05

0453-00	Admin Office	105	4	Business	100	1.05
0453-A0	Admin Office	105	4	Business	100	1.05
0454-00	Admin Office	105	4	Business	100	1.05
0454-A0	Admin Office	105	4	Business	100	1.05
0455-00	Staff Office	555	4	Business	100	5.55
0455-A0	Admin Office	190	4	Business	100	1.9
0455-B0	Conf Room	441	4	Business	100	4.41
0455-C0	Admin Office	190	4	Business	100	1.9
0455-D0	Support Office	170	4	Business	100	1.7
0456-00	Mechanical/Elect	46	4	Storage (mot merc/ storage)	500	0.092
0457-00	Gen Storage	52	4	Storage (mot merc/ storage)	500	0.104

Table 49: Total Occupant Loads

Main Building Total Occupant Load
1086.25
Floor 1
317.15
Floor 2
521.86
Floor 3
153.43
Floor 4
93.81

Table 50: Business Silo Occupant Loads

Business Silo	Occupant Load
	233.15
Storage Below Business Silo	
	4.38

Appendix C – Labeled Floor Plans Based on Occupancy Classification

Table 51: Occupancy Color Designations

Space Designations	
Business	
Education	
Storage	
Mech./ elect.	
Restroom	
Circulation	
Custodial	
Un-assignable	
Exits	
Vertical exits	
Exit access corridors	
Elevators	

Floor 1:

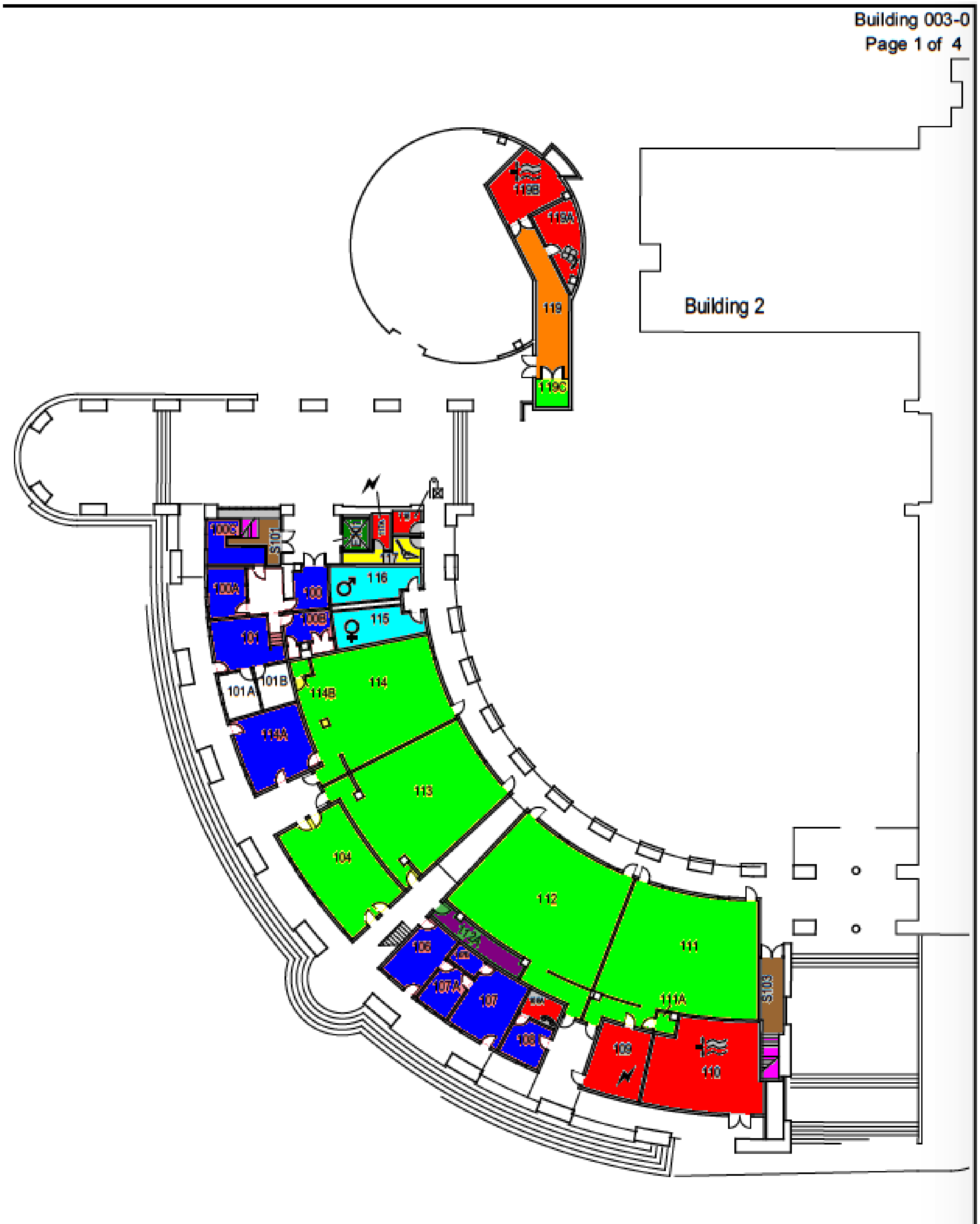


Figure 66: Occupancy Classification of First Floor

Floor 2:

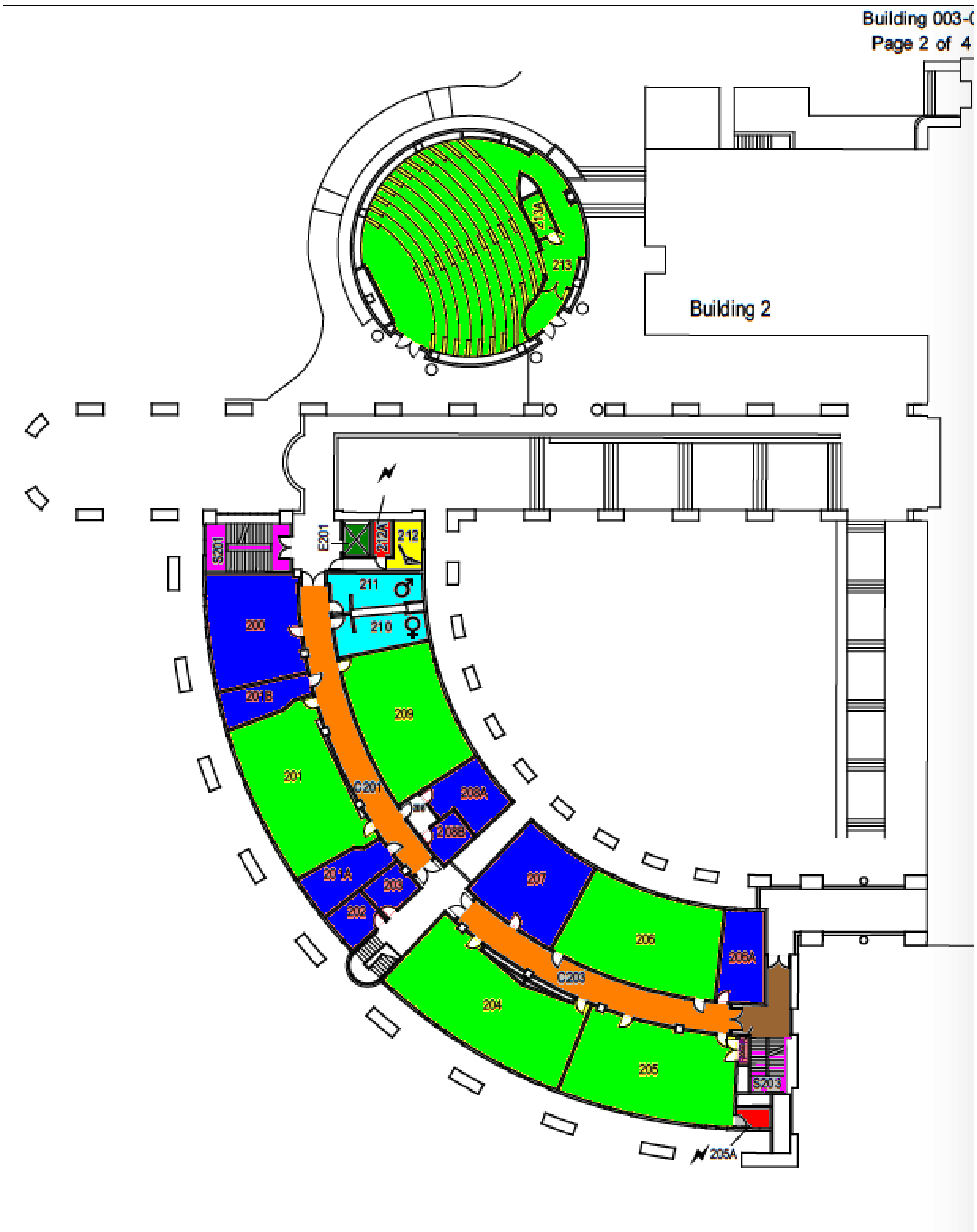


Figure 67: Occupancy Classification of Second Floor

Floor 3:

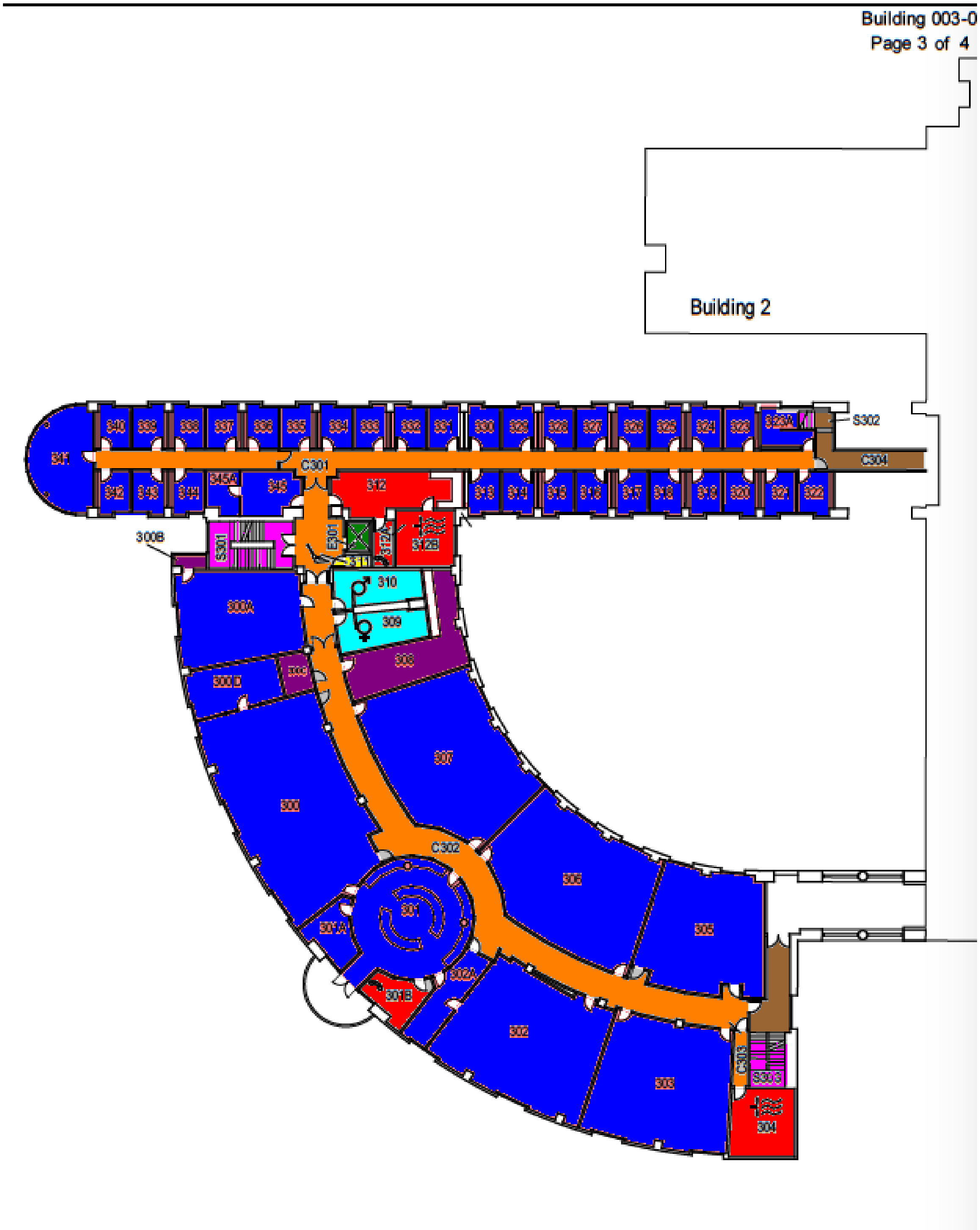


Figure 68: Occupancy Classification of Third Floor

Floor 4:

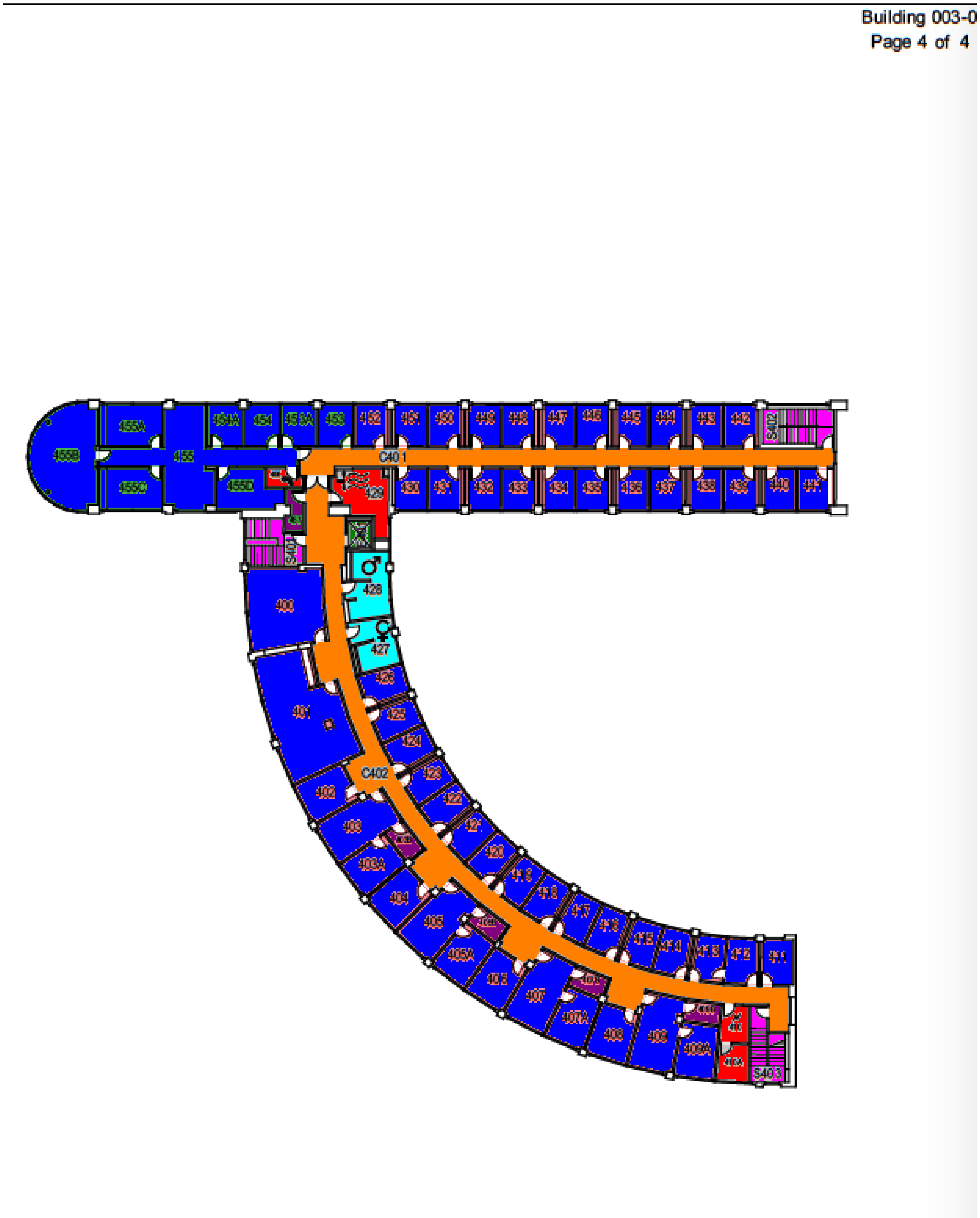


Figure 69: Occupancy Classification of Fourth Floor

Appendix D – Exit Capacity Calculations

Floor 1	N/A (doors lead directly outside)							
Floor 2	Doors (Limiting)	Width (ft)	Exit Capacity Factor	Exit Capacity	Number of Stairwells (Limiting)	Width of Stairway	Exit Capacity	Total Exit Capacity
	1	6	0.2	360	2	41	136	661
						48	165	
Floor 3	3	3	0.2	540	1	60	220	760
Floor 4	3	3	0.2	540		0	540	540
Silo	2	6	0.2	720				720

Horizontal and stairwell capacities are based on Table 7.3.3.1 from the LSC (13th edition). For the two stairways with widths wider than 44 inches the following equation from the LSC (13th edition) was used.

7.3.3.2* For stairways wider than 44 in. (1120 mm) and subject to the 0.3 in. (7.6 mm) width per person capacity factor, the capacity shall be permitted to be increased using the following equation:

$$C = 146.7 + \left(\frac{Wn - 44}{0.218}\right) \qquad \textbf{[7.3.3.2]}$$

where:

C = capacity, in persons, rounded to the nearest integer

Wn = nominal width of the stair as permitted by 7.3.2.2 (in.)