FIRE AND LIFE SAFETY ANALYSIS

The Construction Innovation Center

Matthew Atwell
FPE 596: Culminating Experience in Fire Protection Engineering

Statement of Disclaimer

Keywords

- Prescriptive Based Design
- Performance Based Design
- Life Safety Code
- Required Safe Egress Time (RSET)
- Available Safe Egress Time (ASET)

https://www.google.com/search?q=construction+innovation+center+cal+poly&rlz=1C1CHZL_enUS710US710&espv=2&biw=1093&bih=530&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiZzvyY1u3QAhVhiFQKHStqBEcQ_AUICCgD#imgrc=alXFyE79vLNc0

Executive Summary

In this report you will find the analysis of existing fire protection systems and features that are installed in the Construction Innovation Center at California Polytechnic State University, San Luis Obispo. The Buildings construction was completed in 2008 and is separated into three separate buildings A, B, and C connected by an exterior balcony. This report is separated into two separate analysis Prescriptive and Performance.

The Prescriptive analysis reviews the buildings means of egress, fire alarm systems, the suppression systems, and the structural fire protection. The Prescriptive-based analysis of the Construction Innovation Center confirms that the building meets the requirements of NFPA 101, The Life Safety Code, NFPA 13, NFPA 17, NFPA 72, NFPA 92, The International Building Code (IBC), and The California Building Code (CBC).

The performance-based analysis investigates two different fire scenarios. The first design is set in the lobby of the first floor of Building A. The second fire design scenario examines the effects that a fire would have on Buildings B and C if it started in Building 187, The Simpson Strong-Tie Materials Demonstration Lab, which is in the courtyard of The Construction Innovation Center. For the performance-based analysis Pyrosim and Pathfinder were used. Pyrosim is a type of fire dynamics simulator that simulates fire conditions inside a building including temperature, tenability, and other features. Pathfinder is used to simulate evacuation times. Both design scenarios yielded positive results of Required Safe Egress time (RSET) being greater than the Available Safe Egress Time (ASET).

The Construction Innovation Center meets all code requirements and showed sufficient performance during the fire simulations. I would recommend that the Simpson Strong Tie Demonstrations Lab and The Construction Innovation Center have connected fire alarm systems due to the buildings having about a 20 ft. separation distance. If one building caught on fire it could ignite the face of the other building. The occupants of each building would benefit from being alerted to a fire in the adjacent building.

Contents

Table of Contents

Contents

CAL POLY
SAN LUIS OBISPO

Project Scope

This report will discuss in detail the Fire and Life Safety of The Construction Innovation Center located on California Polytechnic State University Campus in San Luis Obispo. The report will address Egress Analysis, Structural Fire Protection, Fire Suppression, and Fire Detection and Alarm Systems. The report will also review two fire design scenarios in the Performance Based Design section. For the Performance-Based Analysis, Pyrosim and Pathfinder were used. Pyrosim is a type of fire dynamics simulator that simulates fire conditions inside a building including temperature, tenability, and other features. Pathfinder is used to simulate evacuation times.

Code and Standards

For this report various codes were used such as NFPA 101 "The Life Safety code", The SFPE Handbook 5th edition, International Building Code 2015 edition, The California Building Code 2016 edition, as well as various NFPA codes such as NFPA 13 and 72. These codes were used to help determine the prescriptive and performance requirements for The Constructive Innovation Center. The cover of these codes can be seen in Figure 1.

Figure 1: Codes and Standards

The Construction Innovation Center Overview

CBC Table 503

The Construction Innovation Center is located on California Polytechnic State University in San Luis Obispo. The buildings construction was completed in 2008. Its main occupants are students and faculty members of the Construction Management Department. The Construction Innovation Center is Business Group B occupancy. It is separated from laboratories, classrooms, lecture halls, and facility offices. It is Type II-A construction. The building is also fully sprinklered. It is separated into three separate buildings A, B, and C as shown in Figure 2. Even though The Construction Innovation Center is three separate buildings it can be classified as one building. This can be done by reviewing that the height of each building and the aggregate floor area comply with the CBC for frontage and automatic sprinkler system increase.

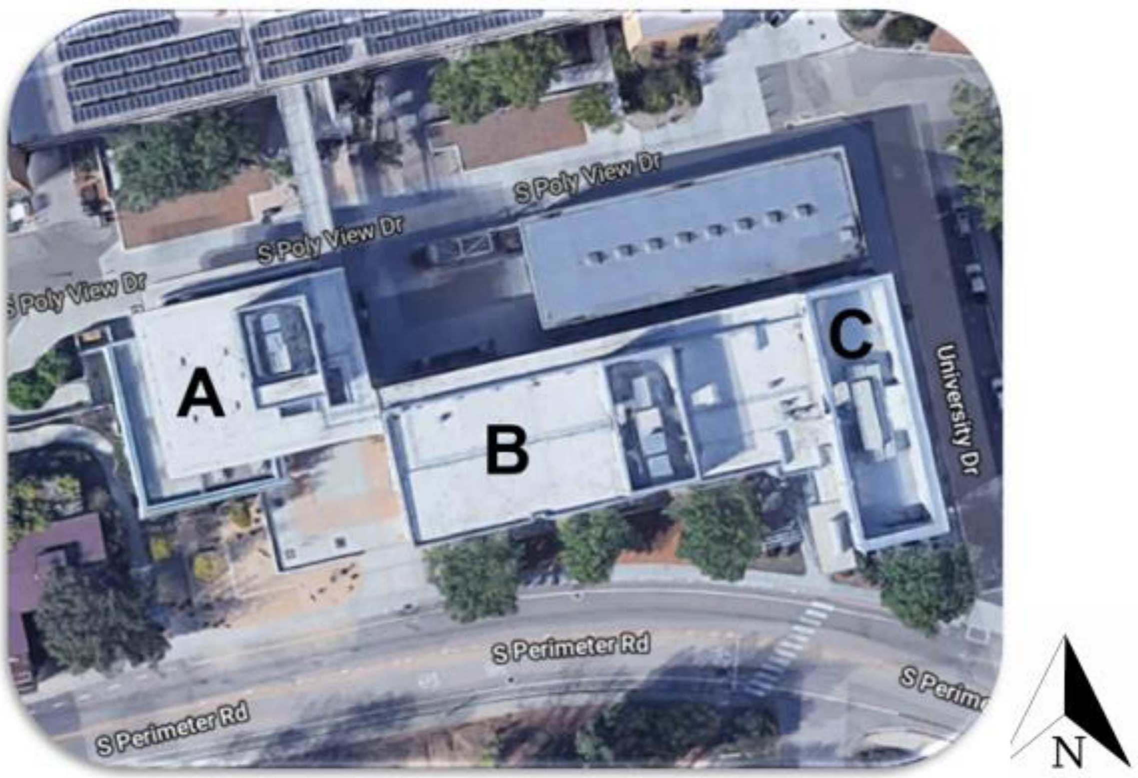


Figure 2: Aerial View of The Construction Innovation Center

CAL POLY
SAN LUIS OBISPO

Floor Plan

Figure 3 shows the first-floor plan of The Construction Innovation Center. The figure shows the three separate buildings A, B, and C.

Figure 3: The Construction Innovation Center, First Floor

CAL POLY
SAN LUIS OBISPO

Occupancy Classification

IBC 304.1

The Construction Innovation Center is classified as a Group B occupancy. The building rooms and spaces have an occupant load of less than 50 occupants and is used for educational purposes above the 12th grade. Figure 4 shows a color-coded representation of the first floor and the diverse types of rooms there are in the Construction Innovation Center. Floors 2 and 3 have similar layouts and can be found in Appendix A.

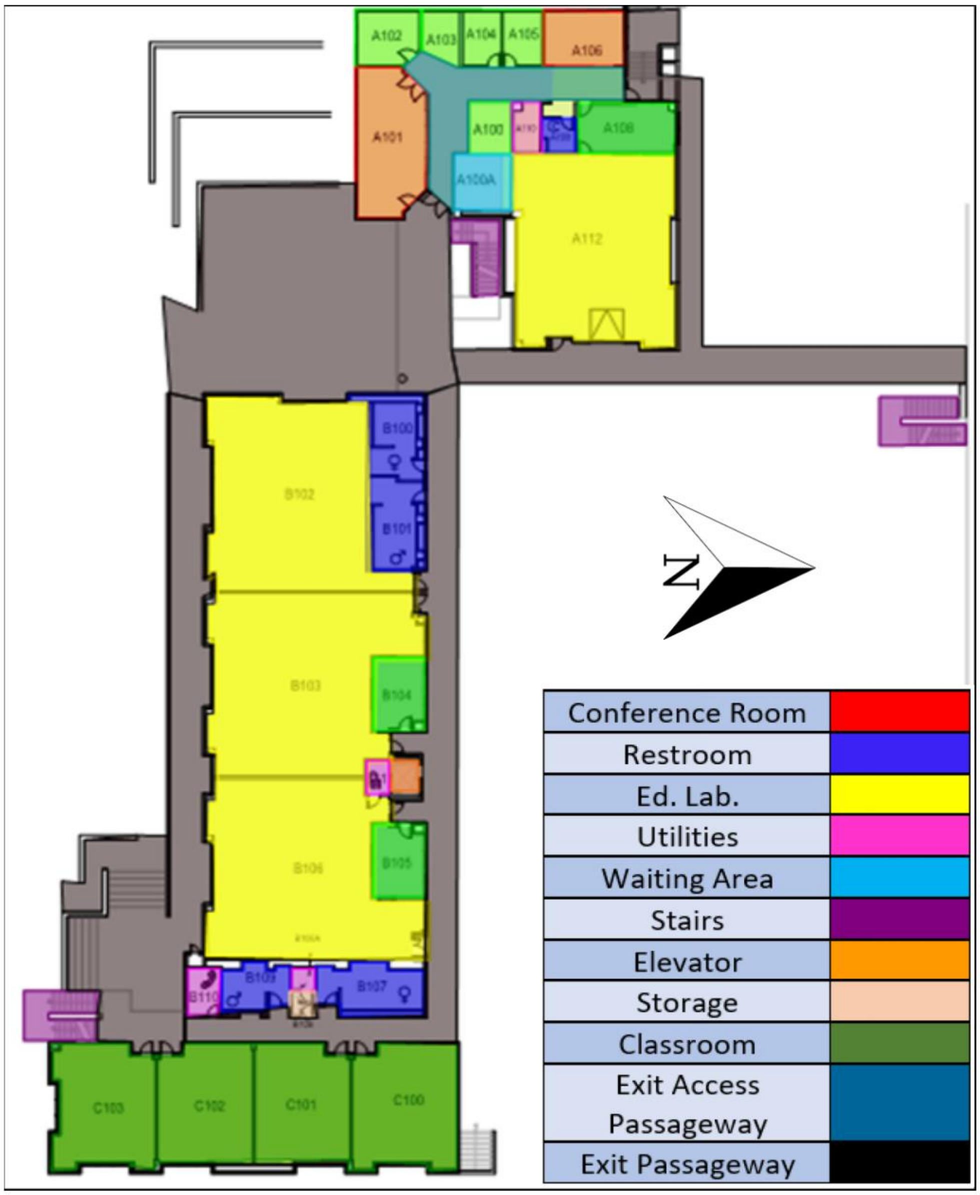


Figure 4: The Construction Innovation Center, first floor color coded

General Construction

IBC Table 601 NFPA 13

General Construction Summary

The Construction Innovation Center is Type IIA Construction. Type IIA has certain requirements set, such as the max height can be 85 feet, max area can be 129,500 ft^2, and the max story height can be six stories for a building under this classification. The Construction Innovation Center complies with this criterion set forth by the IBC.

The Construction Innovation Center has three buildings that are three stories with the max height between them being 58 feet. Even when accounting for frontage increase, the Construction Innovation Center total area is just under 50,000 ft^2, which is well under the 129,500 ft^2 max. Building elements under Type IIA Construction have minimum fire resistance ratings. Elements that fall under one-hour minimum fire resistance ratings are the primary structural frame, exterior bearing walls, interior bearing walls, floor construction and its secondary members, roof construction and its secondary members, and exterior nonbearing walls and partitions. This can be found in Table 1 below. The Construction Innovation Center is permitted to use an automatic sprinkler system in compliance with NFPA 13 as an alternative to the one-hour fire resistance rating required by the IBC. This includes every part of the building excluding the nonbearing walls and partitions exterior. This can be done because of footnote D in Table 1 below. Table 1 will be referenced in the next sections: Exterior Walls, Interior Walls, Floor Construction, Roof Construction, and Shaft Enclosures.

Table 1: IBC Table 601

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls Exterior[e, f] Interior	3 3[a]	2 2[a]	1 1	0 0	2 1	2 0	2 1/HT	1 1	0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	$1^1/_2$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

c. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.

d. Not less than the fire-resistance rating required by other sections of this code.

e. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

f. Not less than the fire-resistance rating as referenced in Section 704.10.

Exterior Walls

IBC Table 601 and 602

As stated earlier, the exterior walls of the building are required to have been constructed with a one-hour fire resistance rating as well as all supporting elements of the walls. The exterior walls must be rated for a fire from the inside if the exterior wall has a separation distance of greater than 10 feet. If the separation distance is 10 feet or less, then the exterior wall must be rated from both sides. The fire walls showing fire separation can be seen in Appendix C. The exterior bearing walls are determined using IBC Table 601 and 602. Whichever of the two tables requires a higher fire resistance rating, will dictate the minimum required fire resistance rating for the exterior bearing walls of the building. This building will use Table 601 and the exterior bearing walls will be required to have a one-hour fire rating. The outermost walls are the exterior nonbearing walls. They do not support the any part of the building except for their own weight. The minimum required fire resistance ratings are based of IBC Table 601 for the fire separation distance of the building.

Interior Walls

Table 601

The interior bearing walls are the inner walls of the Construction Innovation Center that support any structural load. The interior nonbearing walls and partitions are the walls inside the building that only support their own weight. They need to comply with the construction Type IIA fire resistance ratings. Walls that are servicing separate mixed occupancies or corridor walls may be required to be fire rated. All the interior walls of the Construction Innovation Center meet the requirements set for by the IBC.

Floor Construction

The Construction Innovation Center's floor construction is not required to have a fire resistance rating or its secondary members because of IBC Table 601 footnote D. The floor is made up of a three-inch concrete slab over a steel deck. This deck serves as a fire barrier from vertical passage to each floor.

Roof Construction

IBC 714.4.2

The Construction Innovation Center's roof is not required to have a fire resistance rating or its secondary members because of IBC Table 601 footnote D.

Shaft Enclosures

IBC 713.2

The shaft enclosures in the Construction Innovation Center have a fire resistance rating of two hours for the shafts connecting over four stories and a one-hour fire resistance rating for the shafts connecting three or less stories. The material in the shaft enclosures must comply with the material permitted by a Type IIA Construction. The shaft enclosures must have integrity. This integrity is ensured by having self-closing or automatic doors that are activated by smoke detection. I have shown the fire resistance ratings of the shafts in Appendix C.

Fire Rated Corridors and Stairways

LSC Sections 7.2.2.5.1 and 7.1.3.2

I have identified the fire resistance ratings for corridors, stairways, and the building. The Construction Innovation Center meets the fire resistance ratings as stated in the "General Construction Summary". The Construction has 1-hour fire resistance rating for all exterior walls of the building. Also, the stairways have 2-hour resistance ratings for the wall that is connected to the inside of the building. I have illustrated 1-hour fire rated walls, and 2-hour fire resistance rated walls, on the floor plans in Appendix C. Figure 5 shows a typical Fire Rated Stairway.

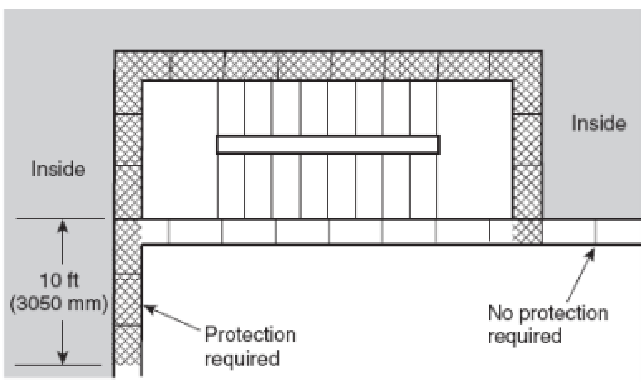


Figure A.7.2.2.5.2(c) Stairway with Nonrated Exterior Wall Exposed by Adjacent Exterior Wall of Building.

Figure 5: Fire Rated Stairway

Fire Separation Table

IBC Table 602

Table 2 shows the required minimum fire resistance rating of each exterior wall, in each story of the building, and must be determined separately. The Construction Innovation Center is under the group B occupancy and falls under the one-hour exterior requirements for separation distances. These distances are measured from the exterior wall of the building to the closest lot line, centerline of a street, an ally or public way, or to the imaginary line between two buildings on the property. The distance between Buildings B and C is less than 5 feet. The distance B and A is between 10 and 30 feet. Buildings B and C have a separation distance between 8 feet to The Simpson Strong Tie Demonstration Lab. The separation distances and fire ratings for The Construction Innovation Center are in compliance with Table 602 from the IBC below.

Table 2: IBC Table 602

TABLE 602
FIRE-RESISTANCE RATING REQUIREMENTS FOR EXTERIOR WALLS BASED ON FIRE SEPARATION DISTANCE[a, d, g]

FIRE SEPARATION DISTANCE = X (feet)	TYPE OF CONSTRUCTION	OCCUPANCY GROUP H[e]	OCCUPANCY GROUP F-1, M, S-1[f]	OCCUPANCY GROUP A, B, E, F-2, I, R, S-2, U
$X < 5^b$	All	3	2	1
$5 \le X < 10$	IA Others	3 2	2 1	1 1
$10 \le X < 30$	IA, IB IIB, VB Others	2 1 1	1 0 1	1[c] 0 1[c]
$X \ge 30$	All	0	0	0

For SI: 1 foot = 304.8 mm.

a. Load-bearing exterior walls shall also comply with the fire-resistance rating requirements of Table 601.

b. See Section 706.1.1 for party walls.

c. Open parking garages complying with Section 406 shall not be required to have a fire-resistance rating.

d. The fire-resistance rating of an exterior wall is determined based upon the fire separation distance of the exterior wall and the story in which the wall is located.

e. For special requirements for Group H occupancies, see Section 415.6.

f. For special requirements for Group S aircraft hangars, see Section 412.4.1.

g. Where Table 705.8 permits nonbearing exterior walls with unlimited area of unprotected openings, the required fire-resistance rating for the exterior walls is 0 hours.

Interior Finish Requirements

CBC 10.2.3.4*

The Construction Innovation Center is assembly type occupancy with an occupant load of over 300. The interior finish requirements for this classification is Type A for exits, Type A or B for exit access corridors, and Type A or B other spaces as shown in Table 3. Class A has a flame spread index of 0-25 and Class B has a flame spread index of 26-75. Interior finish is defined as the exposed surfaces of walls, ceilings, and floors within buildings.

Table 3: CBC Table A.10.2.2

Table A.10.2.2 Interior Finish Classification Limitations

Occupancy	Exits	Exit Access Corridors	Other Spaces
Assembly — New			
>300 occupant load	A	A or B	A or B
	I or II	I or II	NA
≤300 occupant load	A	A or B	A, B, or C
	I or II	I or II	NA
Assembly — Existing			
>300 occupant load	A	A or B	A or B
≤300 occupant load	A	A or B	A, B, or C
Educational — New	A	A or B	A or B; C on low partitions†
	I or II	I or II	NA
Educational — Existing	A	A or B	A, B, or C
Day-Care Centers — New	A	A	A or B
	I or II	I or II	NA

Structural Fire Protection Summary

The Construction Innovation Center is three separate buildings that can be classified as one building. This can be done by checking that the building complies with frontage and automatic sprinkler system protection increase set for by the IBC table 503. The structural fire protection of The Construction Innovation Center meets the requirements set forth by the IBC and CBC. The building elements of The Construction Innovation Center substitute 1-hour fire ratings for the fully automatic sprinkler suppression system as per footnote D in Table 601 from IBC. Except for the nonbearing walls and partitions exterior which are still 1-hour fire rated. The separation distances and fire ratings for The Construction Innovation Center are also in compliance with Table 602 from the IBC. This will complete the structural analysis of the Construction Innovation Center. The next section will review the Buildings egress analysis.

Egress Analysis Overview

The Egress Analysis of the report will review the total occupant load of the Construction Innovation Center, the egress capacity, the number of exits, the arrangements of exits, the common path, dead ends, travel distances, fire rated doors, exit signage, the fire rated corridors, and stairways.

Total Occupant Load

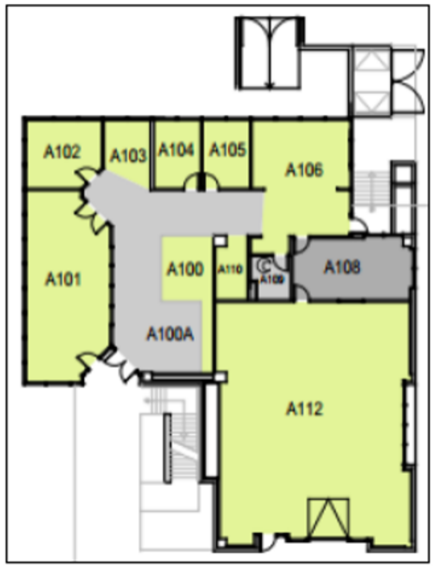
IBC 1004.1.2, 1004.4, 1004.2

For the Construction Innovation Center, I identified and calculated the occupant load for each room, space, and floor. The total occupant load for the construction innovation center is 996 occupants. Table 4 shows occupant loads for Buildings A, B, and C. A complete version of the occupant's load floor by floor and building by building is shown in Appendix B. I also have shown in Table 5, the occupant loads of floor one Building A. For the waiting areas and conference rooms an occupant load factor of 15 ft^2 /person was used. For the lecture halls an occupant load factor of 20 ft^2/person was used. For the Laboratories, an occupant load factor of 50 ft^2/person was used. For the offices, an occupant load factor of 100 ft^2/person was used.

Table 4: Total Occupant Load

	Building A Total	Building B Total	Building C Total	Total
Floor 1	100	124	148	372
Floor 2	59	125	143	327
Floor 3	22	130	145	297
Total				996

Table 5: Occupant Load of Building A Floor 1



Room	Area (ft^2)	Occupant Load Factor	Occupant Load
A 100 Reception	116	100	1
A 100A Waiting Area	165	15	11
A 101 Conference Room	610	15	41
A 102 DCP Office	200	100	2
A 103 Office	110	100	2
A 104 Office	110	100	2
A 105 Office	110	100	2
A 108 Privately Funded Fac	300	100	3
A 112 Heavy/Civil Lab	1800	50	36
Total			100

Egress Capacity

LSC 7.3.1.1.1

The total capacity of the means of egress for any story, balcony, tier, or other occupied space shall be sufficient for the occupancy load thereof. The Egress capacity needs to be greater than the occupant load. Each room is equipped with at least a 36" nominal width floor. This nominal width is sufficient to evacuate every room in the building. The main exit doors of Building A are 72" nominal width. This width is also sufficient to evacuate the building in case of an emergency. The construction Innovation Center is also equipped with 3 sets of stairways with a nominal width of 66". These stairways are available to evacuate 540 occupants in case of an emergency. I have shown the location of the exits and exit signage of Floor One of Buildings A, B, and C below in Figure 6. Floors 2 and 3 can be found in Appendix D. I have also shown the egress calculation capacities below in Tables 6 and 7. These tables confirm that the doorways and stairways can efficiently evacuate the occupants of The Construction Innovation Center in an emergency.

Table 6: All Door Widths and Exit Capacity

	Nominal Width	Effective Width	Equation	Occupants
Double Doors in Building A	72"	60"	(60/.2)	300
Building A, B, and C Room Doors	36"	24"	(24/.2)	120

Table 7: All Stairways and Exit Capacity

	Nominal Width	Effective Width	Equation	Occupants
North Stairway	66"	54"	(54/.3)	180
West Stairway	66"	54"	(54/.3)	180
East Stairway	66"	54"	(54/.3)	180

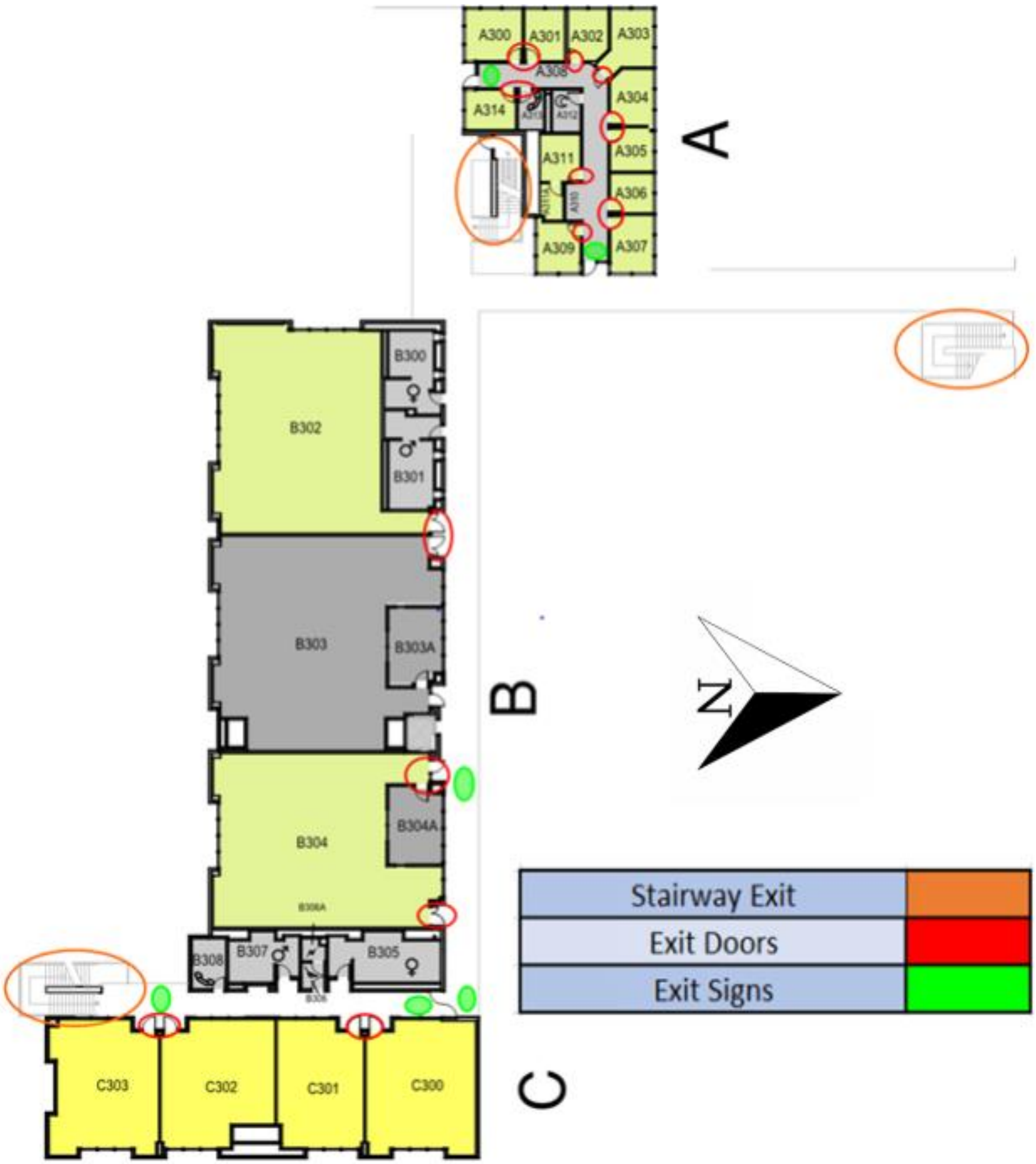


Figure 6: Location of Exits and Exit Signage of Floor one

Number of Exits

LSC Section 7.4.1.2

The next task was to verify that the number of exits was adequate for each room and the overall floor. If a room has fewer than 50 people, it is only required to have 1 exit. Every room on every floor of the Construction Innovation Center has less an occupant load of less than 50. Every room on every floor has at least 1 exit with some having 2. Also, for the overall floor it is required to only have two exits because of an overall occupant load of less than 500 people. Every floor meets this requirement. The Construction Innovation Center has 4 exterior exits on each floor. I have shown the location of the exits and exit signage in Appendix D.

The number of means of egress from any story or portion thereof… shall be as follows:

(1) Occupant load more than 500 but not more than 1,000 – not less than 3
(2) Occupant load more than 1,000 – not less than 4

Arrangement of Exits

LSC Section 7.5.1.1.1, 7.5.1.3.2

All the arrangements are correct for the Construction Innovation Center. The exits shall be located at a distance from one another not less than one-half the length of the maximum overall diagonal dimension of the building or area to be served. This distance is to be measured in a straight line between the nearest edge of the exit, exit accesses, or exit discharges. All exits in each room must be half the distance of the diagonal length of the room if the room has multiple exits. I have shown the location of the exits and exit signage in Appendix D. Appendix D also shows a layout of the buildings floor plan where you can see that the exit arrangement meets the code.

1. Exits shall be arranged to provide access for each occupant to not less than two exits by separate ways of travel.
2. Each room needs two ways of travel to an exit staircase.

Exits and Stairways and Signage

LSC Section 7.10.1.5, 7.10.5.1, 7.10.1.5.2*

The Construction Innovation Center meets the requirements of location for its exit signs. They were placed at the end of hallways above doors or stairs that lead to an exit. Access to exits shall be marked by approved, readily visible signs in all cases where the exit or way to reach the exit is not readily apparent to the occupants. New Sign Placement shall be such that no point an exit access corridor is in excess of the rated viewing distance or 100 ft, whichever is less, from the nearest sign. I have showing the exits, exit strairwats, and signage in Appendix D.

Common Path Limit, Dead-End Limit, and Travel Distance

LSC Table A7.6

Table 8 shows the common path, dead-end, and travel distance limits for new and existing assemblies. The assembly travel distance for a newly constructed sprinklered building is 250 ft. No room is more than 250 ft away from an exit in The Construction Innovation Center. The common path allowed is 20/75 ft for a newly constructed fully sprinklered building. For a common path serving less than or equal to 50 persons use 75 ft. Occupants in the Construction Innovation Center do not walk a common path of more than 75 ft for an exit. This is because the Construction Innovation Center is equipped with a pair of horizontal exits on the 2nd and third floor. The dead-end limit for a business building that is sprinklered is 50 ft. The Construction Innovation Center does not have any dead ends in the building.

Table 8: LSC Table A.76

Table A.7.6 Common Path, Dead-End, and Travel Distance Limits (by occupancy)

	Common Path Limit				Dead-End Limit				Travel Distance Limit			
	Unsprinklered		Sprinklered		Unsprinklered		Sprinklered		Unsprinklered		Sprinklered	
Type of Occupancy	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
Assembly												
New	20/75	6.1/23[a]	20/75	6.1/23[a]	20	6.1[b]	20	6.1[b]	200	61[c]	250	76[c]
Existing	20/75	6.1/23[a]	20/75	6.1/23[a]	20	6.1[b]	20	6.1[b]	200	61[c]	250	76[c]

Horizontal Exit - Fire Rated Doors

CBC 716.5.9

The Construction Innovation Center has a set of fire rated doors. These doors also have safety releasing hardware in case the fire alarm starts. The doors are held open magnetically. When the alarm sounds, the magnets will release the doors and let them become a barrier. The exits are sealing doorways from Buildings B to C. These doors are made of aluminum and have 90-minute fire ratings. Figure 7 shows the locations of the two doors on Floors 2 and 3 that comply with the Life Safety Code. Each door swings opposite ways. One door opens towards Building B and one door opens towards Building C. There are also exit signs of both sides of the door. This indicates these doors are horizontal exits. A horizontal exit may be an element of egress. A horizontal exit provides a path of egress travel from one building to an area in another building on approximately the same level. This affords safety from fire and smoke from the area of incidence and area communicating there with.

Figure 7: Fire Rated Doors Floors 2 and 3 of Buildings B and C

Egress Analysis Summary

A complete egress analysis for The Construction Innovation Center has shown that the exit capacities, the exit locations, and the arrangement of exits are adequate for the occupants of the building. The Construction Innovation Center has no issues with common path of travel, dead end limits, or travel distances for its occupants. The Construction Innovation Center is also equipped with a pair of fire rated doors Between Buildings B and C on Floors 2 and 3 that comply with the Life Safety Code. This will complete the egress analysis for the Construction Innovation Center. The next section will review the Buildings fire alarm systems and signals.

Fire Alarm Systems and Signals Overview

The Construction Innovation Center is equipped with a fire alarm system to alert occupants in case of an emergency. Some components of the fire alarm system are the fire alarm control panel, manual pull stations, heat detectors, multi sensor detectors, photoelectric duct detectors, horns, strobes, and horn strobe combinations. These can be separated into initiating devices and notification devices. These devices need to be inspected and maintained.

Fire Alarm Systems and Signals

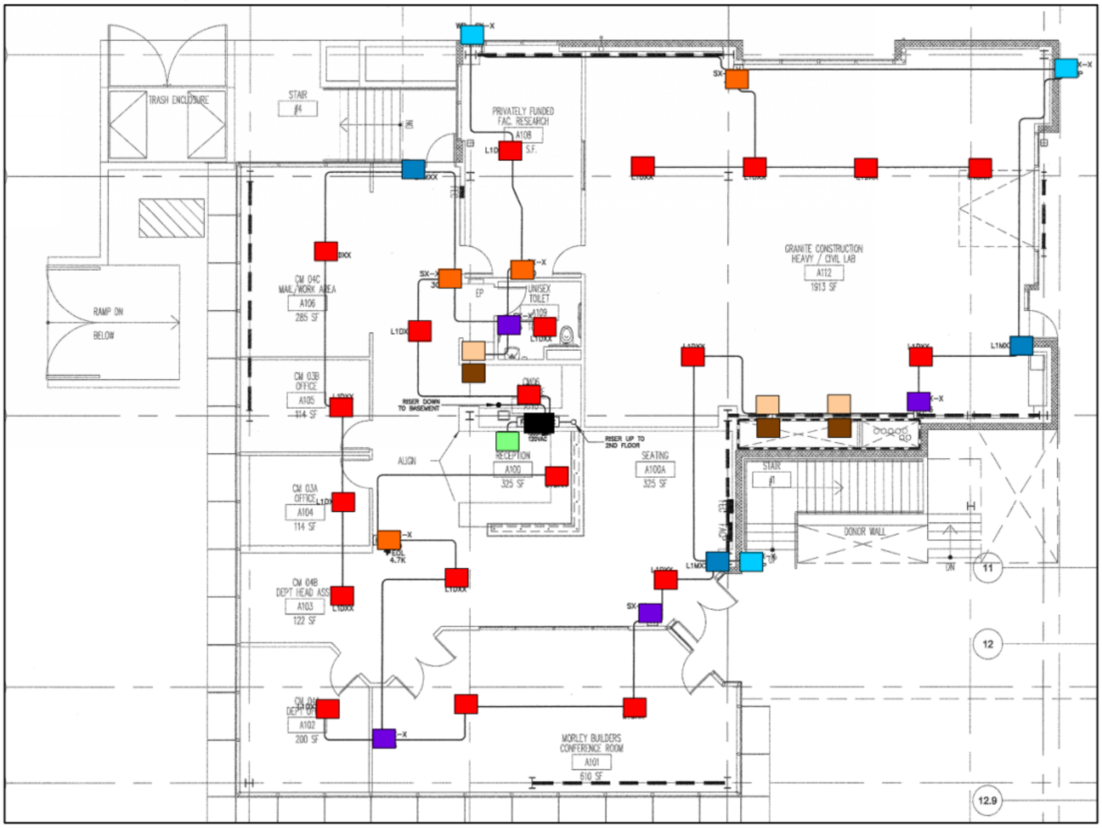
The Construction Innovation Center is not equipped with a mass notification system. It is equipped with a standard notification system. The system helps indicate the existence of an emergency to occupants of the facility. The system in the Construction Innovation is Equipped with the components that are listed in Table 9.

Table 9: Devices in the Construction Innovation Center

Device	Part Number	Mounting	Manufacturer	CSFM Number	Size W*H*D
Addressable Heat Detector	FST-851	Flush	Notifier	7272-0028:196	4" Sq. Deep
Addressable Photoelectric Duct Detector	FSD-751RP	N/A	Notifier	3240-0028:205	N/A
Addressable Fire Alarm Control Panel	NFS-640	Surface	Notifier	7165-0028:214	24" 4.575" 5.218"
Addressable Fire Alarm Box	NBG-12LX	Flush	Notifier	7150-0028:199	4" Sq. Deep
Multi Candela Horn Strobe	GEC3	Flush	Gentex	7135-0569:122	4" Sq. Deep
Multi Candela Strobe	GES3-24WR	Flush	Gentex	7125-0569:123	4" Sq. Deep
Multi Sensor Detector	FAPT-851	Flush	Notifier	7272-0028:206	4"SQ. Deep
Annunciator	LCD - 80	Surface	Notifier	7120-0028:156	4.5" x 8.5" x 2"
Remote Power Supply	FCPS-24FS6	Surface	Notifier	7315-0028:225	14.5" x 15" x 7.2"
Horn	GEH24_R	Flush	Gentex	7135-0569:122	4" Sq. Deep

The Construction Innovation Center has alarm signals, trouble signals, and supervisory signals. Alarm signals are an indication of an emergency that requires immediate action such as a fire. Trouble signals are associated with the electronic portions of the fire protection system. These are used to indicate that there is a change in the normal status of the devices, such as when the smoke detector beeps if the battery is low on a battery-operated device. Supervisory Signal happens when there is a change in the normal characteristics or status of an initiating device. I have marked where the devices are in Floor 1 of Building A in Figure 8. The location of the devices and the number of devices will be reviewed in their respective sections. Also, in Appendix E are the device locations of Floors 1-3 of Buildings A, B, and C.

Floor 1 Building A



Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

Figure 8: Location of Fire Alarm Devices in Building A First Floor

Sequence of Operations Matrix

NFPA 72, A.14.6.2.4

One method used to define the required sequence of operations and to document the actual sequence of operations is an input/output matrix. The Sequence of Operations Matrix in Table 10 is the matrix from the fire alarm plans of the Construction Innovation Center. Information from the matrix can be useful to an engineer to show how a building should operate in an emergency. Also, the matrix can be used for investigation purposes if the buildings alarms did not perform properly during the emergency. An investigator would be able to go back and see what actions did not operate correctly.

Table 10: Sequence of Operations Matrix

SEQUENCE OF OPERATIONS MATRIX

ACTION \ DEVICE	MANUAL PULL STATION	AREA SMOKE/ HEAT DETECTOR	DUCT SMOKE DETECTOR	ELEVATOR LOBBY DETECTOR	ELEVATOR SHAFT AND MACHINE ROOM SMOKE DETECTOR	SPRINKLER WATER FLOW SWITCH	SPRINKLER VALVE TAMPER SWITCH	SPECIAL EXTINGUISHING SYSTEMS	GENERATOR POWER FAILURE	ELEVATOR SHAFT AND MACHINE ROOM HEAT DETECTOR	CORRIDOR SMOKE DETECTOR
ANNUNCIATE AT FIRE CONTROL PANEL	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
ANNUNCIATE AT 24 HOURS ATTENDED REMOTE LOCATION	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
ACTIVATE AUDIBLE ALARM SIGNAL THROUGHOUT BUILDING	YES	YES	YES	YES	NO	YES	NO	YES	NO	NO	YES
SHUT DOWN ALL AIR HANDLING EQUIPMENT/CLOSE FSD	NO	NO	YES	NO	NO	NO	NO	NO	NO	NO	YES
ELEVATOR SHUTDOWN	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO
RECALL ELEVATORS SERVING FIRE FLOOR	NO	NO	NO	YES	YES	NO	NO	NO	NO	NO	NO

Fire Alarm Control Panel

NFPA 72 10.14.7

The FACP is mounted on the surface of the wall and is a Notifier NFS-640 unit for the Construction Innovation Center. The FACP that is installed can be seen in Figure 9. The FACP is the controlling unit of the fire alarm system. It receives information from fire detection sensors. Some information it receives can be the integrity of the equipment and fire information. There is a fire alarm located in the same room as the FACP. This alarm will notify occupants as well as transfer a signal to an of site location before the fire can impair the control panel. The Fire Alarm Control Panel is located on the First Floor of Building A in room A100 and the First Floor of Building B in room B110. I have marked where the device is installed in Appendix E.

Figure 9: Fire Alarm Control Panel

Initiating Devices

Manual Pull Stations

NFPA 72.17.14, 72-17.14.8.5*

Manual fire alarm boxes are used for initiating alarms. This signal is indicative of a fire. There are rules that the manual pull stations need to comply. The manual pull stations must be painted red. The pull stations must be securely mounted. The pull stations must be installed so that they are conspicuous, unobstructed, and accessible. Manual Fire alarm boxes shall be located within 5 ft. of each exit doorway on each floor. The maximum distance between manual pull stations is 200 ft. The manual pull stations in The Construction Innovation Center meet these requirements set by NFPA 72. An example of the manual pull stations that are installed in the Building can be seen in Figure 10. I have marked where the devices are installed in Appendix E.

Figure 10: Manual Pull Station

Heat Detectors

NFPA 72 Table 17.6.2.1, 17.6.3.1.1, 17.6.3.1.3.1

Heat Detectors are used in the Construction Innovation Center in some laboratory rooms instead of some smoke detectors. The heat detectors for this building are under an ordinary temperature classification and have a temperature rating range of 135-174 degrees Fahrenheit and are uncolored. The spacing for the heat detectors shall not exceed their listed spacing, and there shall be detectors within one-half the listed spacing, measured at right angles from all walls or partitions extending upward to within the top 15 percent of the ceiling height. All points on the ceiling shall have a detector within a distance equal to or less than 0.7 times the listed spacing. Also, the heat detectors must be located on the ceiling more than 4 inches from the sidewalls or on the sidewalls with 4 and 12 inches from the ceiling. The heat detectors in The Construction Innovation Center are installed properly and in the correct locations. An example of the heat detectors that are installed in the Building can be seen in Figure 11. I have marked where the devices are installed in Appendix E.

Figure 11: Heat Detector

Multi Sensor Detector

NFPA 72-17.9.4.2

Multi-Sensor Detectors can detect multiple conditions and sense a wider range of fire with greater accuracy. Multi-Sensor Detectors help reduce unwanted alarms and improve detector response to a nonspecific fire source, location and spacing criteria included with the detector installation instructions shall be followed. These detectors can detect for both fire detection and carbon monoxide in a single device. These detectors are installed in rooms that are generally occupied by occupants. An example of the multi sensor detector that are installed in the Building can be seen in Figure 12. I have marked where the devices are installed in Appendix E.

Figure 12: Multi Sensor Detector

Smoke Control

Photoelectric Duct Detector and Smoke Damper

NFPA 17.7.4.2, 17.7.4.3*, 17.7.5.5

The Construction Innovation Center is equipped with addressable photoelectric duct detectors. These are installed in inside the air duct system of HVAC systems and detect smoke if it enters the system. The duct smoke detectors are connected to the fire alarm control panel. Once smoke is detected the photoelectric duct detectors activate the smoke dampers inside the HVAC system. The smoke dampers will close and stop the smoke from circulating around the building. Also, once smoke is detected the HVAC system will turn off. This will also help stop smoke from spreading throughout the building. These detectors should not be used as substitutes for open area smoke detectors. I have marked where the devices are installed in Appendix E.

Figure 13: Photoelectric Duct Detector and Smoke Damper

Annunciating Devices / Audible and Visual Notification

Annunciator

NFPA 72 3.3.21

The Construction Innovation Center is equipped with annunciators throughout the facility. An annunciator is a unit containing one or more indicator lamps, alphanumeric displays, or other equivalent means in which each indication provides status information about a circuit, condition or location. The purpose of the annunciator is to help personnel determine the status of emergency equipment that might affect safety of occupants. The authority having jurisdiction determines the type and location of the annunciators in the facility.

Annunciators are equipped with 80- character backlist liquid crystal display. It has a time and date display field. It can be located up to 3,200 meters from the control panel. It is available with flush or surface mount options. An example of the annunciators that are installed in the Building can be seen in Figure 14. I have marked where the devices are installed in Appendix E.

Figure 14: Annunciator

CAL POLY
SAN LUIS OBISPO

Horn

NFPA 72 18.2, 18.4.8.1-2

Horns are used to notify occupants during an emergency. Notification appliances shall provide stimuli for initiating emergency action and provide information to users, emergency response personnel, occupants. Throughout NFPA 72, Chapter 18.4 it lays out the general requirements for horn alarms. To ensure that audible public signals are clearly heard they shall have a sound level at least 15 dB above the average ambient sound level or 5 dB above the maximum sound level of at least 60 seconds, whichever is greater, measured 5 ft. above the floor in the area required to be served by the system. The horns in The Construction Innovation Center meet the code requirements set by NFPA 72 and are installed properly. An example of the horns that are installed in the Building can be seen in Figure 15. I have marked where the devices are installed in Appendix E.

Figure 15: Horn

Strobe

NFPA 72 18.4.1.1*, 18.5.5, 18.5.5.5.1-8

A strobe is a visible notification system. An average ambient sound level greater than 105 dB shall require the use of a visible notification appliances. I have marked where the devices are installed in Appendix E. Visual notification appliances are spaced differently depending if they are ceiling mounted or wall mounted. I have provided the tables for wall-mounted and ceiling-mounted appliances. Table 11 shows the room spacing for wall mounted and ceiling mounted visible appliances.

Table 11: Room Spacing for Wall-Mounted and Ceiling Mounted Visible Appliances

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

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

Table 18.5.5.4.1(b) Room Spacing for Ceiling-Mounted Visible Appliances

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

Corridors have their own spacing for visual notification systems. Visual notification systems need to be installed in corridors 20 ft. or less. In corridors, visible appliances shall be rated not less than 15 cd. Visible notification appliances shall be located not more than 15 ft. from the end of the corridor with a separation not greater than 100 ft. between appliances. In corridors where more than two visible notification appliances are in any field of view, they shall flash in synchronization. The strobes in The Construction Innovation Center meet the requirements set by NFPA 72 and are installed properly. An example of the strobes that are installed in the Building can be seen in Figure 16. I have marked where the devices are installed in Appendix E.

Figure 16: Strobe

Horn and Strobe Combination

NFPA-72 18

Visible and audio notification combinations systems are used in the Construction Innovation Center. These devices can be more economical in design because they use strobes and horns as one system instead of two. The design characteristics still apply for the combination system. The horn/strobes in The Construction Innovation Center meet the requirements set by NFPA 72 and are installed properly. An example of the horn strobes that are installed in the Building can be seen in Figure 17. I have marked where the devices are installed in Appendix E.

Figure 17: Horn Strobe Combination

Remote Power Supply

NFPA 72, 10.6.8.1*, 10.6.8.2, 10.6.8.3, 10.6.8.4

The Construction Innovation Center is equipped with a remote power supply station. The remote power supply complies with NFPA 72. The location of remotely located power supply shall be identified at the master control unit. The master control unit display shall be permitted to satisfy the requirements set forth by NFPA 72. The location of the remotely located power supplies shall be identified on the record drawings. The fire alarm plans show the calculations to determine the appropriate battery sizes for The Construction Innovation Center. The battery calculations can be found in Appendix H. The voltage drop calculations are shown in Appendix G. The calculations prove that there isn't more than a 10 percent voltage drop throughout the building. These calculations show that the batteries used in The Construction Innovation Center have sufficient spare capacity, and have low enough voltage drops to meet the requirements of NFPA 72. An example of the remote power supply that is installed in the Building can be seen in Figure 18. I have marked where the devices are installed in Appendix E.

Figure 18: Remote Power Supply

Inspections Testing and Maintenance for Fire Alarm Equipment

NFPA 72-14.2.1.1*, 14.2.5, 7.8.2, 7.2.1*

The Construction Innovation Center must follow the requirements for inspection, testing, and maintenance of its fire alarm equipment. The purpose for initial and reacceptance inspections is to ensure compliance with approved design documents and to ensure installation in accordance with this code and other required installation standards. Prior to system maintenance or testing, the record of completion and any information required by Chapter 7 of NFPA 72 regarding the system and system alterations, including specifications, wiring diagrams, and floor plans, shall be provided by the owner or a designated representative to the service of personnel upon request. A supplementary record of Inspection and Testing form must be completed for all systems inspection and testing. Where documentation is required by the authority having jurisdiction the following list shall represent the minimum documentation required for a new fire alarm system, supervising station and shared communication equipment, and emergency communication systems, including new systems and additions or alterations. The inspection and maintenance requirements for The Construction Innovation Center can be found in Table 12. The Fire Alarm equipment testing table can be found in Table 13. The fire alarm inspection requirements can be found in Table 14.

Table 12: Inspection and Maintenance Requirements

(1)*Written narrative providing intent and system description
(2) Riser diagram
(3) Floor plan layout showing locations of all devices, control equipment, and supervising station and shared communications equipment with each sheet showing the following:
  (a) Point of compass (north arrow)
  (b) A graphic representation of the scale used
  (c) Room use identification
  (d) Building features that will affect the placement of initiating devices and notification appliances
(4) Sequence of operation in either an input/output matrix or narrative form
(5) Equipment technical data sheets
(6) Manufacturers' published instructions, including operation and maintenance instructions
(7) Battery capacity and de-rating calculations (where batteries are provided)
(8) Voltage drop calculations for notification appliance circuits
(9) Mounting height elevation for wall-mounted devices and appliances
(10) Where occupant notification is required, minimum sound pressure levels that must be produced by the audible notification appliances in applicable covered areas
(11) Pathway diagrams between the control unit and the supervising station and shared communications equipment
(12) Completed record of completion in accordance with 7.5.6 and 7.8.2
(13) For software-based systems, a copy of site-specific software, including specific instructions on how to obtain the means of system and software access (password)
(14) Record (as-built) drawings
(15) Records, record retention, and record maintenance in accordance with Section 7.7
(16) Completed record of inspection and testing in accordance with 7.6.6 and 7.8.2

Table 13: Fire Alarm Equipment Testing Table

Component	Testing Time frame
Visible Notification	N/A
Audible Notification	N/A
Remote Annunciators	Annual
Heat Detectors	Annual
Manual Fire Alarm Boxes	Annual
Photoelectric Duct Detector	Annual
Smoke Detectors	Annual
Multi-Sensor Detectors	Annual
Fuses	Annual
Functions	Annual
Fire Alarm Control Equipment Fuses	Annual
Fire Alarm Control Equipment lamps and LEDS	Annual
Fire Alarm Control Equipment Interface equipment	Annual
Fire Alarm Control Equipment Primary Power Supply	Annual
Fire Alarm Control Equipment Secondary Power Supply	Annual

Table 14: Fire Alarm Inspection Table

Component	Testing Time frame
Visible Notification	Semi Annual
Audible Notification	Semi Annual
Remote Annunciators	Semi Annual
Heat Detectors	Semi Annual
Manual Fire Alarm Boxes	Semi Annual
Waterflow Devices	Quarterly
Smoke Detectors	Annual
Multi-Sensor Detectors	Semi Annual
Fuses	Annual
Functions	Annual
Fire Alarm Control Equipment Fuses	Annual
Fire Alarm Control Equipment lamps and LEDS	Annual
Fire Alarm Control Equipment Interface equipment	Annual
Fire Alarm Control Equipment Primary Power Supply	Annual
Fire Alarm Control Equipment Secondary Trouble Signals	Semi Annual
Battery Lead Acid	Monthly

Fire Alarm and Systems Summary

The Construction Innovation Center is equipped with initiating and notification devices. These devices meet the requirements set by NFPA 72. The Construction innovation is also equipped with smoke control dampers and photoelectric smoke detectors that work together to help stop smoke from circulating around the building. All the devices cooperate with the sequence of operations in emergency situations. The Construction Innovation Center is equipped with remote power supply station. The battery and voltage drop calculations show that the batteries used in The Construction Innovation Center have sufficient spare capacity, and have low enough voltage drops to meet the requirements of NFPA 72. The fire alarm and systems for The Construction Innovation Center meet all the requirements set in NFPA 72. The Construction Innovation Center is equipped with a fire alarm system to alert occupants in case of an emergency. Some components of the fire alarm system are the fire alarm control panel, manual pull stations, heat detectors, multi sensor detectors, photoelectric duct detectors, horns, strobes, and horn strobe combinations. These can be separated into initiating devices and notification devices. These devices need to be inspected and maintained. This will complete the Buildings fire alarm and systems analysis. The next section will review the Buildings water-based fire suppression systems.

Water-Based Fire Suppression System Overview

The Construction Innovation Center is equipped with a quick response wet pipe sprinkler system. A wet pipe sprinkler system always has water maintained in the piping of the system. The Construction Innovation Center can be split up into Ordinary Hazard Group 1 and Light Hazard Occupancies. The building has two risers one located in the basement of Building A and one in the first floor of building B.

Suppression System Type

NFPA 13, 12.4*, 12.4.1, 12.4.2*

The Construction Innovation Center is equipped with a quick response wet pipe sprinkler system. A wet pipe system is one of the most common fire suppression systems. A wet pipe system is when water is constantly maintained inside the sprinkler piping. When a sprinkler is activated the water immediately discharges from the sprinkler head. A wet sprinkler system cannot be used in sub-freezing environments due to the pipes being filled with water. If the water freezes it could damage the system. Wet pipe systems have some advantages such as low installation costs, maintenance expenses, and can be easily modified. The Construction Innovation Center suppression system is in accordance with NFPA 13. Figure 19 is an overview of the basic components of a Wet Pipe Sprinkler System.

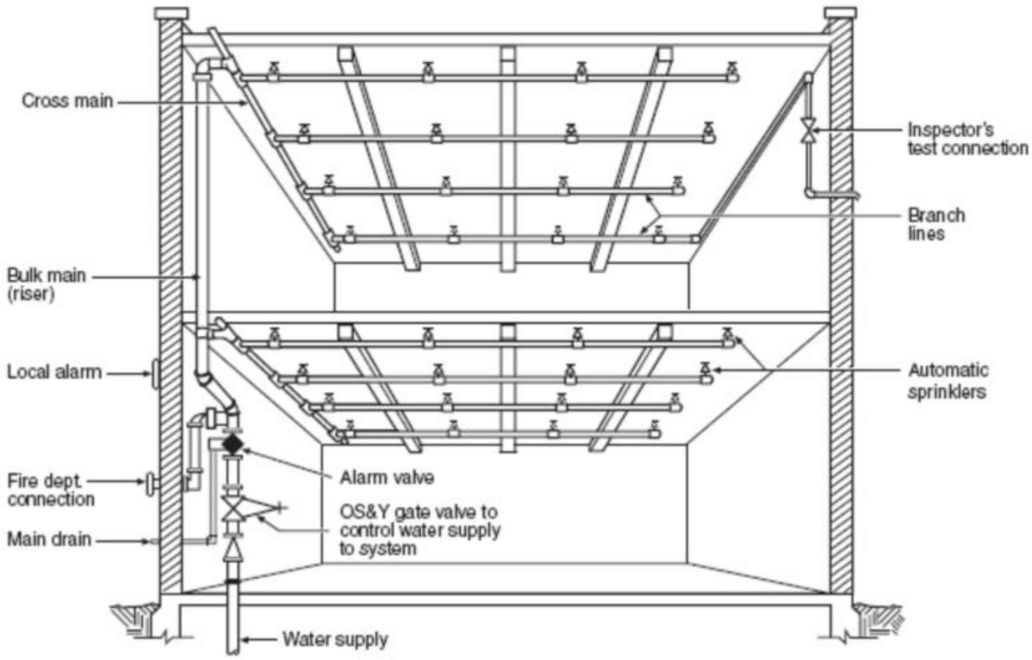


Figure 19: Basic Components of a Wet Pipe Sprinkler System

Hydraulic Supply of the System

NFPA 13 3.8.1.9.2, NFPA 12 3.8.1.9.1

The Construction Innovation Center is split up into 3 buildings but they all have the same static pressure, residual pressure, and flow. Static Pressure is the pressure that exists at a given point under normal distribution systems conditions. Residual pressure is the pressure that exists in the distribution system, measured at the residual hydrant at the time the flow readings are taken at the flow hydrant. Flow is in units of gallons per minute. This data was obtained on 09/03/02 at Hydrant 1-06-05 #37. Table 15 shows the static pressure and the residual pressure data that was obtained.

Table 15: Pressure and Flow Table

	Building A	Building B & C
Static Pressure	90 PSI	90 PSI
Residual Pressure	82 PSI	82 PSI
Flow	1138 GPM	1138 GPM

Occupancy Classification

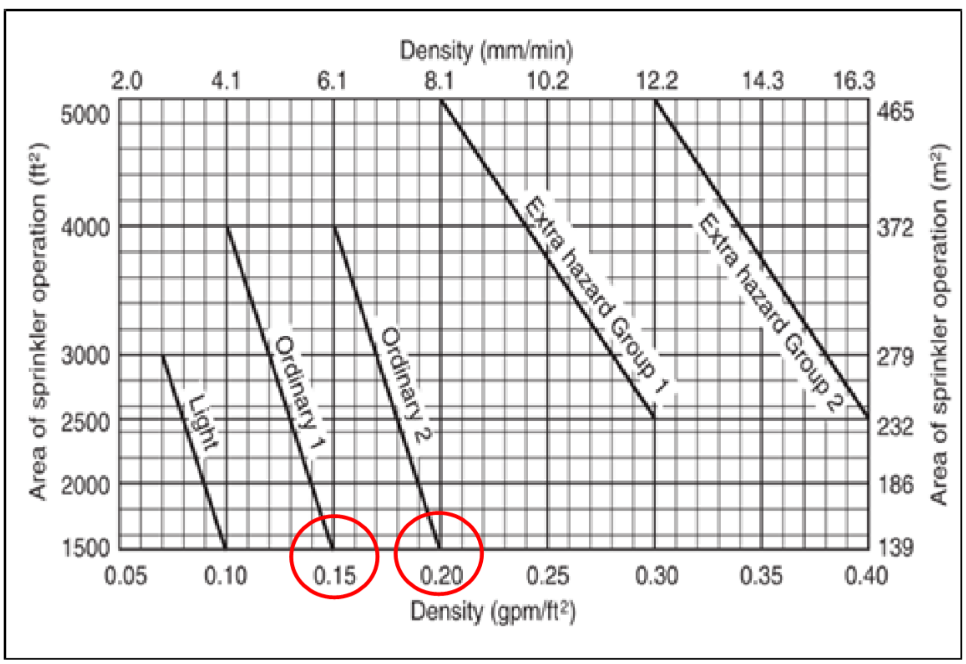
NFPA 13 Figure 11.2.3.1.1, Table 11.2.3.1.2

There are 6 occupancy classifications. Light hazard, Ordinary Hazard Group 1, ordinary hazard Group 2, Extra Hazard Group 1, and Extra Hazard Group 2. The Construction Innovation Center can be separated into two occupancy classifications: Light hazard occupancy for office rooms and general areas, also, Ordinary Hazard Group 1 for storage, service, and laboratory rooms. Light Hazard occupancies are areas where the combustibility of contents is low and have fires with lower rated of expected heat release. Ordinary Hazard Group 1 are areas with moderate combustibility, where items are stockpiled do not exceed 8 feet and moderate rates of heat release are expected. Using these occupancy classifications, you can set the sprinkler design criteria. Table 16 shows the densities for the occupancies and the combined hose stream allowance for the coverage area. These numbers can be found in Tables 17 and 18.

Table 16: Most Remote Location from Riser

Occupancy	Density (GPM/ft^2)	Combined Hose (GPM)	Coverage Area (ft^2)
Ordinary Hazard Group 1	0.15	250	1500
Light Hazard	0.1	100	1500

Table 17: Sprinkler Density/Area Curves



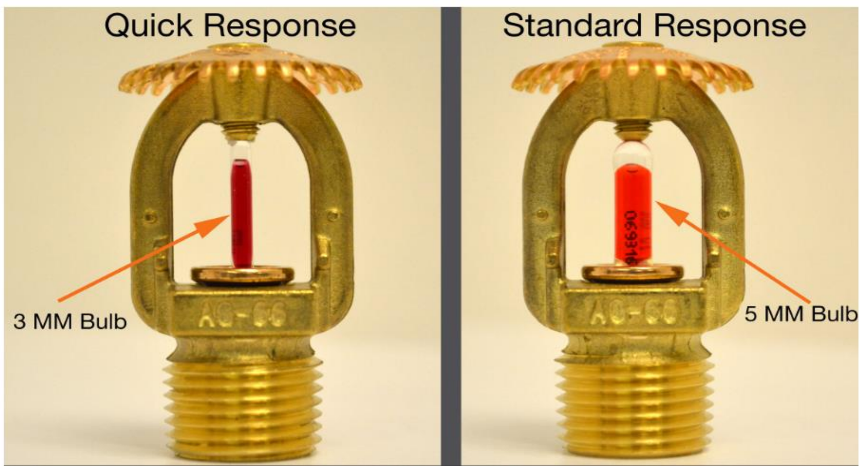
CAL POLY
SAN LUIS OBISPO

Table 18: Hose Stream Allowance and Water Supply Duration Requirements for Hydraulic Calculated Systems

Occupancy	Inside Hose		Total Combined Inside and Outside Hose		Duration (minutes)
	gpm	L/min	gpm	L/min	
Light hazard	0, 50, or 100	0, 190, or 380	100	380	30
Ordinary hazard	0, 50, or 100	0, 190, or 380	250	950	60–90
Extra hazard	0, 50, or 100	0, 190, or 380	500	1900	90–120

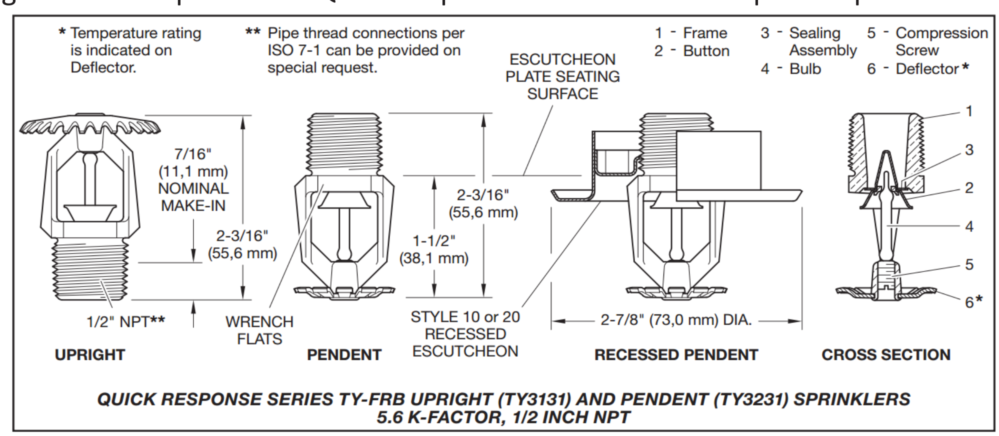
Sprinkler Heads

The Construction Innovation Center is built with concealed and upright TYCO Series TY-FRB Quick-Response Sprinklers. These Sprinklers have a K factor of 5.6 and ½" NPT. These sprinklers are required for light occupancy classification (NFPA 13). A quick response sprinkler is like a standard response sprinkler. Some benefits of a quick response sprinkler are that a quick response sprinkler discharges higher on the walls to keep the fire from climbing and maintain a lower ceiling temperature. Cooling the room helps reduce the likelihood of a flashover event inside the building. The quick response sprinkler has a physical difference in the size of the bulb. The standard bulb is 5 mm and a quick response bulb is 3 mm. The smaller bulb requires a lower temperature to activate. Figure 20 shows a comparison of quick response and standard response sprinkler bulbs. Figure 21 shows the quick response series TY-FRB upright sprinklers that are installed in The Construction Innovation Center.



http://www.qrfs.com/1--Fire-Sprinklers-Standard-Response-vs-Quick-Response_b_4.html

Figure 20: Comparison of Quick Response and Standard Response Sprinkler Bulbs



QUICK RESPONSE SERIES TY-FRB UPRIGHT (TY3131) AND PENDENT (TY3231) SPRINKLERS
5.6 K-FACTOR, 1/2 INCH NPT

https://www.tyco-fire.com/TD_TFP/TFP/TFP171_11_2015.pdf

Figure 21: Quick Response Series TY-FRB Upright Sprinklers

CAL POLY
SAN LUIS OBISPO

Riser Information

The Construction Innovation Center has two sets of 3” risers. One for building A and one for buildings B and C. The Construction Innovation Center is a 3-story building. Multistory buildings are required to have control valves, check valves, and a main drain valve. The flow control valves that are used for this building are 3” GD-4765-8N GRVD BFV. The control valves are used to separate each floor of the 3-story building for testing purposes. The Construction Innovation Center has 3” Tyco Model CV-IF grooved check valves. The check valves help control the flow direction. The check valves also separate the source of water supply from one another. The main drain valve for the center is 1.25” AGF #1000 TEST-An-Drain valve with a 0.5” orifice. The piping in the system is arranged so that the water can be drained to this valve. The Riser locations can be found in Appendix J. The Riser information can be found in Appendix I. The risers meet the requirements set for by NFPA 13.

Hydraulic Demand

The hydraulic demand is measured at the most remote location of sprinklers in the building. I have marked where the most remote area is below in Figure 22. The most remote sprinklers are used for this calculation because in theory if you have enough pressure and supply to reach these sprinklers then you have enough pressure and supply to reach the rest of the building. For this report, the third floor of Building B was used fire the most remote location due to the distance from the riser. Figure 23 shows the hydraulic supply and demand for the building. The graph shows the static point, residual point, and the total demand point. With this graph it can be determined that a fire pump is not needed for The Construction Innovation Center.

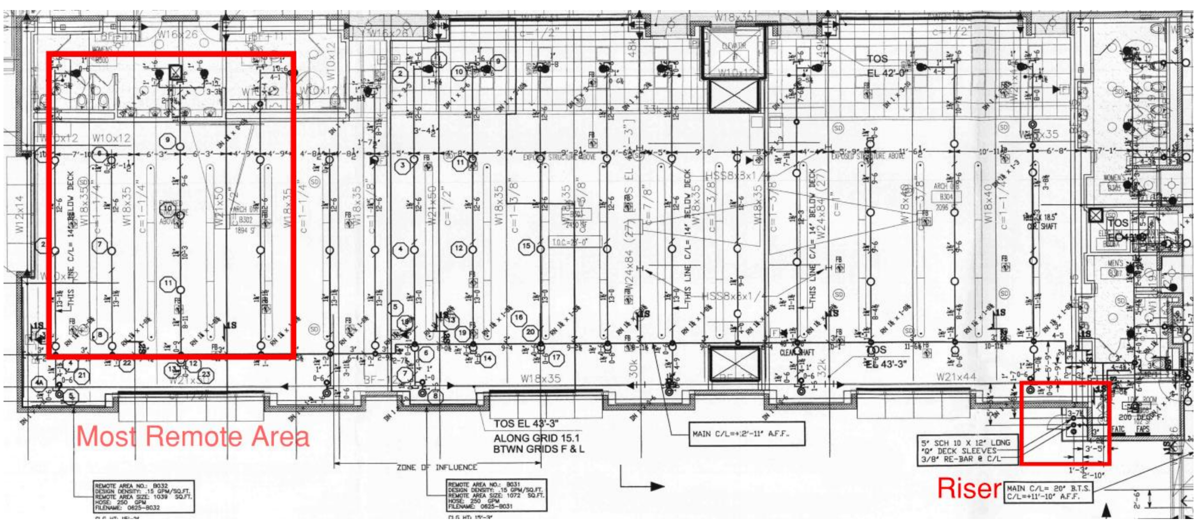


Figure 22: Most Remote Location from Riser

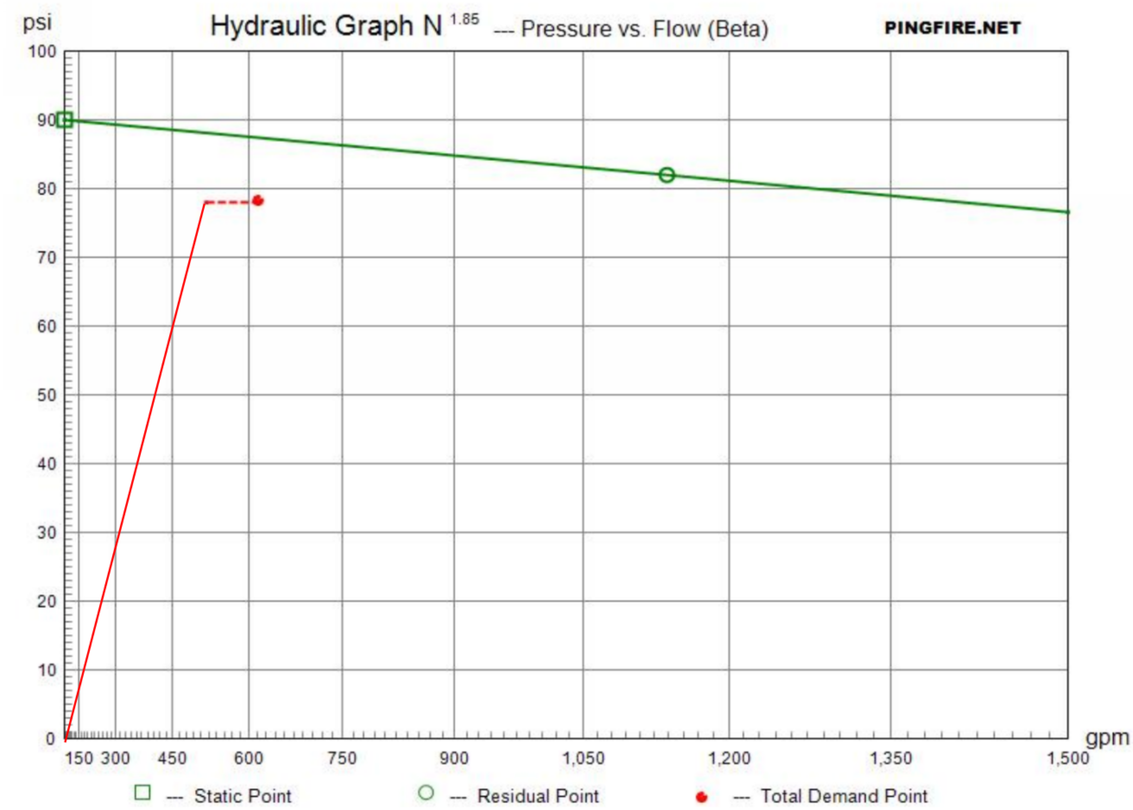


Figure 23: Supply and Demand Curve

Fire Department Connection

NFPA 13 6.7, 8.17.2*, 8.17.2.4.6*, 8.17.2.4.7.1

The Construction Innovation Center is equipped with fire department connections. The building is required to have the connections per NFPA 13. Fire department connections are used to help supply water to the water suppression system and keep an efficient pressure. The location of the connections is important as well. They cannot block any driveways. They must be in a location where the hose does not block any egress paths or entrance paths. The connections should also be located at the nearest point of the fire department apparatus accessibility. In most cases this means the connections should be located near the street side of the building which they are for The Construction Innovation center. Also, the connection should not be attached to branch line piping. The area around the connections must be maintained and clear of obstructions. Lastly, the connections need to be located with a clear sign with letters at least 1 in in height on a plate. The Construction Innovation Center meets these requirements set forth by NFPA 13.

Sprinkler Inspection

NFPA 25 5.2.1.1.1*, 6.2.3-4,13.8, 13.2.7.1.1*

The components of the fire suppression system are required to be inspected at different periods of time. Sprinklers and spare sprinklers are required to be inspected annually. Sprinklers that show signs of leakage, corrosion, physical damage, loss of fluid in the glass bulb, or load detrimental to the sprinkler performance should be replaced. Hose connections and piping is also required to be inspected annually. Fire department connections should be inspected quarterly. Some inspection requirements are to check if the gaskets are in place, see if the check valve is leaking, and that the identification signs are in place. The hanger, seismic bracing, and pipe fittings should be inspected quarterly per NFPA 25. The internal components of the piping are inspected to ensure that there are no obstructions of foreign organic and inorganic material every 5 years. Lastly gauges for a wet pipe system should be inspected monthly to make sure the gauge is operable and to see if there is any physical damage.

Sprinkler Testing and Maintenance

NFPA 25 13.2.5*, Table 5.1.1.2

Components in the water suppression system shall be permitted to be tested and maintained. Main drain test should be done quarterly. A main drain test should be conducted for each water supply lead-in to a building water-based fire protection system to determine whether there has been a change in the condition of the water supply. The sprinklers in the Construction Innovation Center are fast response sprinklers in a normal environment. The testing and maintenance requirements for the sprinklers are at 20 years and every 10 years thereafter. The system valves should be tested and maintained quarterly to make sure the system is operating correctly.

Water-Based Fire Suppression System Summary

The sprinkler system installed in the Construction Innovation Center is sufficient for protecting the occupants and the building in a fire situation. The Construction Innovation Center has two sets of 3” risers. One for building A and one for buildings B and C. The Construction Innovation Center is a 3-story building. Multistory buildings are required to have control valves, check valves, and a main drain valve. The Construction Innovation Center is built with concealed and upright TYCO Series TY-FRB Quick-Response Sprinklers. These Sprinklers have a K factor of 5.6 and ½” NPT. These sprinklers are required for light occupancy classification (NFPA 13). The system meets all the requirements set forth in NFPA 13. While analyzing the water demand of the system it can be concluded that a fire pump is not needed for The Construction Innovation Center.

Prescriptive Based Analysis Summary

This prescriptive based analysis discussed in detail the Fire and Life Safety of The Construction Innovation Center located on California Polytechnic State University Campus in San Luis Obispo. The report addressed the Egress Analysis, Structural Fire Protection, Fire Suppression, and Fire Detection and Alarm Systems. The Construction Innovation Center is three separate buildings that can be classified as one building. The structural fire protection of The Construction Innovation Center meets the requirements set forth by the IBC and CBC. After going through a complete egress analysis for The Construction Innovation center it was shown that the exit capacities, the exit locations, and the arrangement of exits are adequate for the occupants of the building. The Construction Innovation Center is equipped with initiating and notification devices. These devices meet the requirements set by NFPA 72. The Construction Innovation Center is also equipped with smoke control dampers and photoelectric smoke detectors that work together to help stop smoke from circulating around the building. The fire suppression system installed in the Construction Innovation Center is sufficient for protecting the occupants and the building in a fire situation. Building A is supplied with one riser and Buildings B and C are supplied with another riser. The system meets all the requirements set forth in NFPA 13. While analyzing the water demand of the system it can be concluded that a fire pump is not needed for The Construction Innovation Center. The next half of the report will be over the performance-based analysis of The Construction Innovation Center.

Performance Based Analysis

NFPA 101 5.2

Performance based analysis is another method from the regular prescriptive approach. The Life Safety Code has multiple options for design fire that can be considered for a performance-based analysis. For this report the Life Safety Codes, Design Fire Scenario 1 was chosen. Design Scenario 1 accounts for occupant activities, location of occupants, room sizes, fuel properties, ventilation conditions, and the location of ignition.

The objective of a performance-based analysis is to determine whether the occupants will egress the Construction Innovation Center before they are harmed or before the conditions become untenable. This is called RSET vs ASET. RSET is the required safe egress time. ASET is the available safe egress time. In Figure 24 it shows that RSET is the detection time + alarm time + pre-evacuation time + movement time. Figure 24 also shows that ASET is the time from emergency start until the tenability limit is reached. The tenability limit is the time it takes for the area to become uninhabitable. I used two different software programs to construct my performance-based analysis, Pyrosim and Pathfinder.

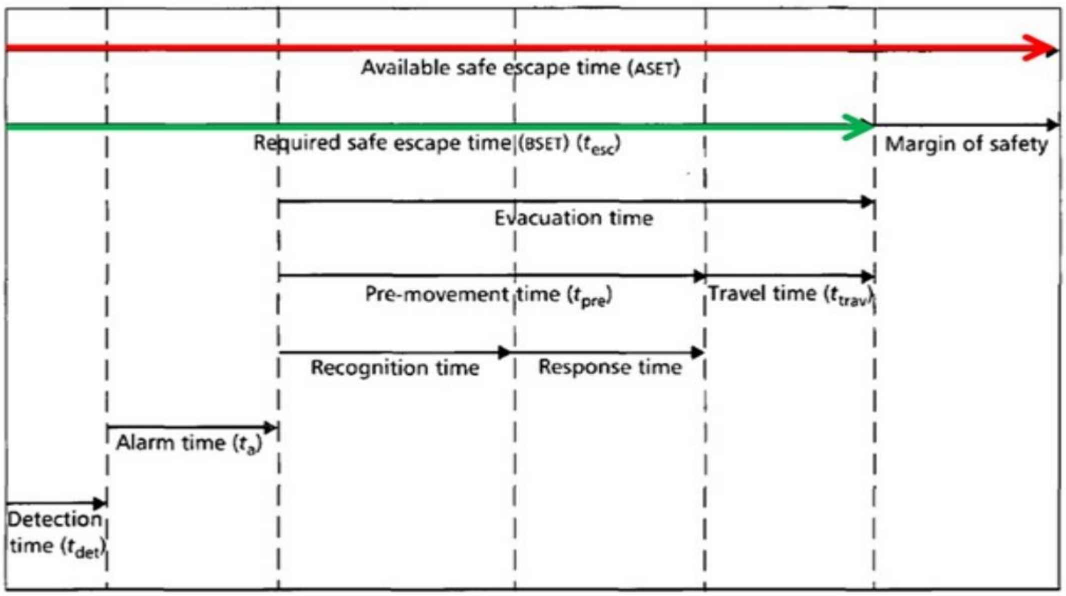


Figure 24: RSET VS ASET

Pyrosim

Pyrosim is a Fire Dynamics Simulator created by Thunderhead Engineering. Pyrosim is the leading software for quickly and accurately working with FDS Models. Pyrosim can measure the tenability conditions of a building or room during a fire situation.

Pathfinder

Pathfinder is an agent-based evacuation simulator. The program can show movement simulations of occupants with high-quality 3D animated results, that gives reliable answers quickly.

From *the SFPE handbook Ch.2 4-50* there is an equation for Evacuation time.
Evacuation time = Time to notification + Reaction Time + Pre-evacuation time + Travel time

Time to notification time is a period it takes for smoke and heat to spread enough to set off an alarm system. Reaction time is the time it takes an occupant to perceive the alarm or fire cue and act. Pre-evacuation time is the time that elapses while the occupant is preparing to leave. Travel time is the time to move to a location of safety. Travel time can be affected by the age, agility, and commitment to the task at hand by the occupants of the building.

Characteristics of Occupants

Some factors that influence evacuation time are time of day, weather, age of occupants, and familiarity with their surroundings. The Construction Innovation Center is a college building that is mostly occupied between 0700 and 1800. This means all occupants should be awake inside the building. The weather should not be a problem for this building. The building is in San Luis Obispo, California where the weather is generally fair. The weather being fair should help people from being reluctant to leave the building. Occupants being between the ages of 18-65 should not have a challenging time evacuating this building. If occupant's have disabilities the building is equipped with exit access exterior walkways. Pre-evacuation time for this building might take some time since students and faculty are the occupants. The occupants might take their time to shut down and pack up their belongings. Also, there is no training on how to evacuate this building, so it might take some time for an individual to come up with a plan before evacuating.

Building A Design Scenario 1

LSC 5.5.3*

For my first fire scenario I used the first floor waiting area in Building A as seen in Figure 25. For this scenario, I referenced the Life Safety Codes design scenarios and picked Design Scenario 1. Design Scenario 1 from the Life Safety Code considers a typical fire for the occupancy. It also accounts for occupant activities, location of occupants, room size, fuel properties, ventilation conditions, and location of ignition.

Figure 25: Chairs of Fire Ignition

Fire Design Objectives

LSC 909.8.1

For this Scenario I have set some design objectives to meet for the occupants of the building. I wanted to limit the heat exposure to the occupants. Thermal burns or first-degree burns occur at around 50-60 degrees Celsius and would develop in less than a second at around 70 degrees Celsius.

I wanted to maintain 5 feet of clearance from the smoke zone to the ground level. The height of the lowest horizontal surface of the smoke layer interface shall be maintained not less than 5 feet above the walking surface that forms a portion of a required egress system within the smoke zone.

Lastly, I wanted to ASET > RSET. ASET is the available safe egress time. RSET is the required safe egress time.

Heat Release Criteria

The heat release rate for the fire scenario is centered around 4 chairs that are in the waiting area of the lobby. The chairs are made of polyurethane fiber batting. These chairs must also comply with California Bulletins 116,117, and 133. 116 and 117 require that the article meets the flammability requirements set forth by the California Bureau of home furnishings and care should be exercised near an open flame or with burning of cigarettes. Bulletin 133 was designed to reduce the reliance on chemical flame retardants. This standard was set to significantly reduce the speed of which a fire would spread. It also states that the max kw per chair can't be more than 80 kw for a chair in a public space. Using this information, a max HRR of 320 kw was selected (80 kW per chair). Using Overholt's Calculator I calculated a ramp up time of 83 seconds for a t^2 fast fire as seen in Figure 26. Overholt's calculator calculates a t^2 heat release curve that can be used to estimate transient fire growth for fire design purposes. The t^2 equation is a parabola that uses the growth equation (Qdot = alpha x t^2). In this equation alpha is the growth coefficient (fast, ultra fast, etc.). You can either use the t^2 ramp to have it grow until a specified HRR or a specified time to see what the corresponding HRR or time would be. The output is a plot of HRR vs Time.

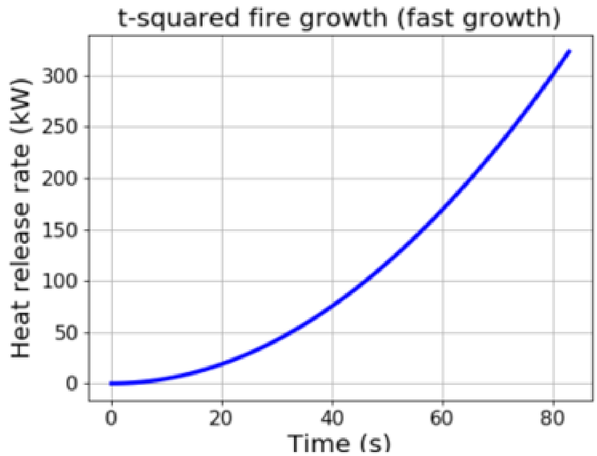


Figure 26: Overholt's Model for 320 kW at 83 seconds

After Running the Pyrosim model it was clear that the sprinklers would activate and limit the growth of the fire at about 58 seconds and 68 degrees Celsius as seen in Figure 27. Then using Overholt's Calculator again I found a max HRR of 157 kW at 58 seconds as seen in Figure 28. The Pyrosim model was ran again using a ramp up time of 58 seconds and a max heat release rate of 157 kw was achieved. This simulation assumes that the fire will remain constant at 157 kw when the sprinklers are activated.

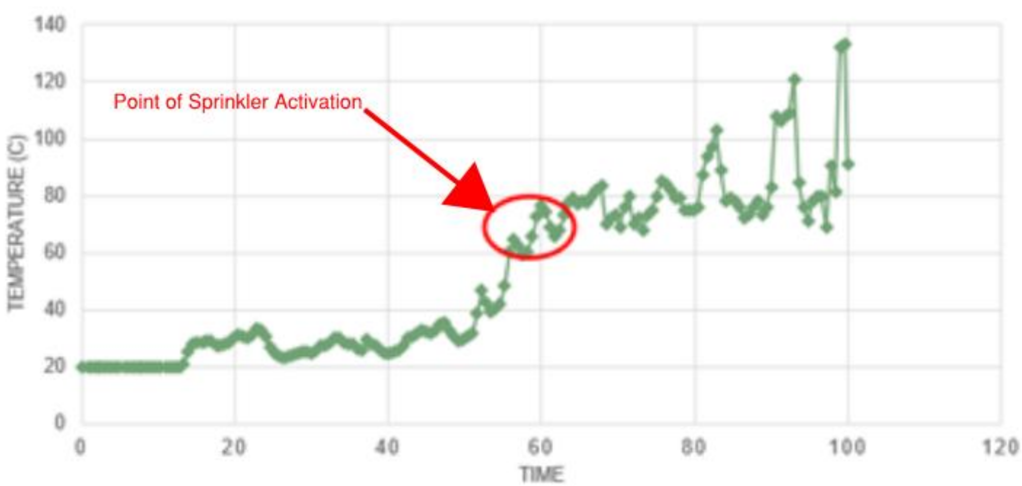


Figure 27: Sprinkler Temperature Above Fire

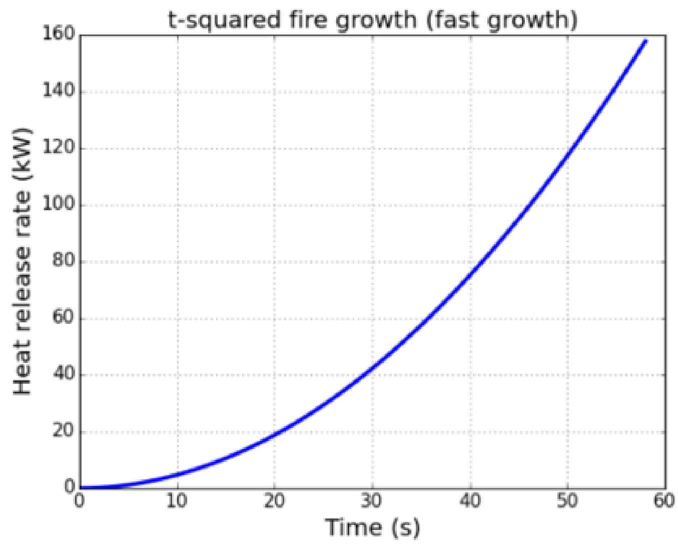


Figure 28: Overholt's Model for 157 kW at 58 seconds

Results of Design Fire 1

Pathfinder Assumptions and Results

For the occupants closest to the fire there was no pre-evacuation time. But the occupants in the various rooms in the building were set to a pre-evacuation time of 15 seconds for the first floor due to the occupant's location next to the fire and having the ability of seeing and smelling smoke. As well as hearing other occupants evacuate. For the second and third floor a pre-evacuation time of 30 seconds was used since these occupants would not see or smell the smoke. They would be alerted from the notification systems and may take some time to gather their belongings and ponder how severe the situation is. The pre-evacuation time information was found in the SFPE Handbook 5th edition table 58.5. I have pulled the table from the SFPE Handbook and have listed it below in table 20.

Table 20: Range of Times associated with pre-evacuation actions

Action	Range of timing (minutes)
Preparation (Action task, personal)	0.5–5
Communicating with others (Information task)	3
Looking out the window (Information task)	1–5
Helping, by authorities (Action task, emergency)	4–10

Below I have images of the Pathfinder results. It was determined that the first floor would be fully evacuated after 61 seconds. In Figure 29 I have shown Floor 1 Pathfinder results in increments of 0,15,30, and 59 seconds. 0 seconds shows the occupant locations before the fire started. 15 seconds shows that the occupants closest to the fire have started to evacuate. 30 seconds shows that all the occupants have started to evacuate from the first floor. 59 seconds shows the last occupants evacuating. In Figure 30, I have shown Floors 2 and 3 Pathfinder results in increments of 0, 45, 61, and 128 seconds. 0 seconds shows the occupant locations before the fire started. 45 seconds shows that the occupants have started to evacuate. 128 seconds shows the last occupants evacuating.

Floor 1 Building A

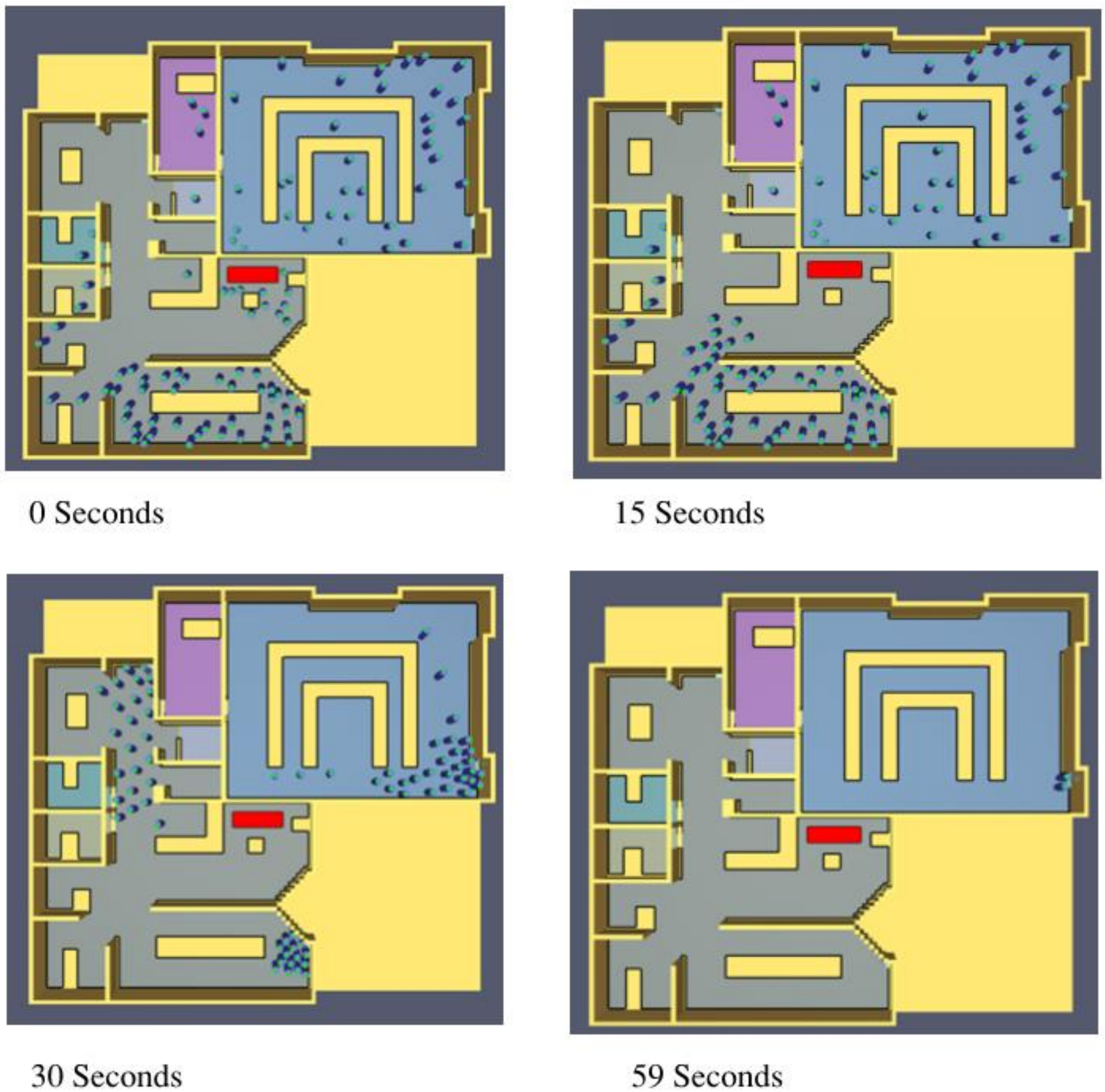


Figure 29: Floor 1 Building A Pathfinder

Floor 2 and 3 Building A

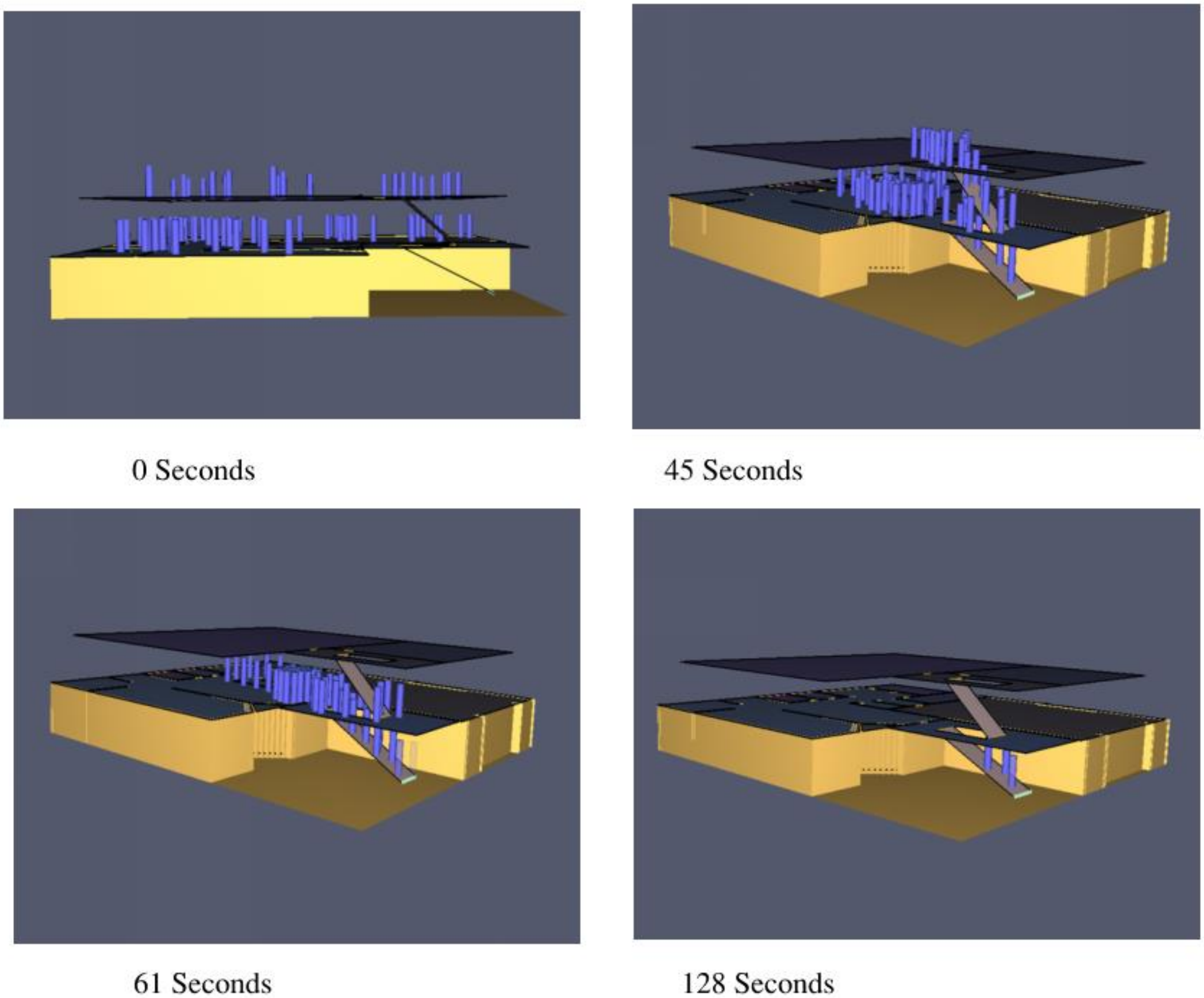


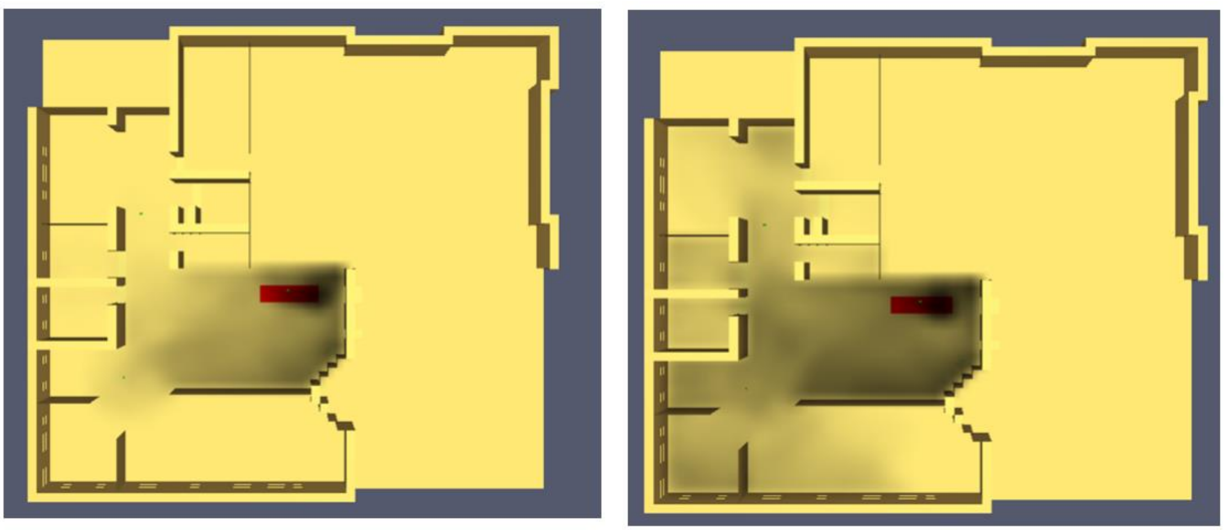
Figure 30: Floor 2 and 3 Building A Pathfinder

Pyrosim Results

Pysosim was used to measure the tenability of the building. As stated earlier, the objectives of this fire scenario were to limit the occupants to heat exposure of less than 50 degrees Celsius and maintain 5 feet of clearance from the smoke zone to the ground level. At these points the building would become untenable. The last objective was to make sure RSET > ASET. To meet these objectives a Pyrosim model was developed for the first floor of Building A. Slice files were placed in the model to measure visibility and temperature of the first floor.

Smokeview Results

Figure 31 shows the smoke spread on the first floor of Building A. The picture on the left is the smoke spread at the 61 seconds which is the time of first floor evacuation. The picture on the left shows the smoke spread at 128 seconds which is the time of seconds and third floor evacuation.



61.1 seconds 128 seconds

Figure 31: Smokeview Fire Design Scenario 1

Visibility Results

The Visibility criteria set was to maintain 5 ft. of clearance from the smoke zone to the ground level. The Construction Innovation Center maintained the 5 ft. of clearance while occupants were still present in the building. I have shown this in Figure 32 and 33. Figure 32 shows a slice file of the visibility at 61 seconds. This is the time that the first floor has fully been evacuated and shows that only small sections have less than 5 ft of clearance. Figure 33 shows a slice file of the visibility at 128 seconds. This is the time that the second and third floor have been fully evacuated and shows that 5 ft. of clearance is still maintained.

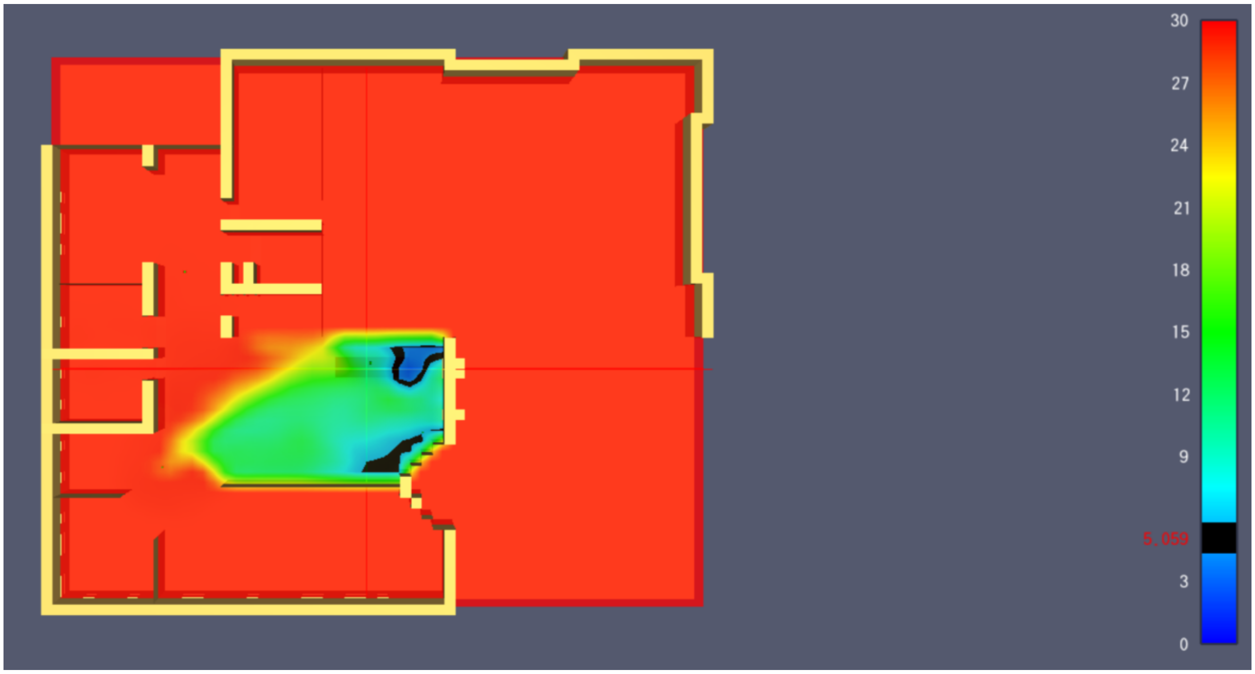


Figure 32: Visibility of 5 feet at 61 seconds

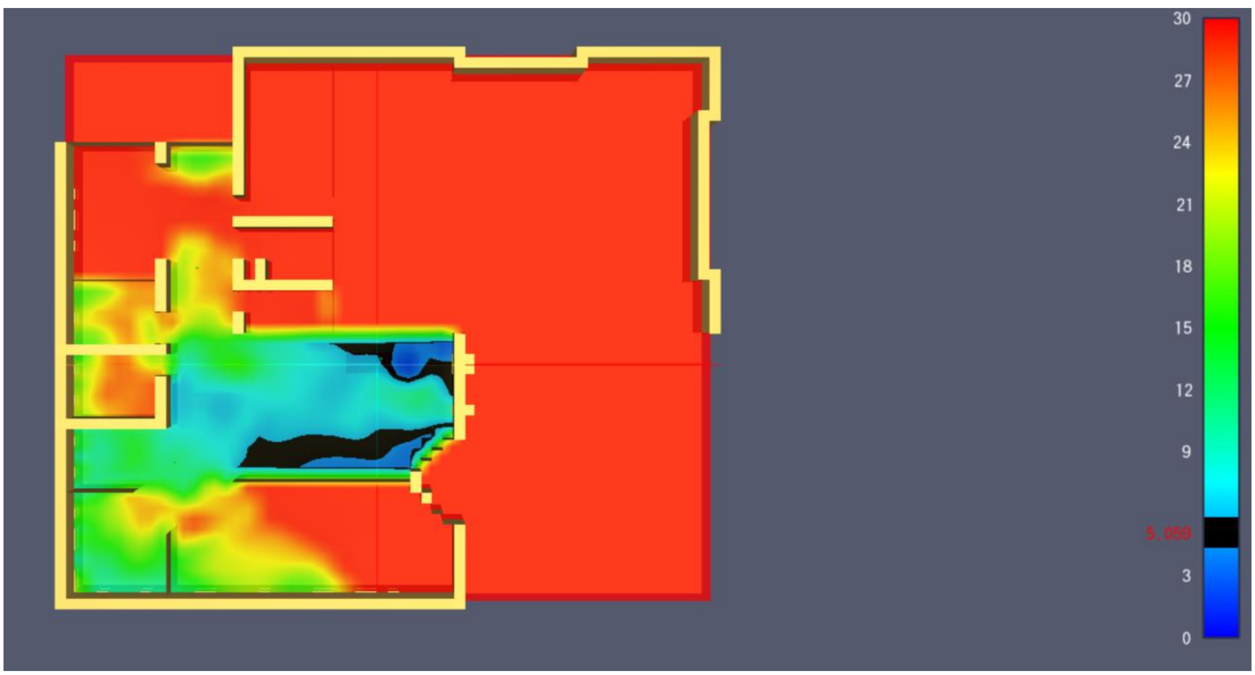


Figure 33: Visibility of 5 feet at 128 seconds

Temperature Results

The temperature criteria was set to maintain temperatures of less than 50-60 degrees Celsius while occupants are present. The Construction Innovation Center met this requirement. Figure 34 shows that the temperature spread is between 25 – 40 degrees Celsius around the fire at 61 seconds. Also, most of the building is still at ambient temperature of 20 degrees Celsius. Figure 35 shows that the temperature spread is between 30-40 degrees Celsius around the fire at 128 seconds. Also, most of the building is still at ambient temperature. 61 seconds is the time of first floor evacuation and 128 seconds is the time of second and third floor evacuation.

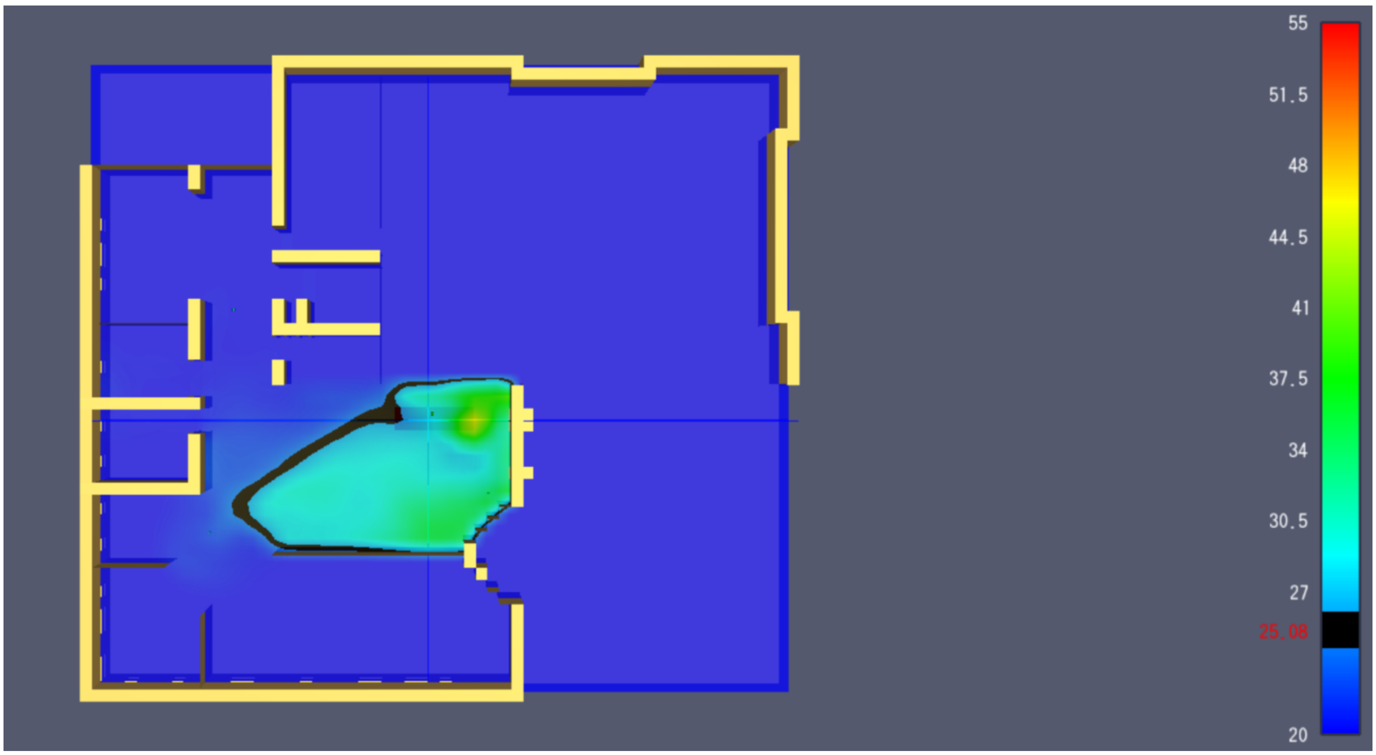


Figure 34: Max Temperature at 61 seconds

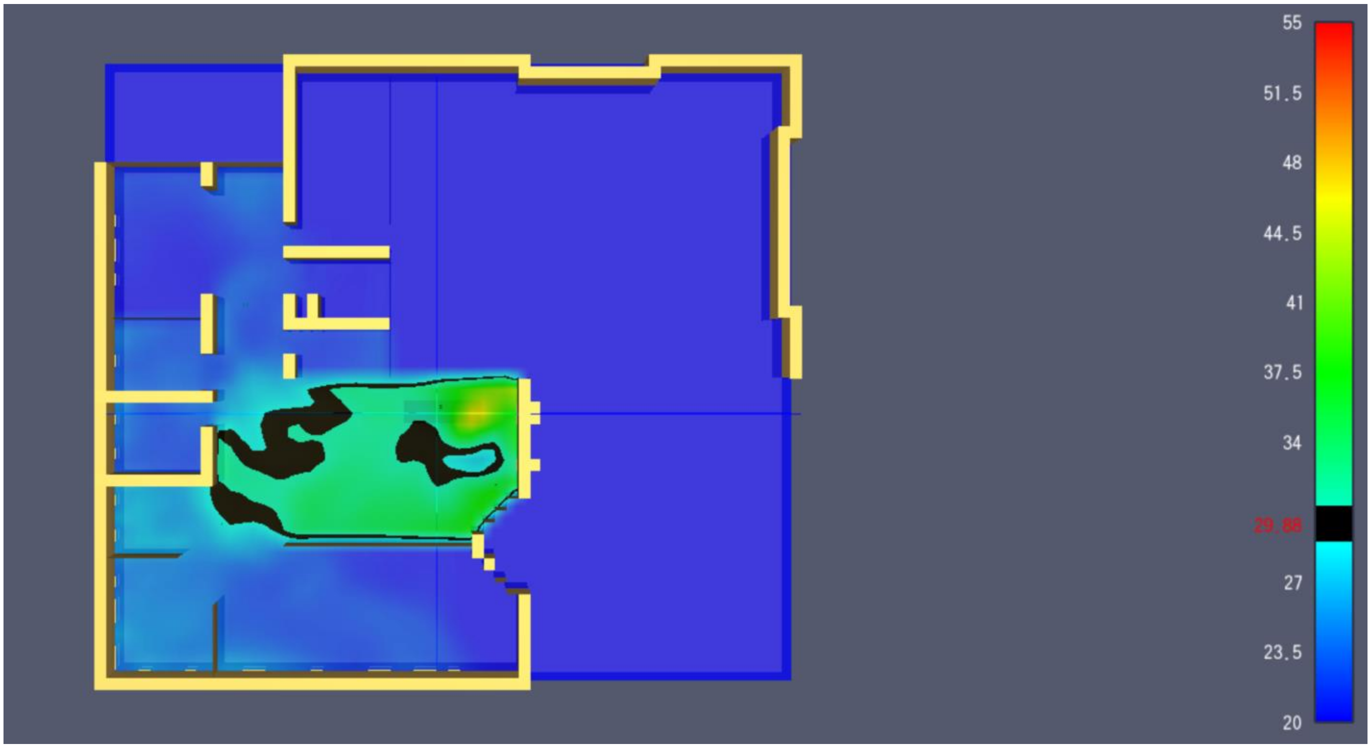


Figure 35: Max Temperature at 128 seconds

Fire Design Scenario 1 Summary

Fire design scenario 1 was centered around the lobby of the first floor of Building A. In the lobby there are 4 chairs present that are the ignition source of the fire. After running simulations in Pathfinder and Pyrosim it was concluded that the max visibility does not reach 5 feet above the walking surfaces, and the max temperature does not reach about 50 degrees Celsius before the occupants have fully evacuated. Time of evacuation of the first floor is 61 seconds. This makes 61 seconds the required egress of time (RSET) of the first floor. The first floor became unattainable at about 210 seconds. 210 seconds is the available safe egress time (ASET) for the first floor. If a safety factor of 2 is used and the 61 seconds is doubled to 122 seconds the occupants still have more than enough time to escape the first floor. The second and third floors RSET is 128 seconds. The ASET was not modeled for the second and third floor.

Fire Design Scenario 2

For my second fire scenario I modeled a fire that started in Building 187 – Simpson Strong-Tie Material Demonstration Lab. It is located Buildings 186 courtyard adjacent from buildings B and C as shown in Figure 36. There is a separation distance of approximately 8 ft. I chose this design to see if a fire in this structure would endanger occupants during an evacuation of Buildings B and C. Fire design scenario 1 from the Life Safety Code was chosen as a guideline for this design. Fire design scenario 1 accounts for the occupant's activities, location of the occupant, fuel properties, ventilation conditions, and location of ignition. Lastly, the model will be simulated with 5-10 mph winds. These winds are average for the San Luis Obispo area. The wind information was found on weatherspark.

Figure 36: Overview of Buildings 186 and 187

Fire Design Objectives

For this Scenario, I have set some design objectives to meet for the occupants of the building. I wanted to limit the heat exposure to the occupants. Thermal burns or first-degree burns occur at around 50-60 degrees Celsius and would develop in less than a second at around 70 degrees Celsius.

I wanted to maintain 5 feet of clearance from the smoke zone to the ground level. The height of the lowest horizontal surface of the smoke layer interface shall be maintained not less than 5 feet above the walking surface that forms a portion of a required egress system within the smoke-zone.

I also will model the heat flux that the fire produces on the face of Building B. I have set the tenability limit of heat flux to 2.5 kW/m^2. This is equivalent to 200 degrees Celsius and would produce serious skin pain to occupants.

Lastly, I wanted to ASET > RSET. ASET is the available safe egress time. RSET is the required safe egress time.

Heat Release Criteria

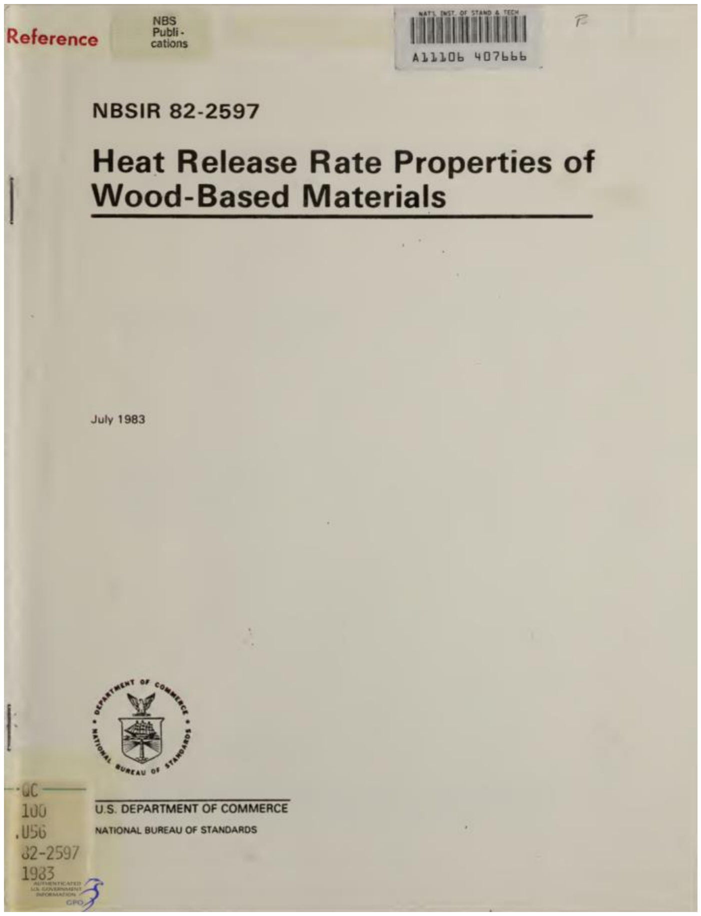
Lumber Timber

The heat release criteria for this design scenario is modeled off the timber construction that The Simpson Strong- Tie Material Demonstration Lab is made of. The lumber/timber is made of Douglas Fir-Larch, which can be found in the construction plans for the building. Figure 37 is pulled from the construction plans confirming that the lumber/timber is Douglas fir-Larch. I have found a heat release rate of 90 to 134 kW/m^2 for Douglas fir larch which can be seen in Figure 39. This information was found in, “Heat Release Rate Properties of Wood-Based Materials” developed by the U.S. Department of Commerce, Figure 38.

LUMBER/TIMBER

1. LUMBER GRADES, MINIMUM (U.O.N.): DOUGLAS FIR-LARCH

Figure 37: Lumber/Timber Type



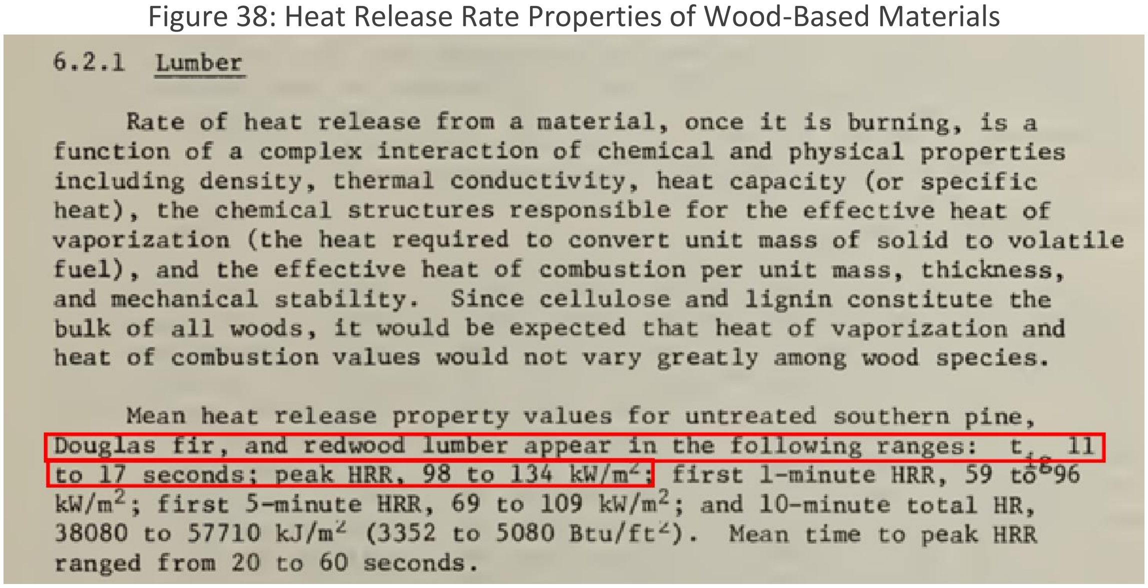
NBSIR 82-2597

Heat Release Rate Properties of Wood-Based Materials

July 1983

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

Figure 38: Heat Release Rate Properties of Wood-Based Materials



6.2.1 Lumber

Rate of heat release from a material, once it is burning, is a function of a complex interaction of chemical and physical properties including density, thermal conductivity, heat capacity (or specific heat), the chemical structures responsible for the effective heat of vaporization (the heat required to convert unit mass of solid to volatile fuel), and the effective heat of combustion per unit mass, thickness, and mechanical stability. Since cellulose and lignin constitute the bulk of all woods, it would be expected that heat of vaporization and heat of combustion values would not vary greatly among wood species.

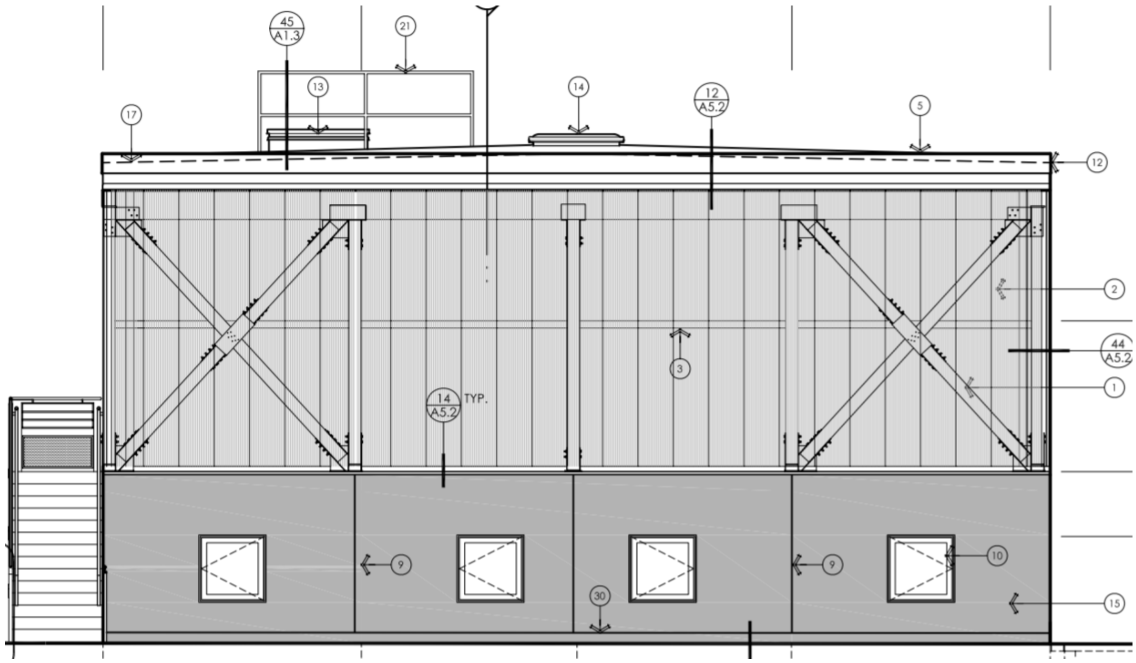
Mean heat release property values for untreated southern pine, Douglas fir, and redwood lumber appear in the following ranges: t_{ig} 11 to 17 seconds; peak HRR, 98 to 134 kW/m^2; first 1-minute HRR, 59 to 96 kW/m^2; first 5-minute HRR, 69 to 109 kW/m^2; and 10-minute total HR, 38080 to 57710 kJ/m^2 (3352 to 5080 Btu/ft^2). Mean time to peak HRR ranged from 20 to 60 seconds.

Figure 39: Heat Release Rate of Douglas fir-Larch

CAL POLY
SAN LUIS OBISPO

Polycarbonate System

In addition to the wood lumber/timber frame the Building has a polycarbonate glazing system wrapped around the building. The polycarbonate layer is about 40 mm thick and is translucent in color. I pulled a cross section of Building 187 from the construction plans. This cross section can be seen below in Figure 40. I also highlighted numbers 1,2, and 15 from the cross section in figure 40. Number 1 is locating the Douglas fir larch wood columns located behind the polycarbonate glazing. Number 2 is showing the polycarbonate glaze that is all around the side of the building. Number 15 is showing that the bottom of the building is made of concrete. The concrete portion of the building is not modeled in this simulation. I modeled that the building will be ignited halfway up. I have found that polycarbonate glaze has a max heat release rate of about 560 kW/ m^2 this can be seen in Figure 41 below. Figure 41 is a graph showing heat release rate data from cone calorimetry for Polycarbonate. This information was found in, "A Finite Element Analysis on the Modeling of Heat Release Rate, as Assessed by a Cone Calorimeter for Char Forming Polycarbonate" developed by David Statler jr. and Rakesh K. Gupta. 130 kW/m^2 was chosen as the heat release rate based on the range of the Timber. 560 kW/ m^2 was chosen as the heat release rate for the polycarbonate blazing. For the overall heat release rate 560 kW/ m^2 and 130 kW/m^2 was added together for a total of 690 kW/m^2. 690 kW/m^2 was then used to model the fire. There was no ramp up time for this fire because I wanted to see the effects of the fire on the face of Buildings B and C.



1. TYPE IV CONSTRUCTION. MANUFACTURED WOOD (7" x 7" NOMINAL COLUMNS) AND CUSTOM "SIMPSON" CONNECTORS BEHIND POLYCARBONATE GLAZING SYSTEM.

2. 40mm TRANSLUCENT POLYCARBONATE SYSTEM.

15. PAINTED CAST IN PLACE CONCRETE WALLS. COLOR TO MATCH PRECAST PANELS ON BUILDINGS A B AND C.

Figure 40: Cross Section of Building 187 – Simpson Strong-Tie Material Demonstration Lab

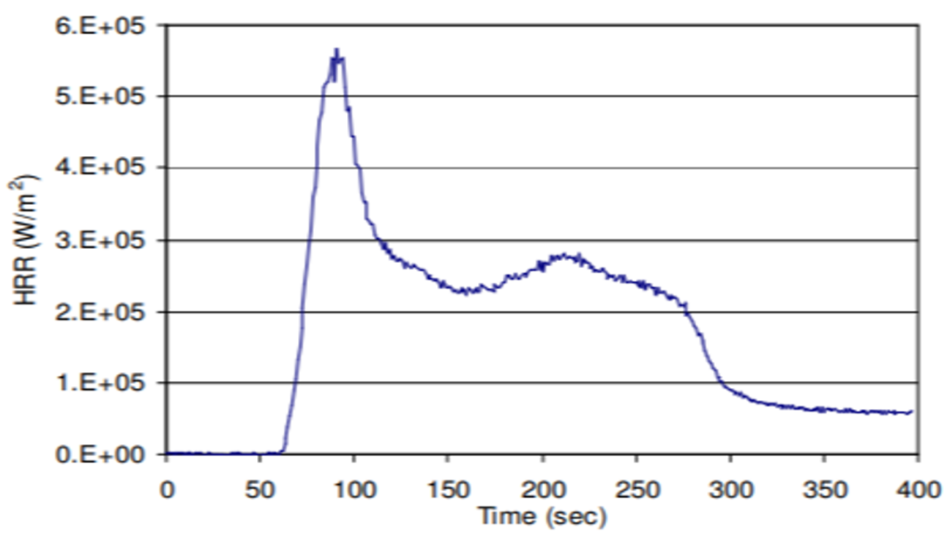
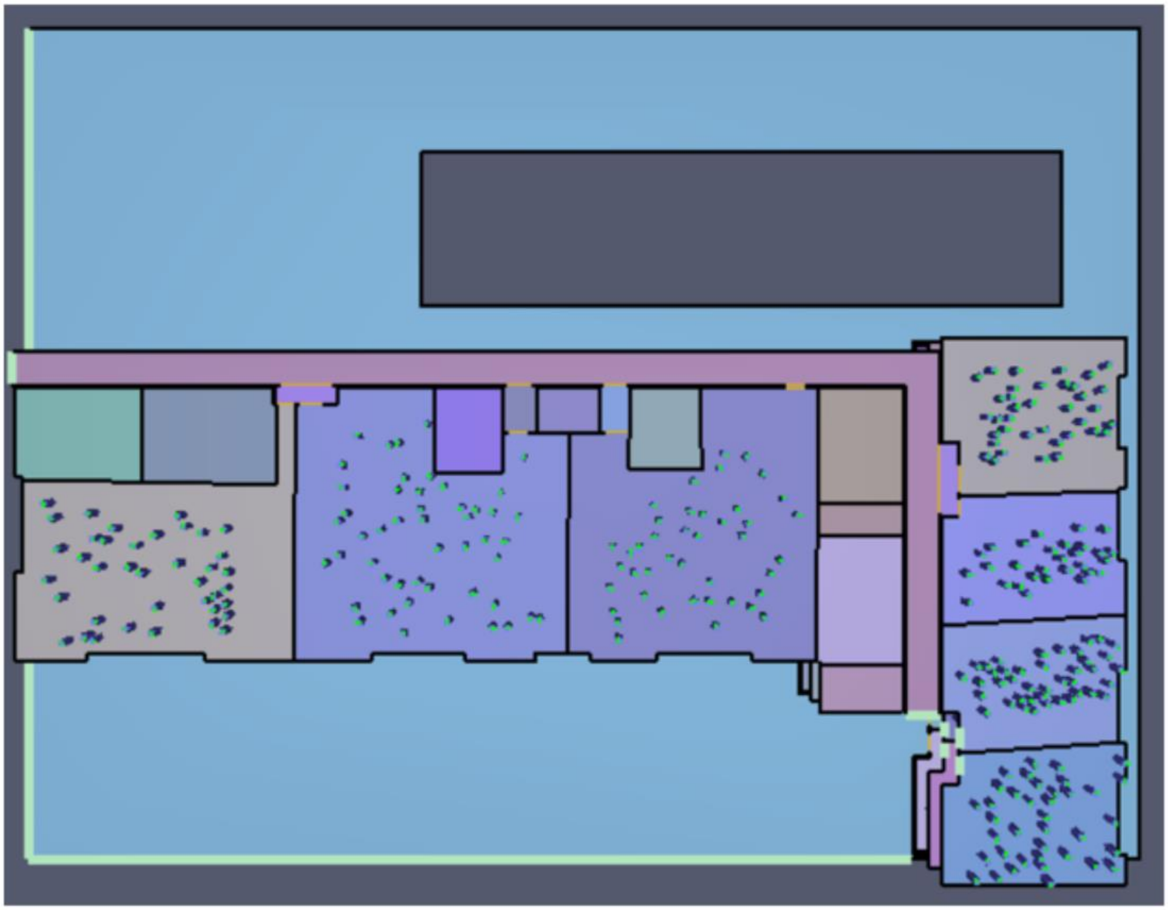


Figure 41: Heat Release Rate Data from Cone Calorimetry for Polycarbonate

Results of Design Fire 2

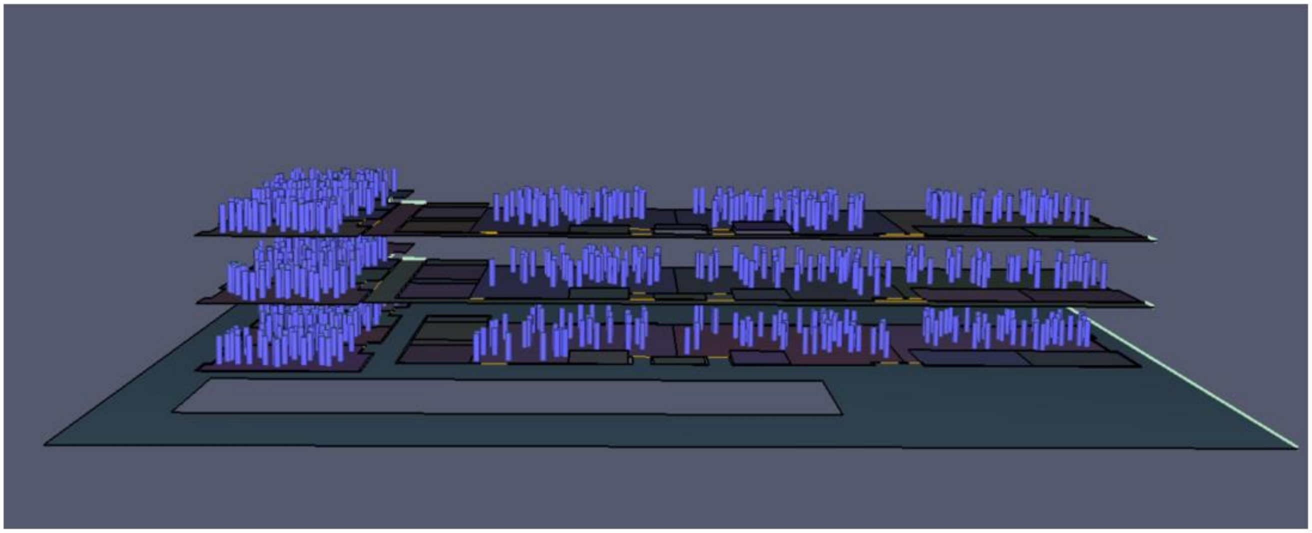
Pathfinder Assumptions and Results

Some assumptions were made for the evacuation of Buildings B and C. First, it was assumed it would take 30 seconds for the occupants to start evacuating. It would take the occupants 30 seconds to gather their belongings and begin to evacuate. The pre evacuation time information was found in the SFPE Handbook 5th edition. I have listed the pre evacuation times in Table 20 above. Below I have images of the Pathfinder results. It was determined that it would take Buildings B and C, 2 minutes and 20 seconds to fully evacuate. Figure 42 and 43 show a top view and side view of Buildings B and C before evacuation began. Figure 44 shows evacuation after 1 minute. In this Figure some occupants have evacuated the rooms and are walking along the exterior hallway towards the exits. Figure 45 shows evacuation at 1 minute 30 seconds. At this time the occupants have passed through the fire rated doors that are located on Floors 2 and 3. The fire rated doors are made from aluminum and have 90-minute fire ratings. Figure 46 shows the last room C101 being evacuated at 1 minute 45 seconds. Also, Figure 46 shows the time of total evacuation of 2 minutes and 20 seconds.



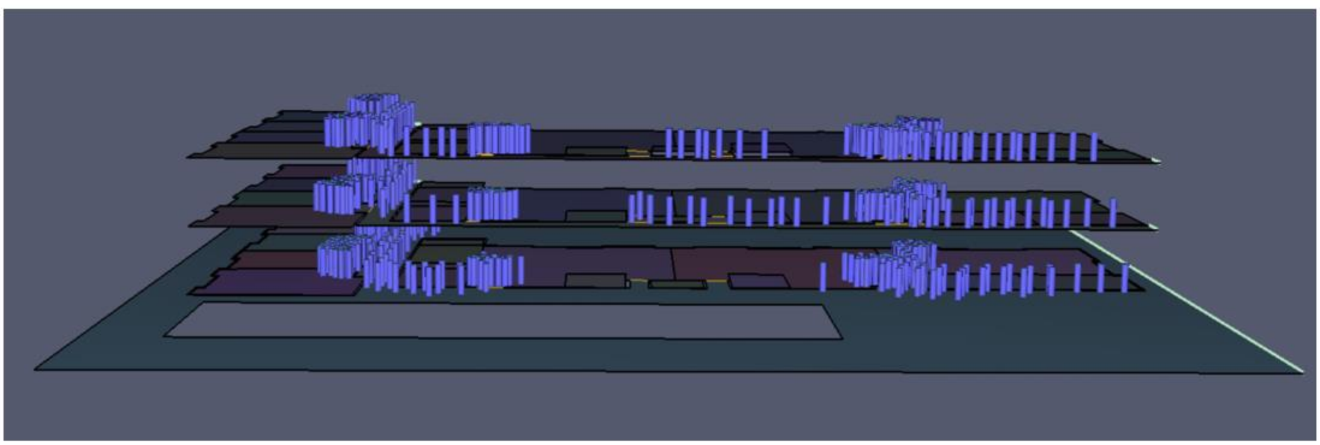
B and C Top View 0 Seconds

Figure 42: Top View of Buildings B and C Before Evacuation



0 Seconds

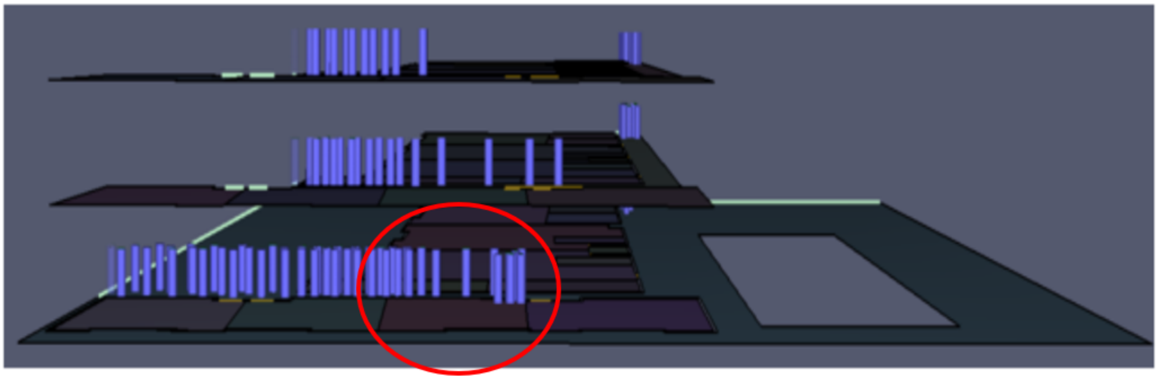
Figure 43: Side View of Buildings B and C Before Evacuation



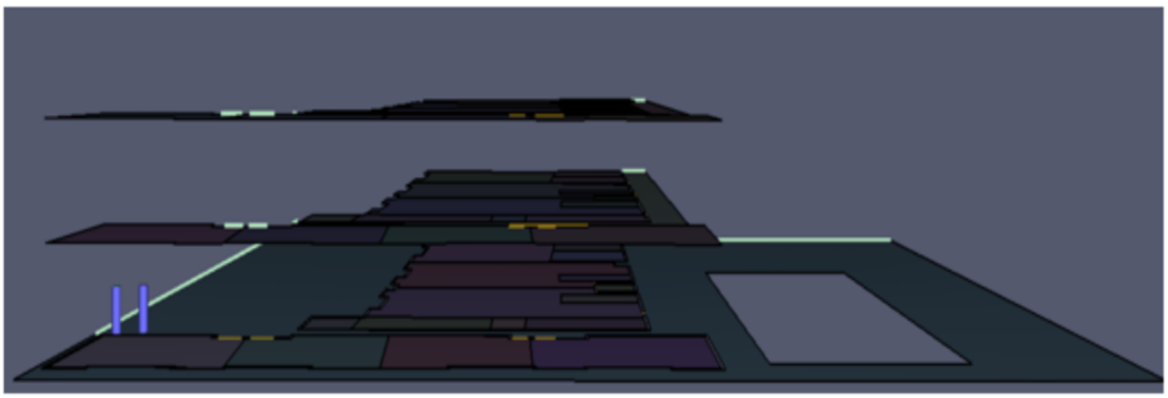
1 Minute

Figure 44: Side View of Buildings B and C 1 Minute into Evacuation

Figure 45: Occupants Pass Fire Rated Doors



Side View Room C101 is Last to Evacuate 1 Minute 45 Seconds



Full Evacuation 2 Minutes 20 Seconds

Figure 46: Occupants Evacuate Last Room and The Entire Building

Pyrosim Results

Pysosim was used to measure the tenability of the exterior walking paths during the fire. As stated earlier the objectives of this fire scenario was to limit the occupants to heat exposure of less than 50 degrees Celsius, maintain 5 feet of clearance from the smoke zone to the ground level on the walking paths, and to keep the heat flux on the face of building B to less than 2.5 kw/m^2. The last objective was to make sure RSET > ASET. To meet these objectives a pyrosim model was developed modeling Buildings B and C and Building 187. Slice files were placed in the model to measure visibility and temperature of the walking paths. Also, devices were placed to measure heat flux.

Smokeview Results

Figure 47 shows the Smoke View results from Design Fire Scenario 2. Figure 47 is a side view of the buildings at 6 seconds. This shows the beginning of the smoke plume starting. Figure 48 shows a top view of the buildings after 2 minutes and 20 seconds. In Figure 48 you can see the smoke plume being blown over buildings B and C by the wind that is set at 10 mph. The smoke plume is also being blown over the egress paths.

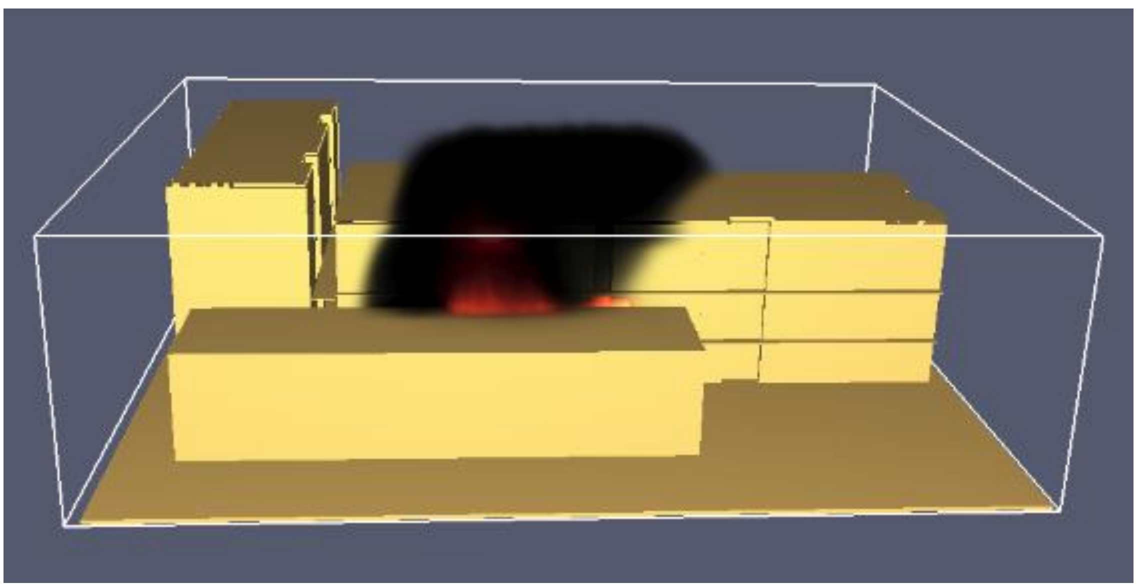


Figure 47: Smoke view side view at 6 seconds

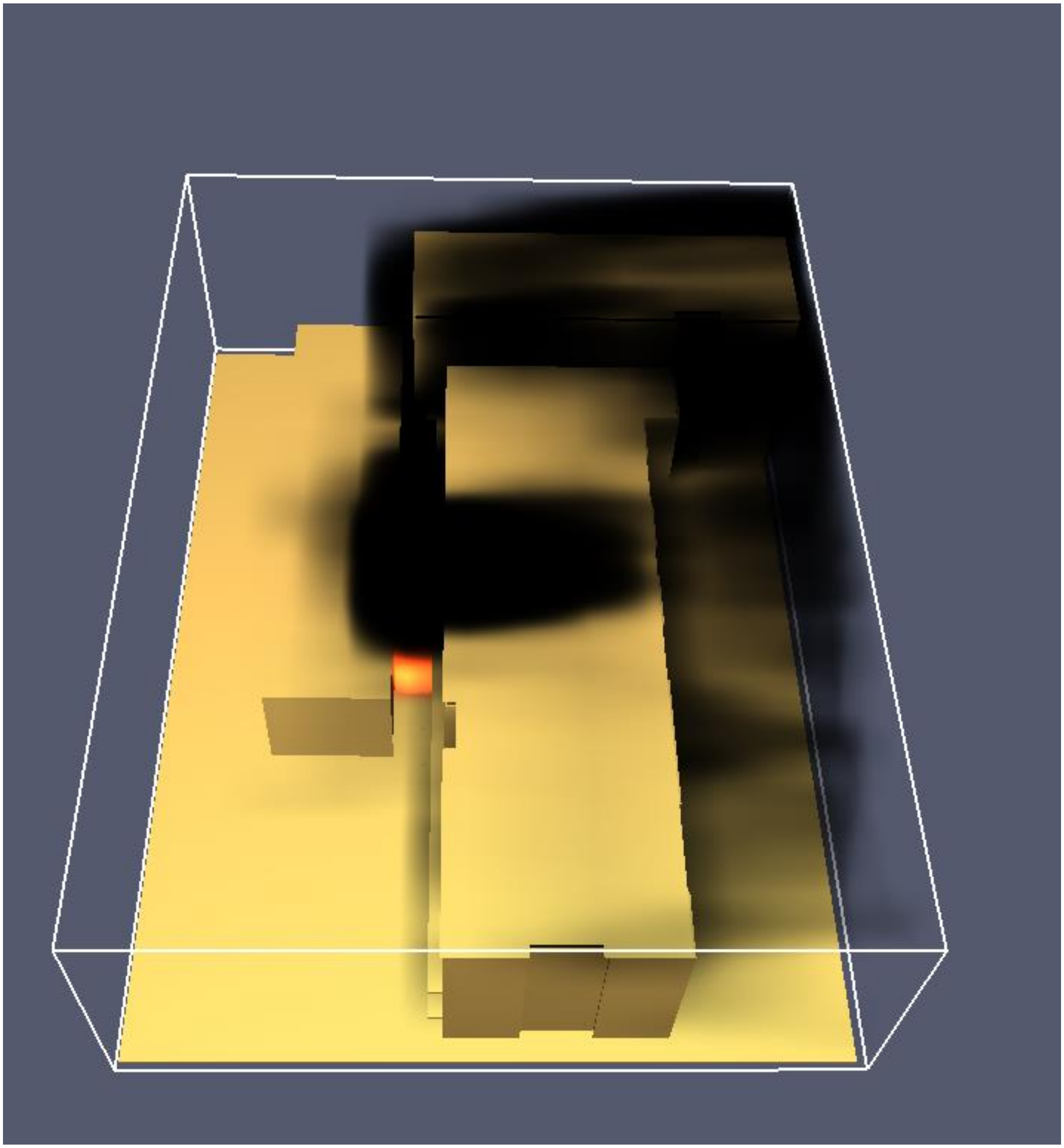


Figure 48: Smoke view top view at 20 minutes 20 seconds

Visibility Results

The Visibility criteria set was to maintain 5 ft. of clearance from the smoke zone to the ground level. The Construction Innovation Center did not maintain the 5 ft. of clearance while occupants were still present on the walking paths. Figure 49 shows a top view of visibility on the 3rd floor walking path at 45 seconds. The figure shows that the walking paths visibility is below the tenability limit. Figure 5 is a side view that is also taken at 45 seconds. This view shows that the 2nd floor exit passageway has also reached the tenability limit.

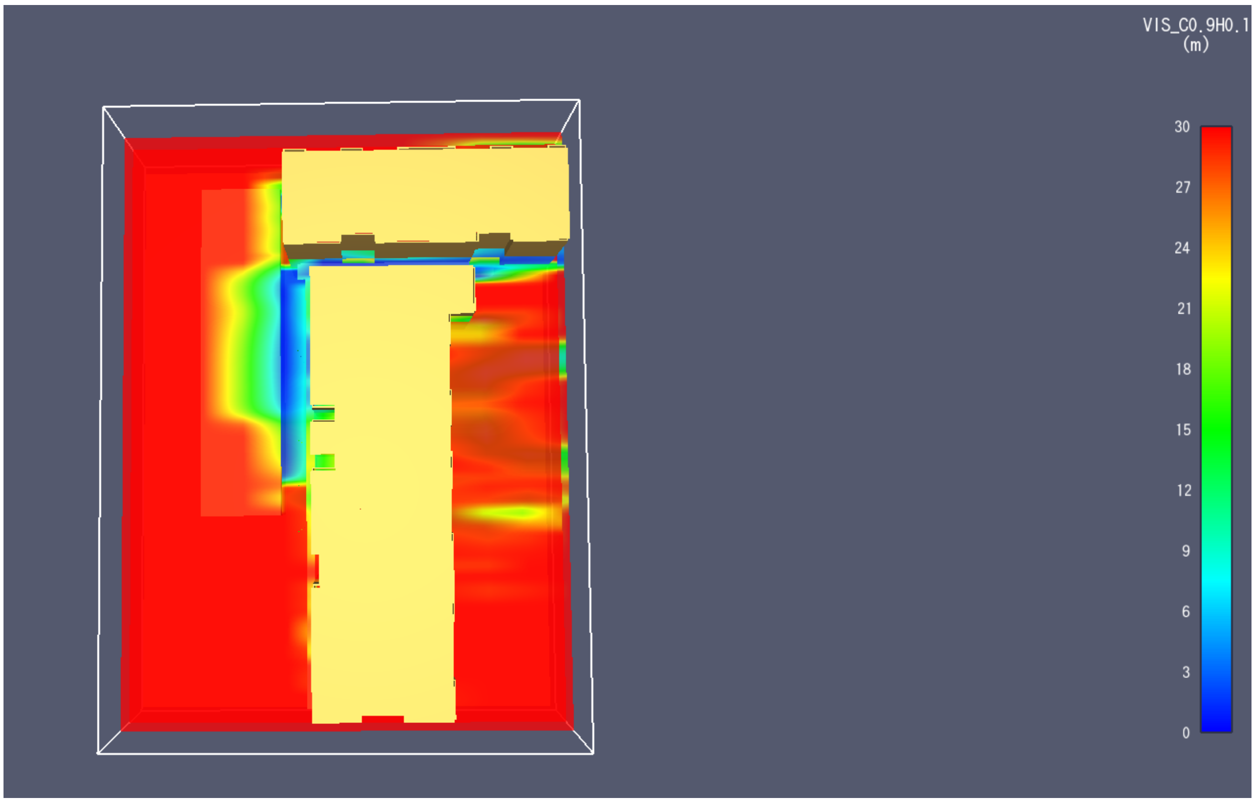


Figure 49: Visibility at 45 Seconds

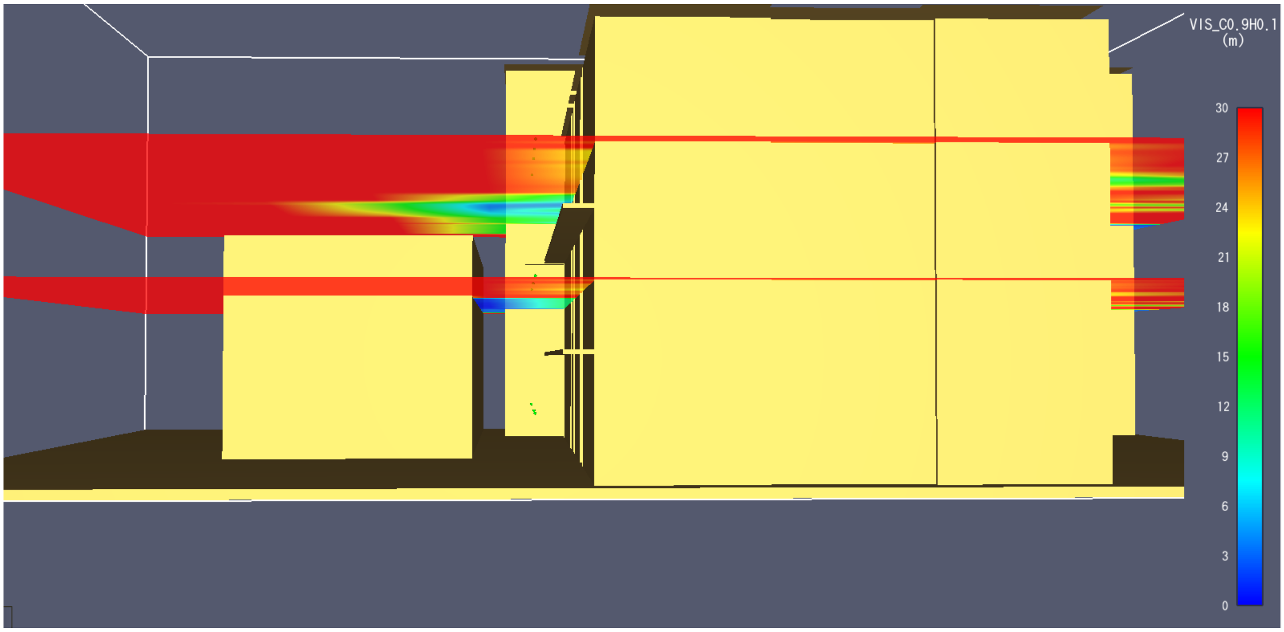


Figure 50: Visibility at 45 Seconds

Temperature Results

The temperature criteria set was to maintain temperatures of less than 50-60 degrees Celsius while occupants are present. The Construction Innovation Center did not meet this requirement. Figure 51 shows that the max temperature reached on the face of Building B reaches a high of 265 degrees Celsius at 45 seconds. Figure 52 shows a max temperature of the 265 degrees Celsius at 1 minute.

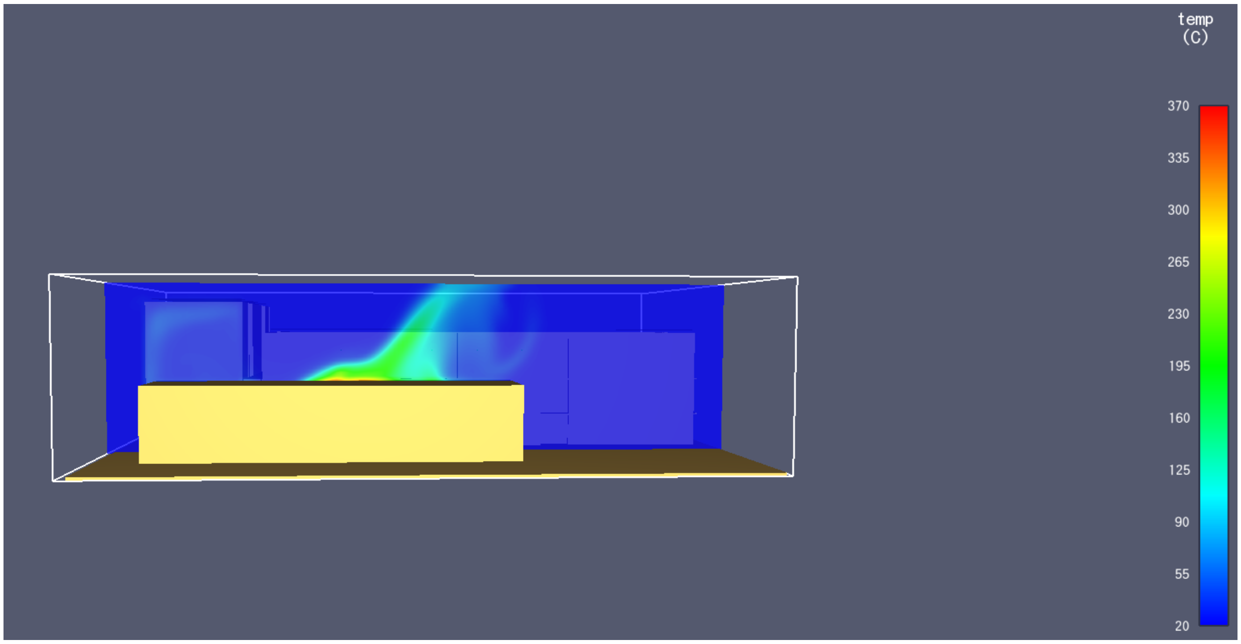


Figure 51: Max Temperature at 45 Seconds

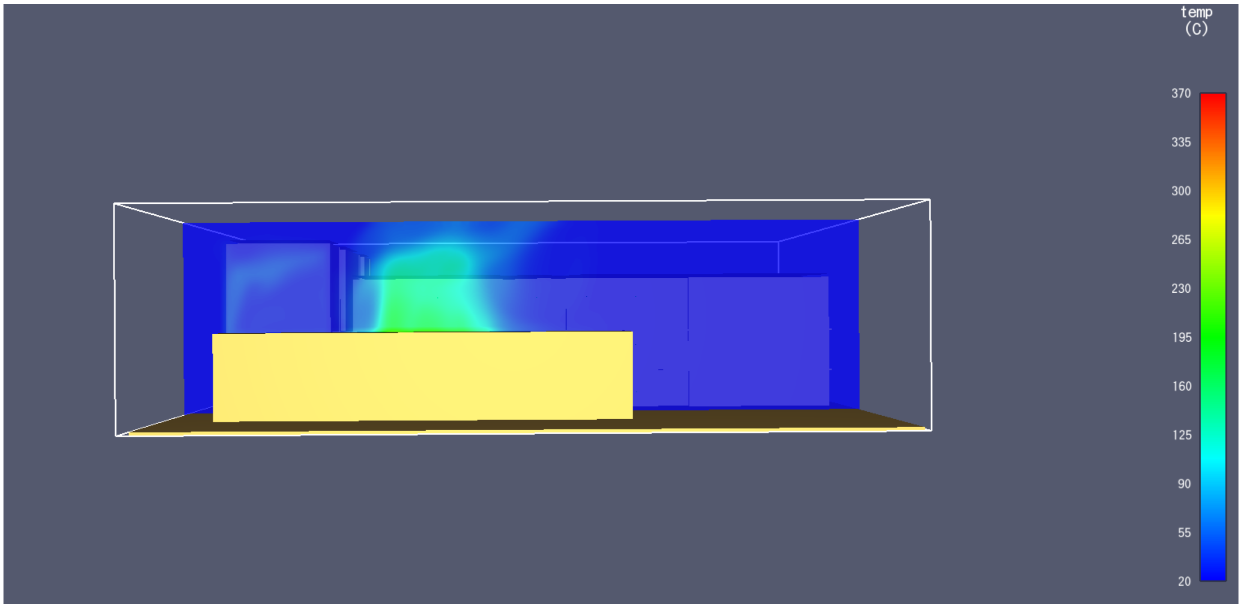


Figure 52: Max Temperature at 1 Minute

Heat Flux Results

The last result I wanted to check was the heat flux that was being produced by the fire onto the face of Building B. Heat flux is the amount of heat transferred per unit area per unit time from or to a surface. For the simulation 10 heat flux gauges were placed on the face of Building B. I have shown the place of these gauges in Figure 53. I also graphed the results in Figure 54 of 2 of the gauges. The gauges graphed show that Building B will be facing intense heat flux from the fire. These heat flux ranges show that Building B's face and walking path sees a very serious amount of heat flux. The range is anywhere from kW/m^2 to 75 kW/m^2. This is much greater than the tenability limit set of 2.5 kW/m^2.

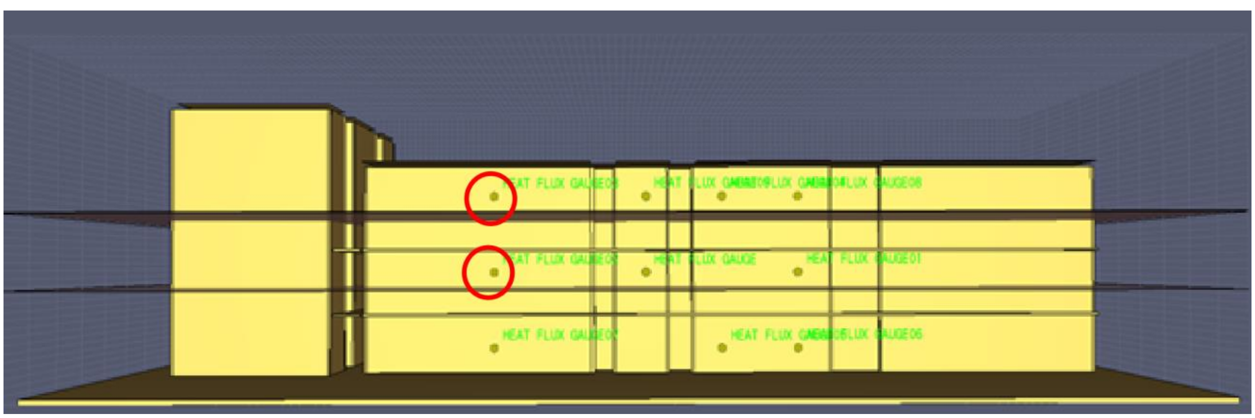


Figure 53: Heat Flux Device Placement

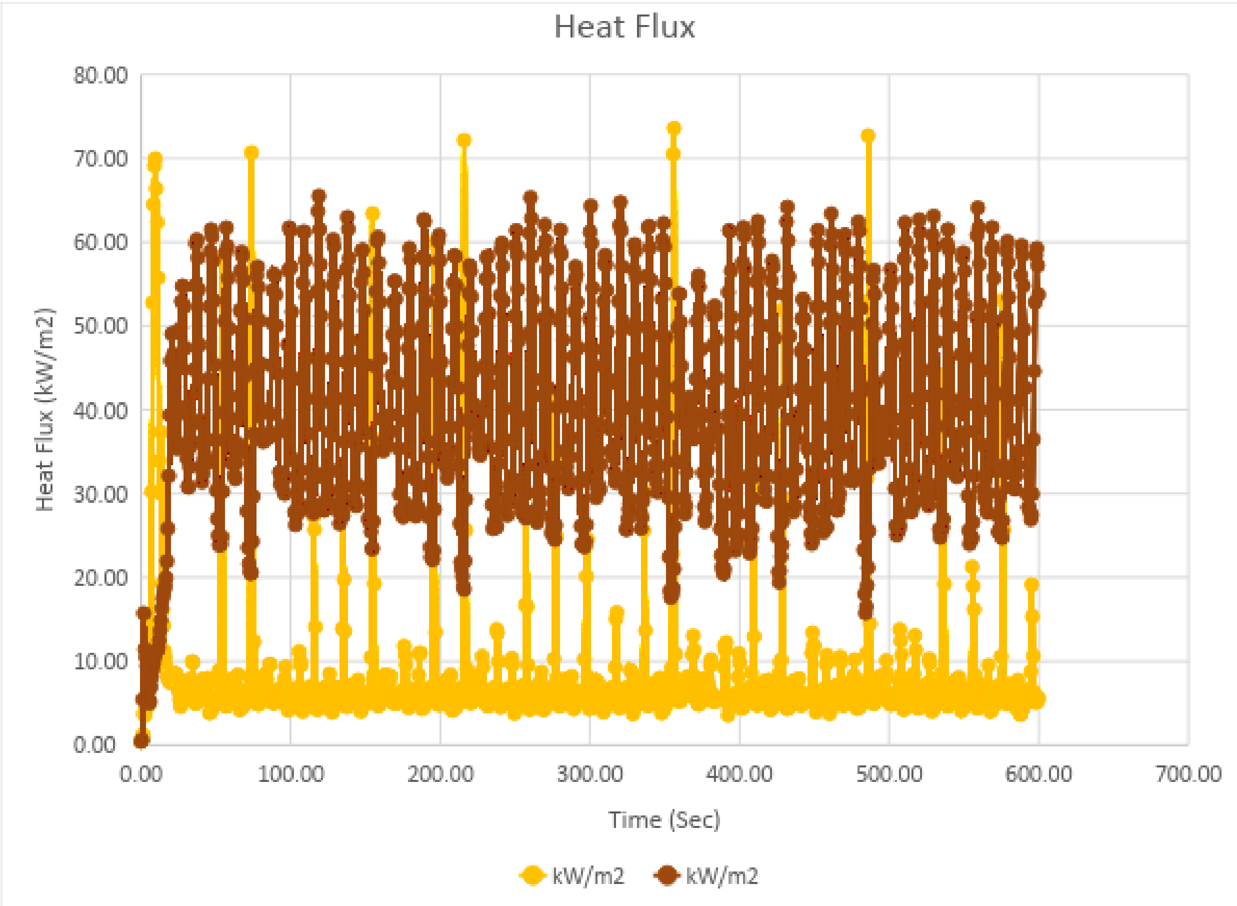


Figure 54: Heat Flux Graph

Fire Design Scenario 2 Summary

For the second fire scenario, I modeled a fire that started in Building 187 – Simpson Strong-Tie Material Demonstration Lab. It is located Buildings 186 courtyard adjacent from Buildings B and C. After running the simulations in pathfinder and Pyrosim it was concluded that a fire in Building 187 severely affects the tenable conditions of Building 186. It was concluded that the max visibility does reach 5 feet above the walking surfaces, and the max temperature surpasses the tenable max temperature of 50 degrees Celsius before the occupants have fully evacuated. Time of evacuation of the building is 2 minutes and 20 seconds. A max temperature of 265 degrees is reached before the occupants have fully evacuated. Also, the max heat flux on the building reaches well over the tenable limit of 2.5 kW/m^2 before the occupants have fully evacuated. A max heat flux of 75 kW/m^2 is reached before the occupants have fully evacuated.

The Construction Innovation Center does not meet all code requirements and showed insufficient performance during the fire simulations. I would recommend that the Simpson Strong Tie Demonstrations Lab and The Construction Innovation Center have connected fire alarm systems due to the buildings having about an 8 ft. separation distance. The occupants of each building would benefit from being alerted to a fire in the adjacent building. I would also like to recommend that both Buildings 186 and 187 have an exterior sprinkler system due to the possibility of dangerous fire situations. An exterior sprinkler system would help limit the amount of heat released and help provide tenable conditions while occupants escape.

Performance Based Analysis Summary

The first design of performance-based analysis for The Construction Innovation Center showed positive results. The criteria set for the buildings was that the occupants needed to be evacuated before the conditions of the building reached 50 – 60 degrees Celsius and the building had to maintain a 5 ft. of clearance from the smoke zone to the ground level while occupants are present. Lastly, ASET had to be greater than RSET. The first scenario was modeled around the lobby of the fire floor of Building A. There are 4 chairs present that are the ignition source of the fire. After running the simulations in Pathfinder and Pyrosim it was concluded that The Construction Innovation Center met the tenable conditions. Thus RSET > ASET.

The second design of performance-based analysis for The Construction Innovation Center showed negative results. The second design scenario was modeled around Building 187 – The Simpson Strong-Tie Material Demonstration Lab, which is in the courtyard of Building 186. After running the simulations in Pathfinder and Pyrosim it was concluded it was concluded that the max visibility does reach 5 feet above the walking surfaces, and the max temperature surpasses the tenable max temperature of 50 degrees Celsius before the occupants have fully evacuated. A max temperature of 265 degrees is reached. Also, the max heat flux on the building reaches well over the tenable limit of 2.5 kW/m^2. A max heat flux of 75 kW/m^2 is reached. Time of evacuation of the first floor is 2 minutes and 20 seconds.

The Construction Innovation Center does not meet all code requirements and showed insufficient performance during the fire simulations. I would recommend that the Simpson Strong Tie Demonstrations Lab and The Construction Innovation Center have connected fire alarm systems due to the buildings having about an 8 ft. separation distance. The occupants of each building would benefit from being alerted to a fire in the adjacent building. I would also like to recommend that both Buildings 186 and 187 have an exterior sprinkler system due to the possibility of dangerous fire situations. An exterior sprinkler system would help limit the amount of heat released and help provide tenable conditions while occupants escape

Conclusion

In this report you have found the analysis of existing fire protection systems and features that are installed in the Construction Innovation Center at California Polytechnic State University, San Luis Obispo. The Building's construction was completed in 2008 and is separated into three separate buildings A, B, and C connected by an exterior balcony. This report was separated into two separate analysis Prescriptive and Performance.

The Prescriptive analysis reviewed the building's means of egress, fire alarm systems, the suppression systems, and structural fire protection. The Prescriptive-based analysis of the Construction Innovation Center confirmed that the building meets the requirements of NFPA 101 The Life Safety Code, NFPA 13, NFPA 17, NFPA 72, NFPA 92, the International Building Code (IBC), and the California Building Code (CBC).

The performance-based analysis investigated two different fire scenarios. The first design is set in the lobby of the first floor of Building A. The second fire scenario examines the effects that a fire would have on Buildings B and C if it started in Building 187, The Simpson Strong-Tie Materials Demonstration Lab, which is in the courtyard of the Construction Innovation Center. For the performance-based analysis. Pyrosim and Pathfinder were used. Pyrosim is a type of fire dynamics simulator that simulated fire conditions inside the buildings including temperature, tenability, and other features. Pathfinder was used to simulate evacuation times. Both design scenarios yielded positive results of Required Safe Egress time (RSET) being greater than the Available Safe Egress Time (ASET).

The Construction Innovation Center does not meet all code requirements and showed insufficient performance during the fire simulations. I would recommend that the Simpson Strong Tie Demonstrations Lab and The Construction Innovation Center have connected fire alarm systems due to the buildings having about an 8 ft. separation distance. The occupants of each building would benefit from being alerted to a fire in the adjacent building. I would also like to recommend that both Buildings 186 and 187 have an exterior sprinkler system due to the possibility of dangerous fire situations. An exterior sprinkler system would help limit the amount of heat released and help provide tenable conditions while occupants escape.

References

(ed.), M. J. (2016). SFPE Handbook of Fire Protection Engineering, 5th edition. Society of Fire Protection Engineers: Springer.

Arthur E. Cote, P. (. (2008). Fire Protection Handbook, 20th Edition. National Fire Protection Association.

NFPA 101 Life Safety Code. (2015) National Fire Protection Association.

NFPA 13 Standard for the Installation of Sprinkler Systems. (2016) National Fire Protection Association.

NFPA 25 Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems. (2017) National Fire Protection Association.

NFPA 72 National Fire Alarm and Signaling Code. (2010). National Fire Protection Association

International Building Code 2012. 2012 ed. Country Club Hills, IL: International Code Council, 2014. Print.

Overholt, K. (2017, January). Scientific software development and scientific computing. Retrieved from www.koverholt.com

NIST. (2016). Fire Dynamics Simulator Technical Reference Guide, Volume 3: Validation. National Institute of Standards and Technology

"Cal Poly Construction Innovation Center." *Thoma Electric*, 2017, thomaelectric.com/cal-poly-construction-innovation-center/.

"Heat Release Rate Properties of Wood-Based Materials." *FDsys - Browse Code of Federal Regulations (Annual Edition)*, US Government Publishing Office, 1 Jan. 1983, www.gpo.gov/fdsys/pkg/GOVPUB-C13-c36205f5e8205bd7183d3f63470ed813/content-detail.html.

David L. Statler Jr, et al. "A Finite Element Analysis on the Modeling of Heat Release Rate, as Assessed by a Cone Calorimeter, of Char Forming Polycarbonate." *COMSOL Conference 2008 Boston*, Sept. 2009.

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.

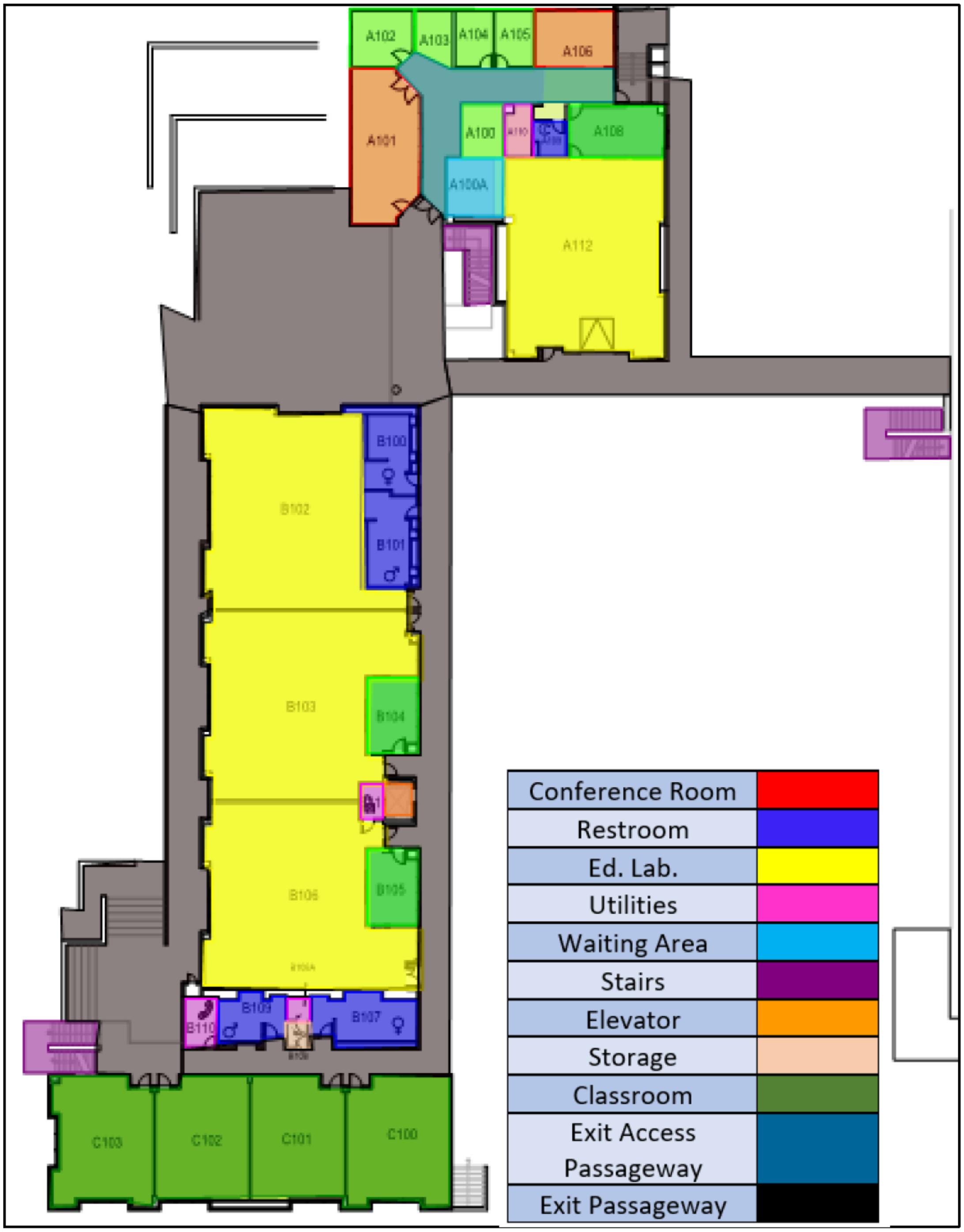
"WeatherSpark.com." *Average Weather in May in Douala, Cameroon - Weather Spark*, weatherspark.com/y/1286/Average-Weather-in-San-Luis-Obispo-California-United-States-Year-Round.

California Building Standards and Commission. *2016 California Fire Code* . title 24, part 9, CBSC.

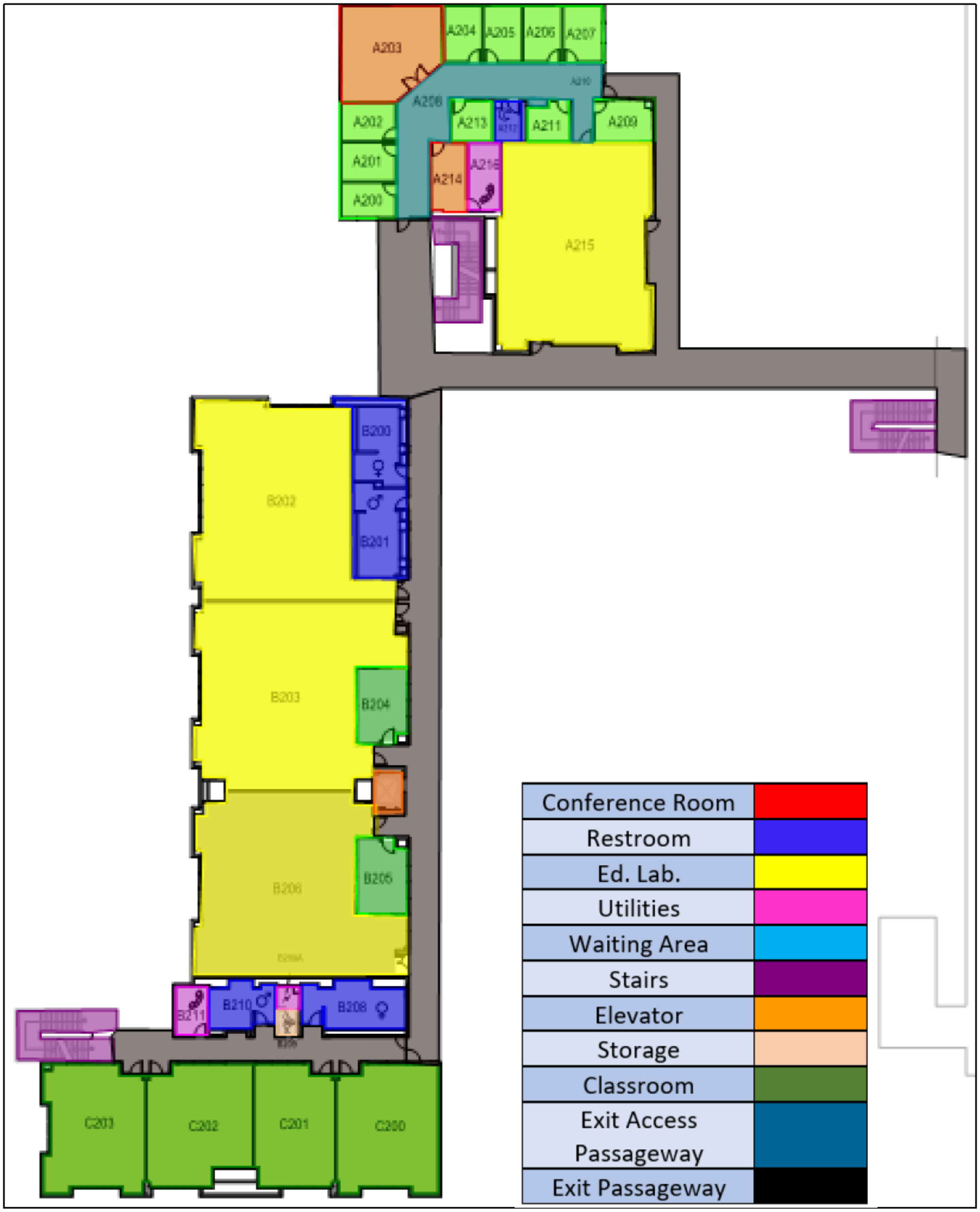
Appendix

A: Colored Rooms

Floor 1

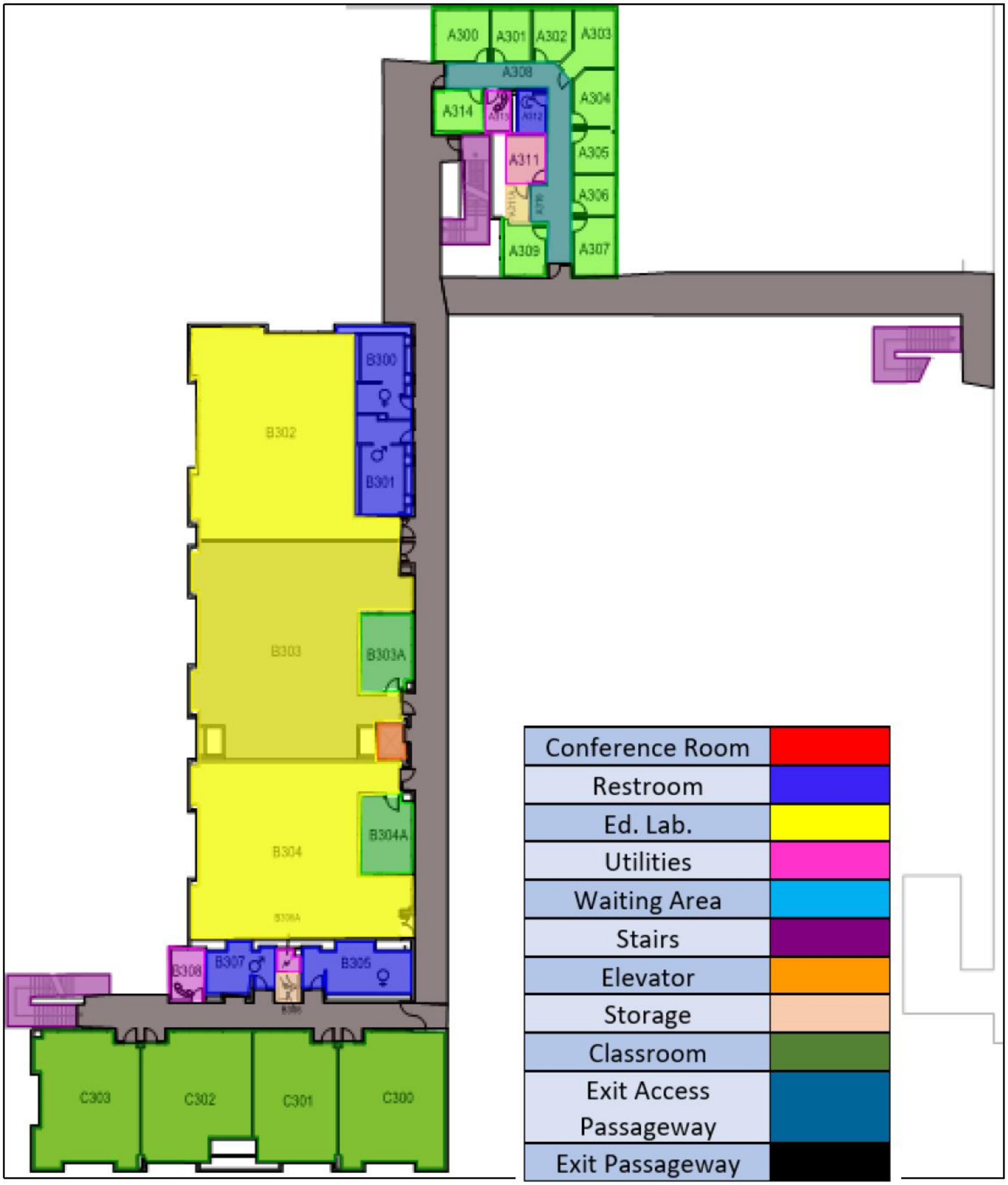


Floor 2



CAL POLY
SAN LUIS OBISPO

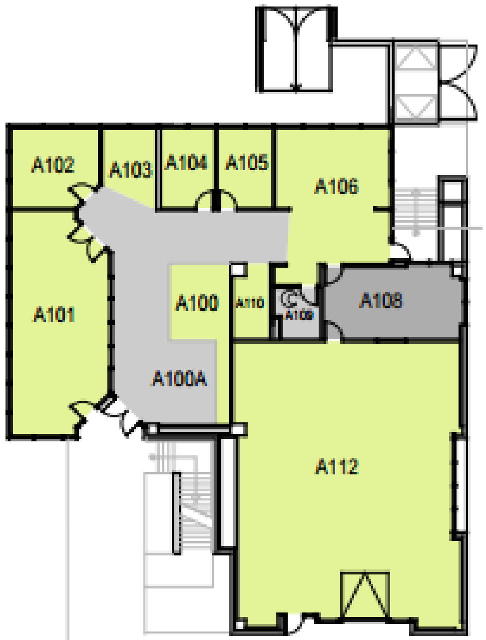
Floor 3



CAL POLY
SAN LUIS OBISPO

B: Occupant load

Floor 1 Building A



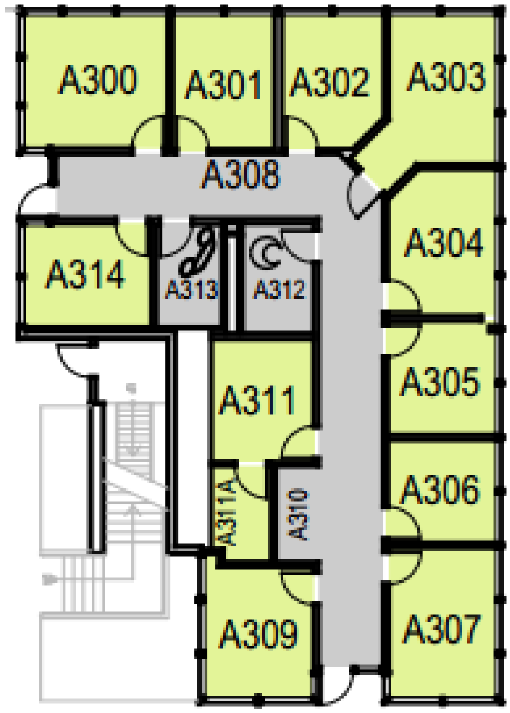
Room	Area (ft^2)	Occupant Load Factor	Occupant Load
A 100 Reception	116	100	1
A 100A Waiting Area	165	15	11
A 101 Conference Room	610	15	41
A 102 DCP Office	200	100	2
A 103 Office	110	100	2
A 104 Office	110	100	2
A 105 Office	110	100	2
A 108 Privately Funded Fac	300	100	3
A 112 Heavy/Civil Lab	1800	50	36

CAL POLY
SAN LUIS OBISPO

Floor 2 Building A

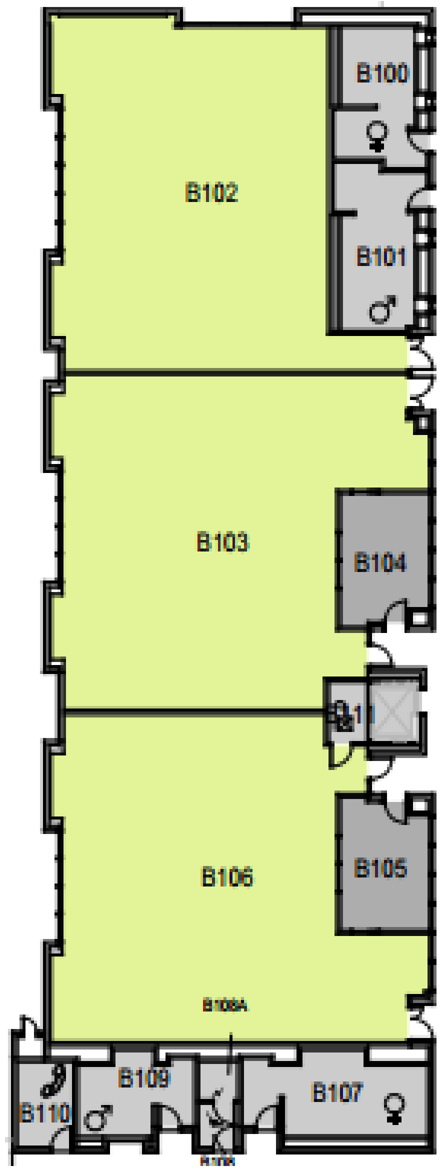
Room	Area (ft^2)	Occupant Load Factor	Occupant Load
A 200 Office	100	100	2
A 201 Office	110	100	2
A 202 Office	110	100	2
A 203 Conference Room	530	15	36
A 204 Office	115	100	2
A 205 Office	115	100	2
A 206 Office	115	100	2
A 207 Office	110	100	2
A 209 Office	300	100	3
A 211 Office	110	100	2
A 213 Office	160	100	2
A 215 Lab	1998	50	40

Floor 3 Building A



Room	Area (ft^2)	Occupant Load Factor	Occupant Load
A 300 Office	110	100	2
A 301 Office	110	100	2
A 302 Office	110	100	2
A 303 Office	110	100	2
A 304 Office	110	100	2
A 305 Office	110	100	2
A 306 Office	110	100	2
A 307 Office	110	100	2
A 309 Office	110	100	2
A 311 Office	110	100	2
A 314 Office	110	100	2

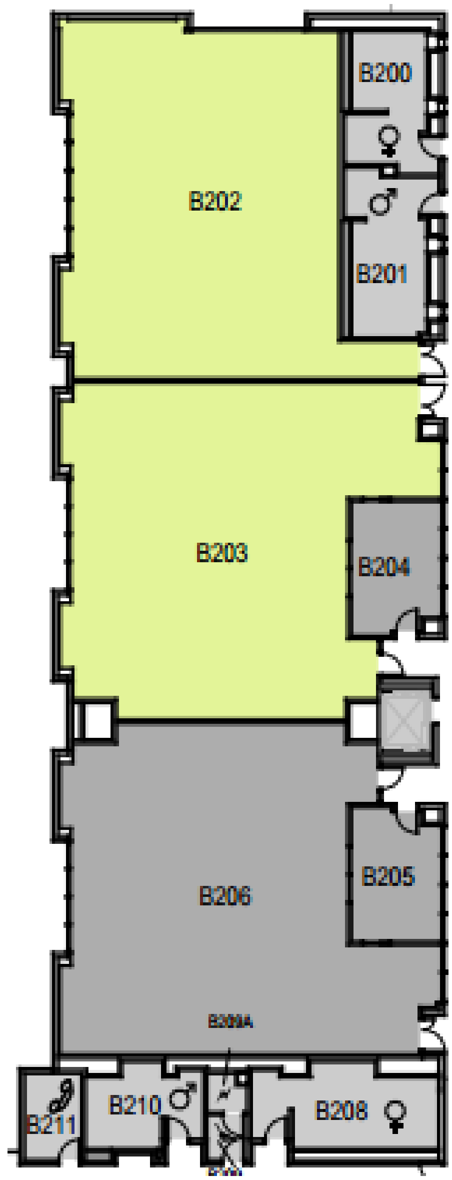
Floor 1 Building B



Room	Area (ft^2)	Occupant Load Factor	Occupant Load
B 102	1987	50	38
B 103	1994	50	40
B 104 Private Research	235	100	3
B 105 Private Research	235	100	3
B 106 Lab	1989	50	40

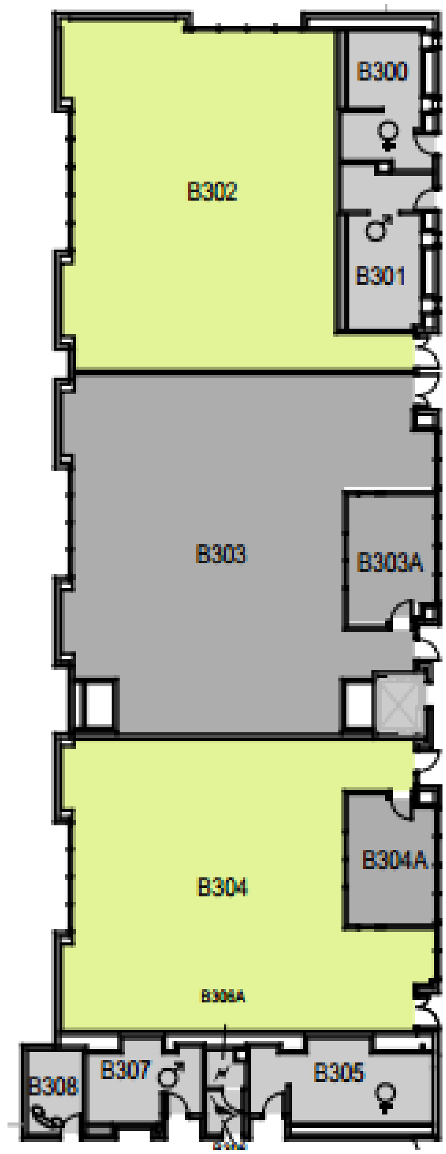
CAL POLY
SAN LUIS OBISPO

Floor 2 Building B



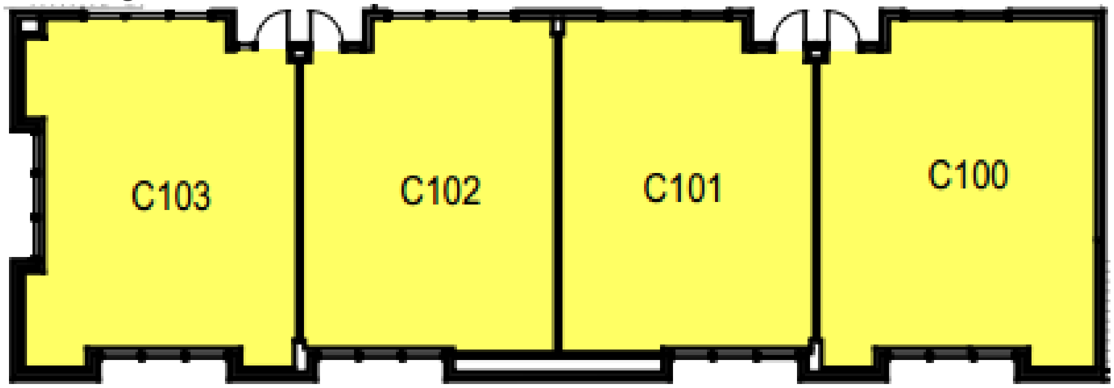
Room	Area (ft^2)	Occupant Load Factor	Occupant Load
B 202 Lab	1902	50	39
B 203 Lab	1966	50	40
B 204 Office	235	100	3
B 205 Office	235	100	3
B 206 Lab	1989	50	40

Floor 3 Building B



Room	Area (ft^2)	Occupant Load Factor	Occupant Load
B 302 Lab	1904	50	39
B 303 Lab	2450	50	49
B 304 Lab	2094	50	42

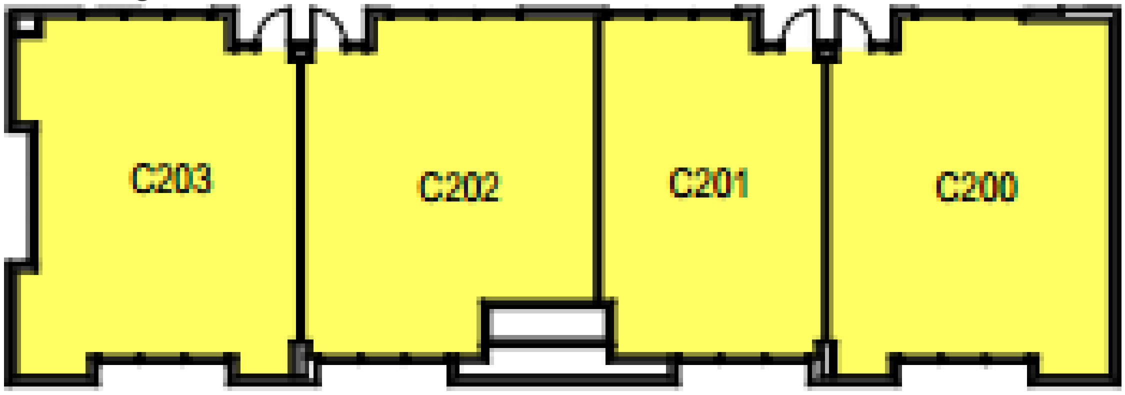
Floor 1 Building C



Room	Area (ft^2)	Occupant Load Factor	Occupant Load
C 100	728	20	37
C 101 Lecture	722	20	37
C 102 Lecture	721	20	37
C 103 Lecture	735	20	37

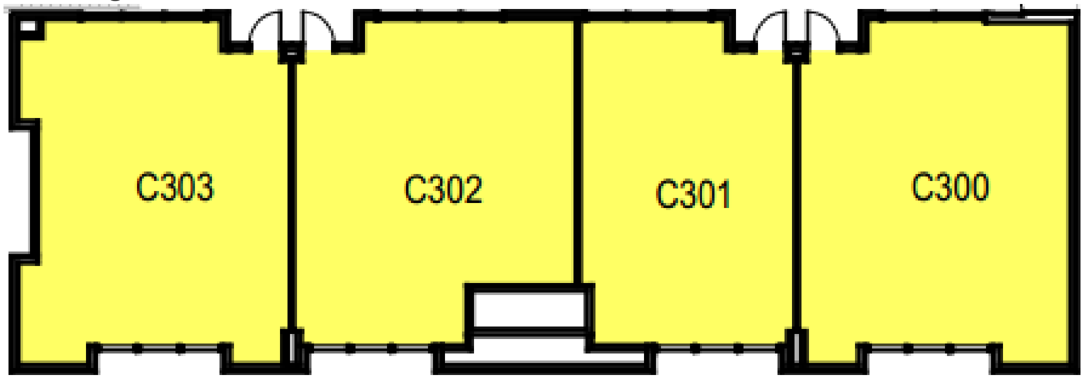
CAL POLY
SAN LUIS OBISPO

Floor 2 Building C



Room	Area (ft^2)	Occupant Load Factor	Occupant Load
C 200 Lecture	753	20	38
C 201 Lecture	466	20	29
C 202 Lecture	749	20	38
C 203 Lecture	769	20	38

Floor 3 Building C



Room	Area (ft^2)	Occupant Load Factor	Occupant Load
C 300 Lecture	735	20	37
C 301 Lecture	564	20	29
C 302 Lecture	821	20	41
C 303 Lecture	759	20	38

C: Fire Rated Walls

Floor 1

CAL POLY
SAN LUIS OBISPO

Floor 2

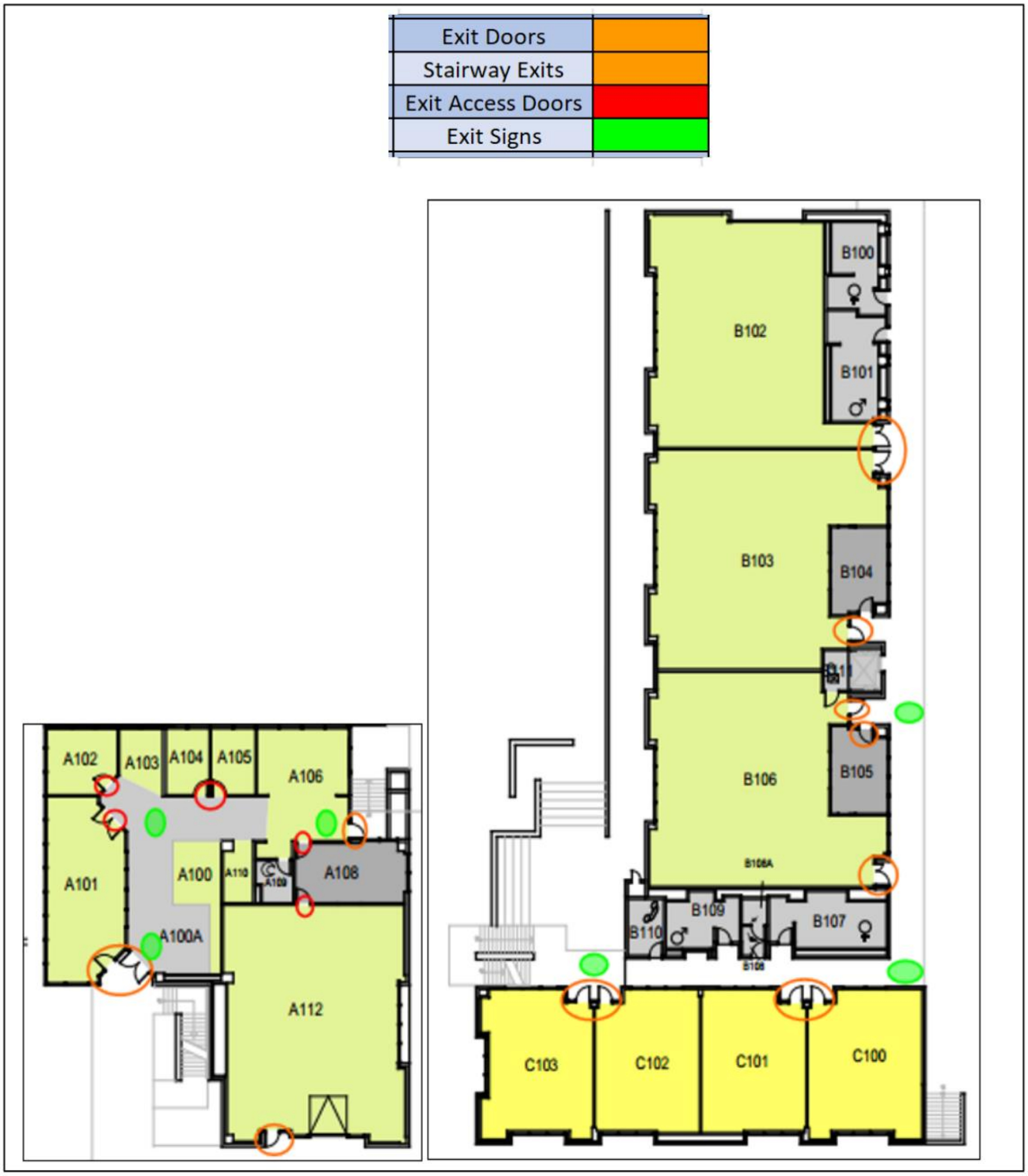
CAL POLY
SAN LUIS OBISPO

Floor 3

CAL POLY
SAN LUIS OBISPO

D: Exits and Exit Signage

Floor 1

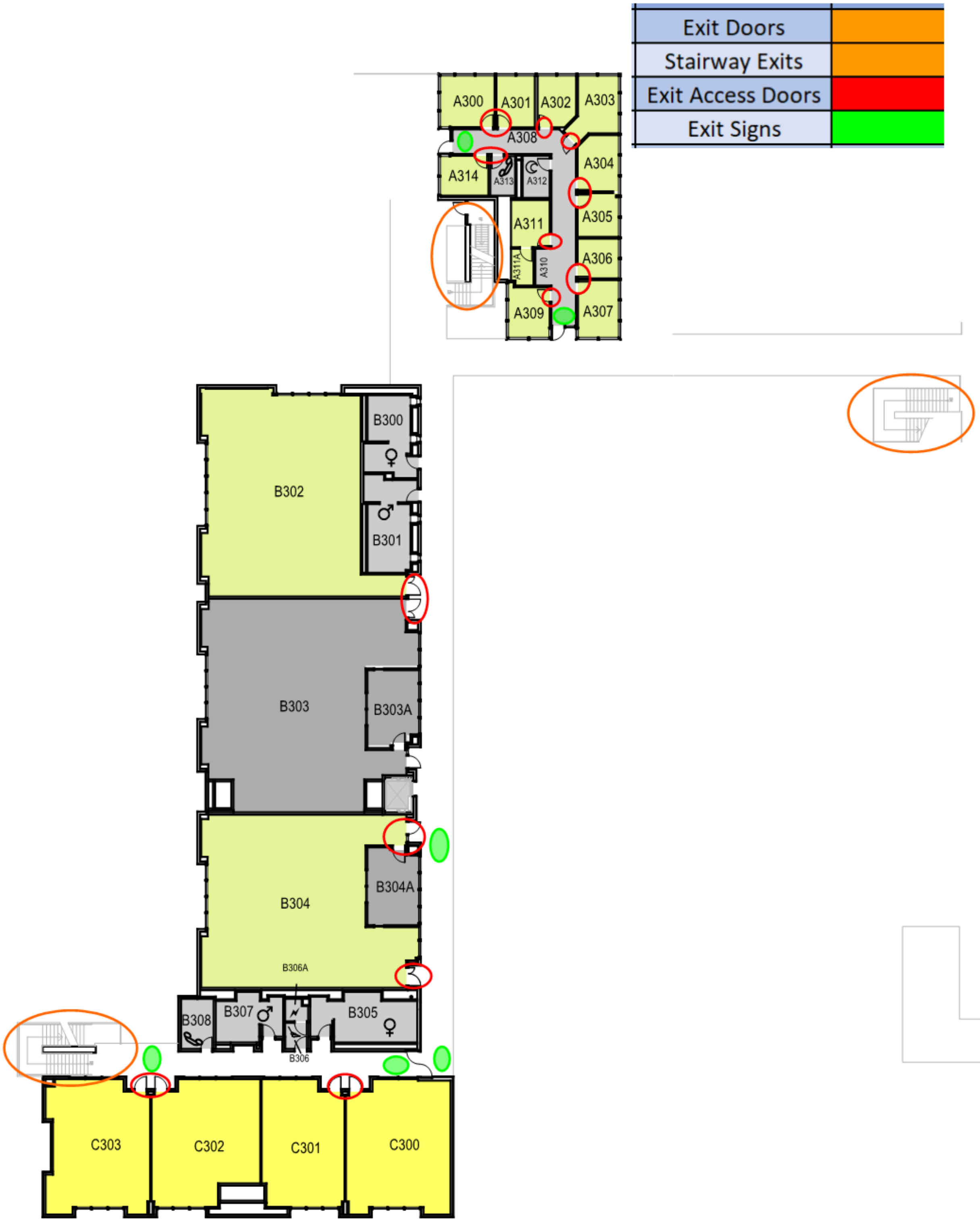


CAL POLY
SAN LUIS OBISPO

Floor 2


Exit Doors
Stairway Exits
Exit Access Doors
Exit Signs
A203
A204
A205
A206
A207
A213
A211
A209
A202
A201
A200
A214
A216
A215
B200
B202
B201
B203
B204
B205
B206
B211
B210
B208
C203
C202
C201
C200

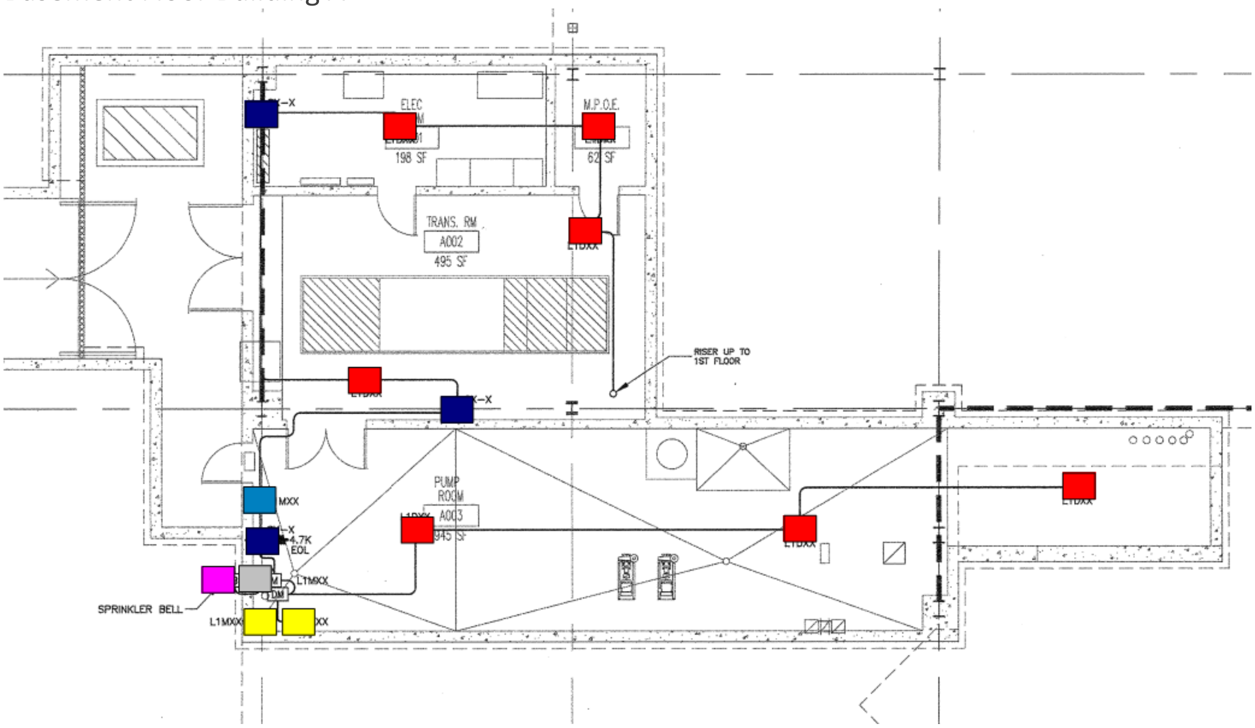
Floor 3



CAL POLY
SAN LUIS OBISPO

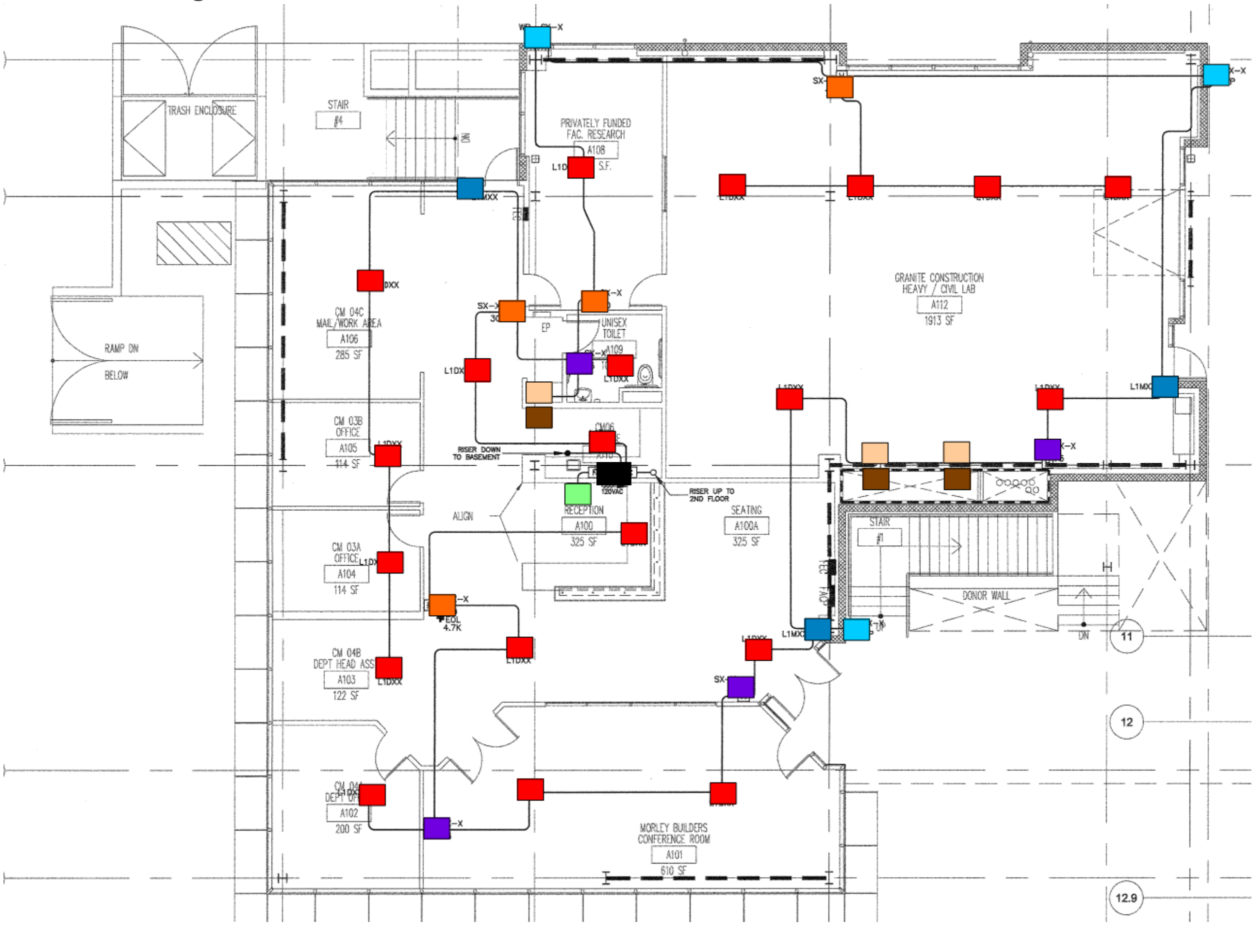
E: Location of Devices

Basement Floor Building A



Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

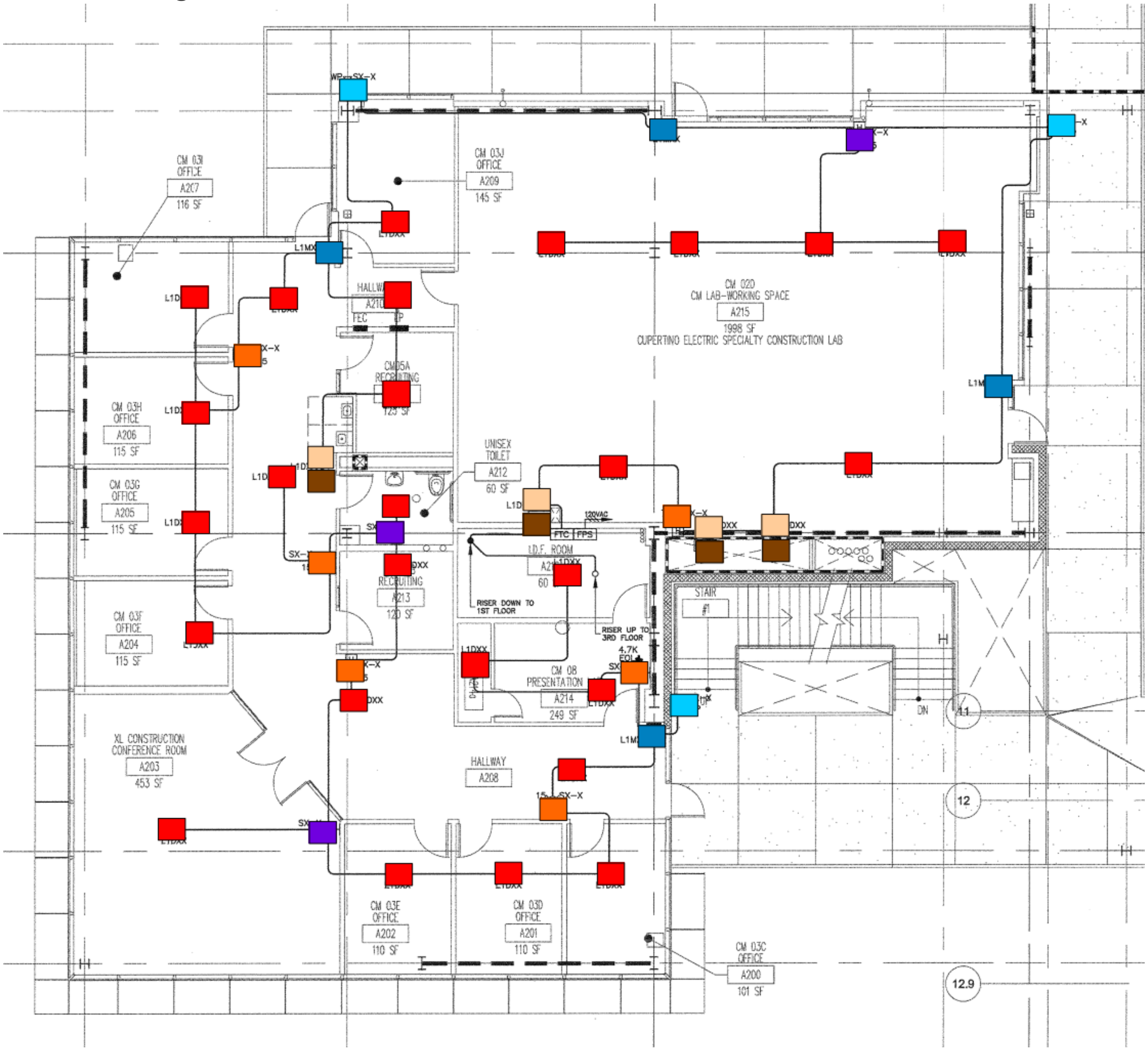
Floor 1 Building A



Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

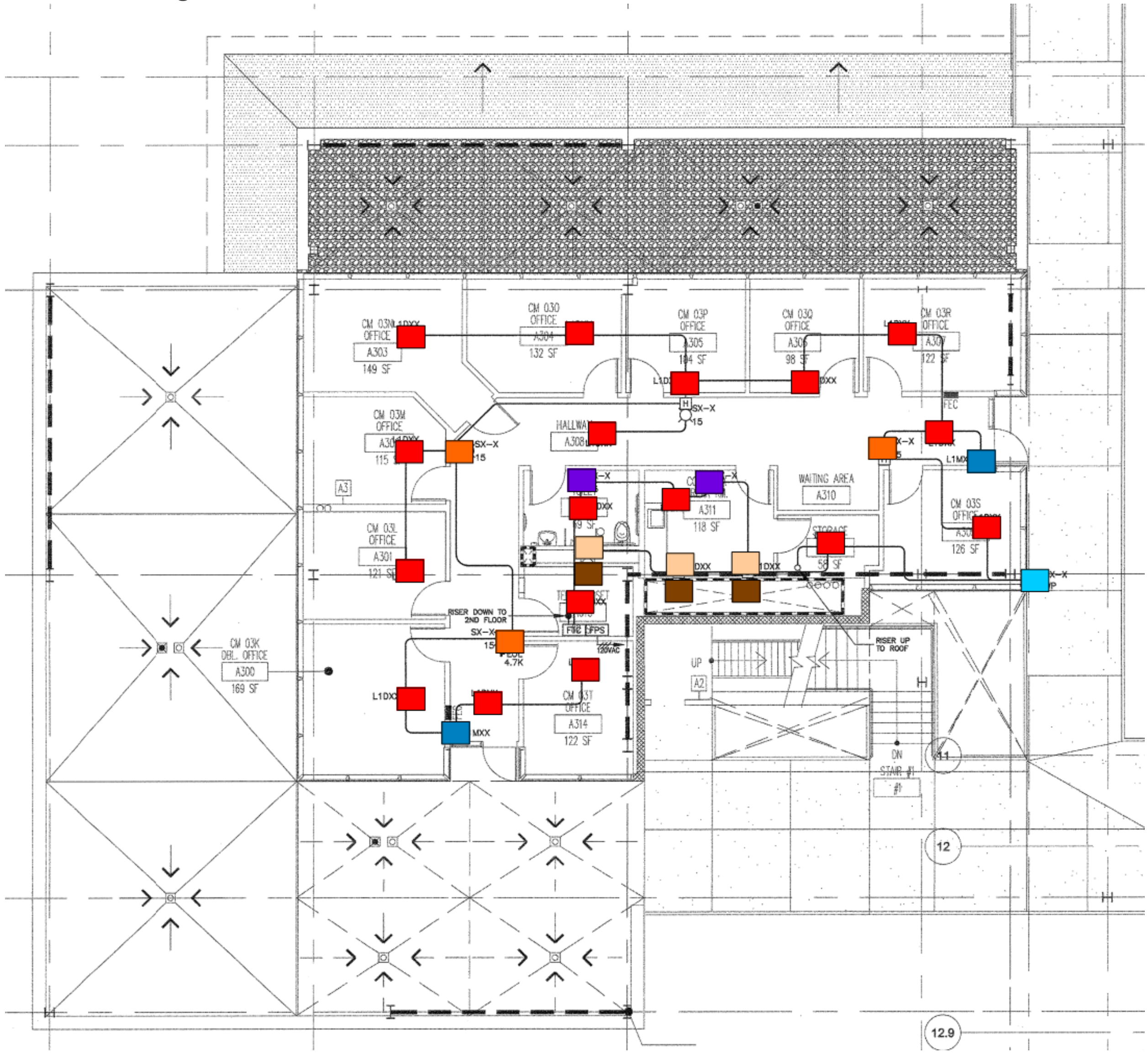
CAL POLY SAN LUIS OBISPO

Floor 2 Building A



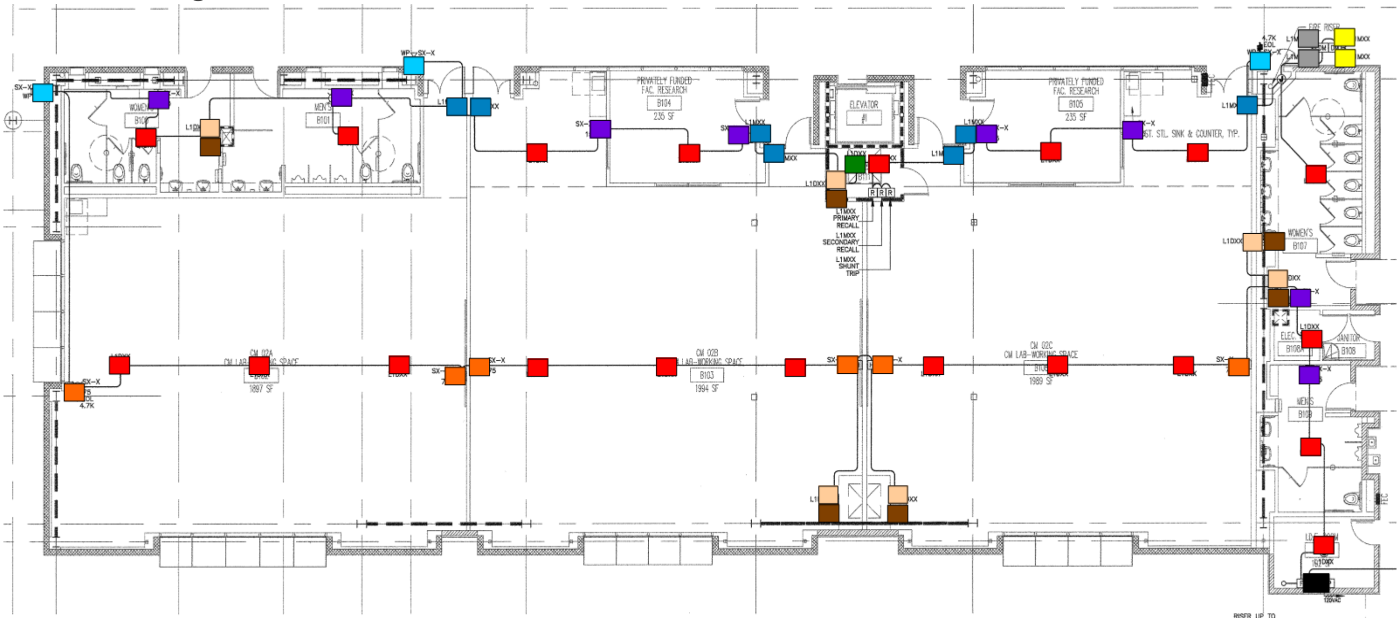
Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

Floor 3 Building A



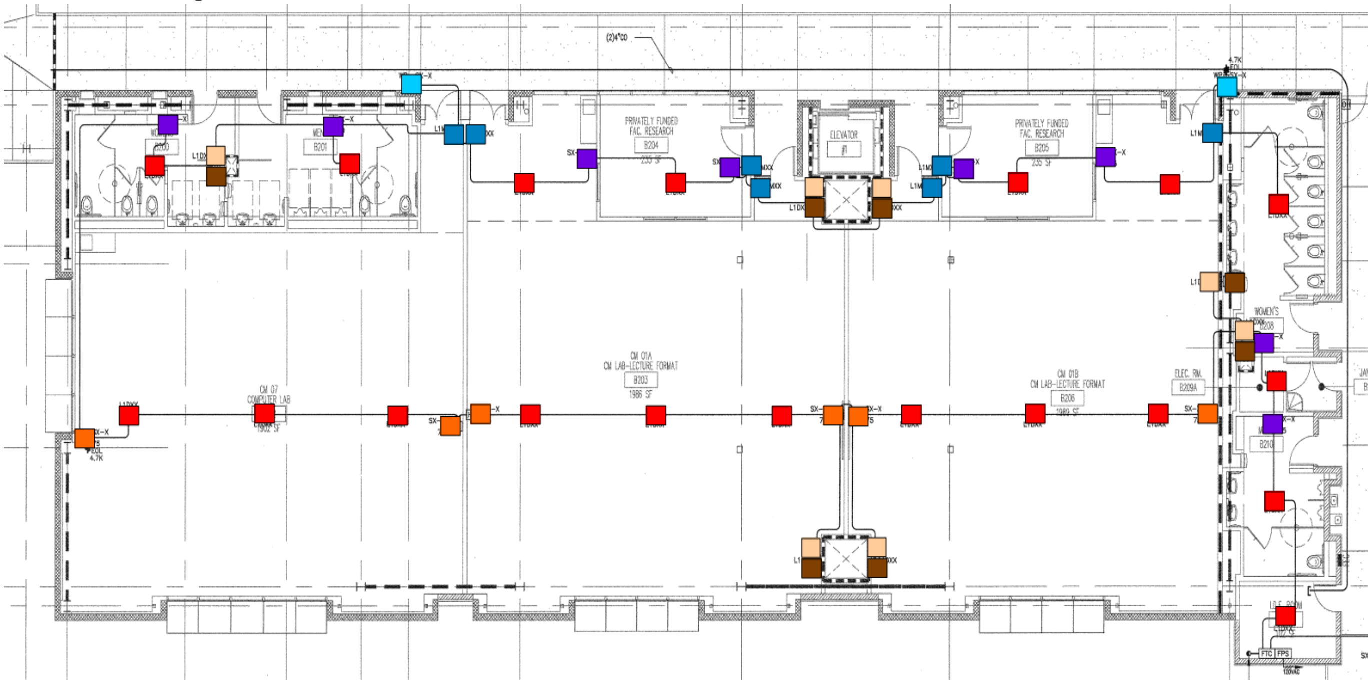
Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

Floor 1 Building B



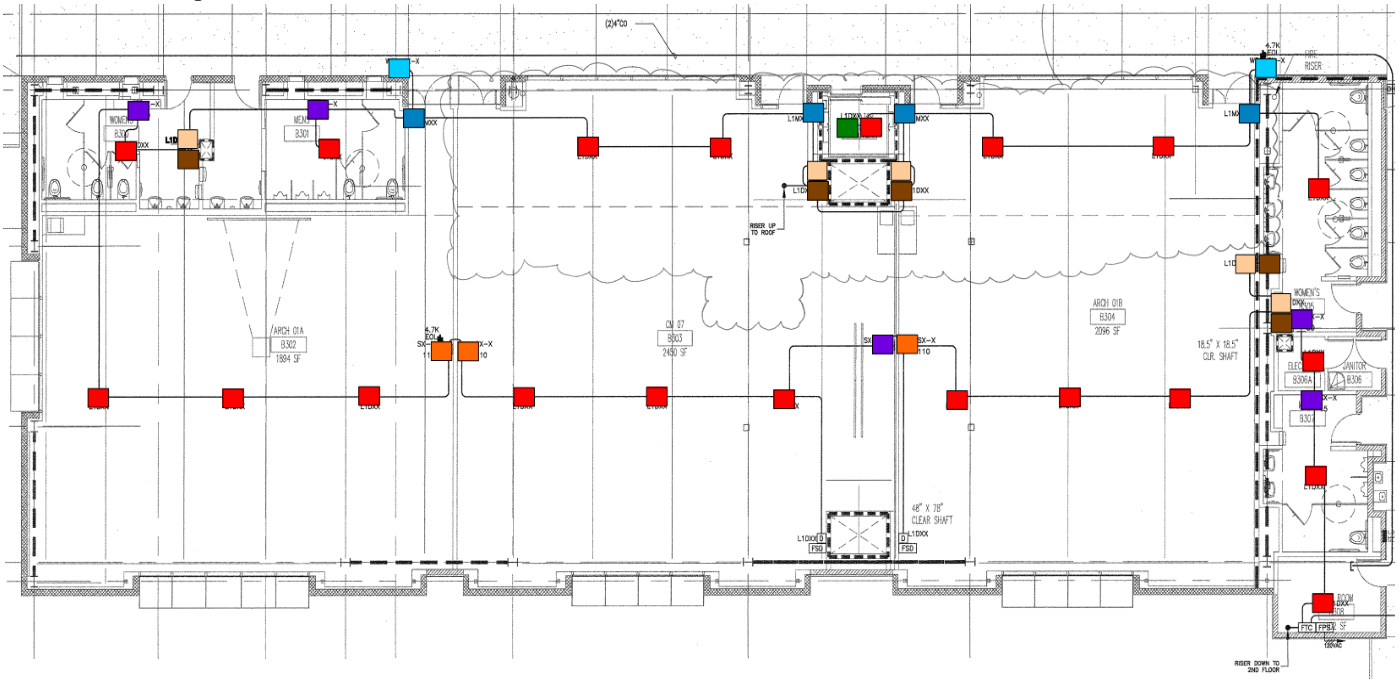
Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

Floor 2 Building B



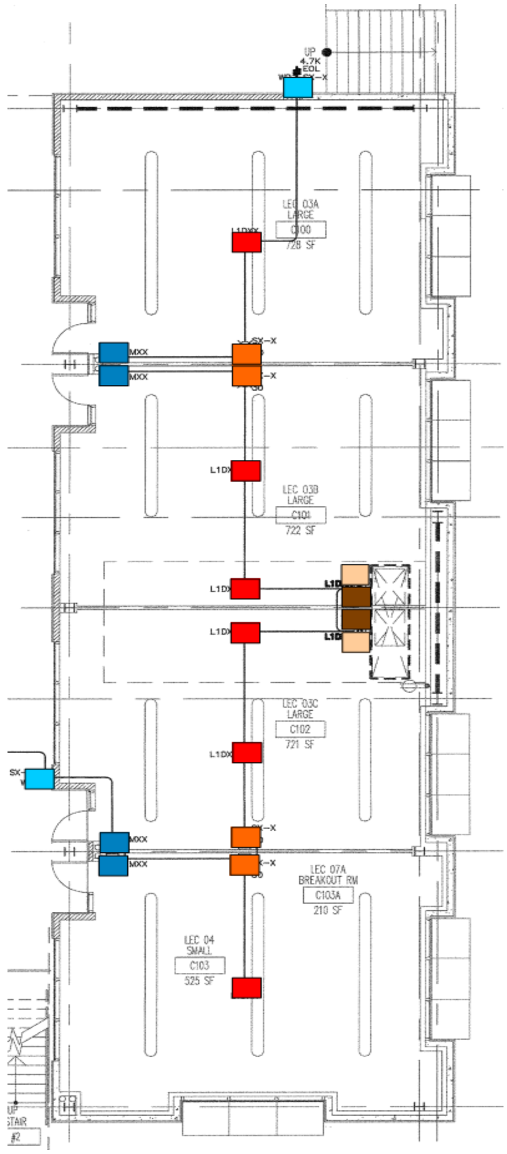
Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

Floor 3 Building B



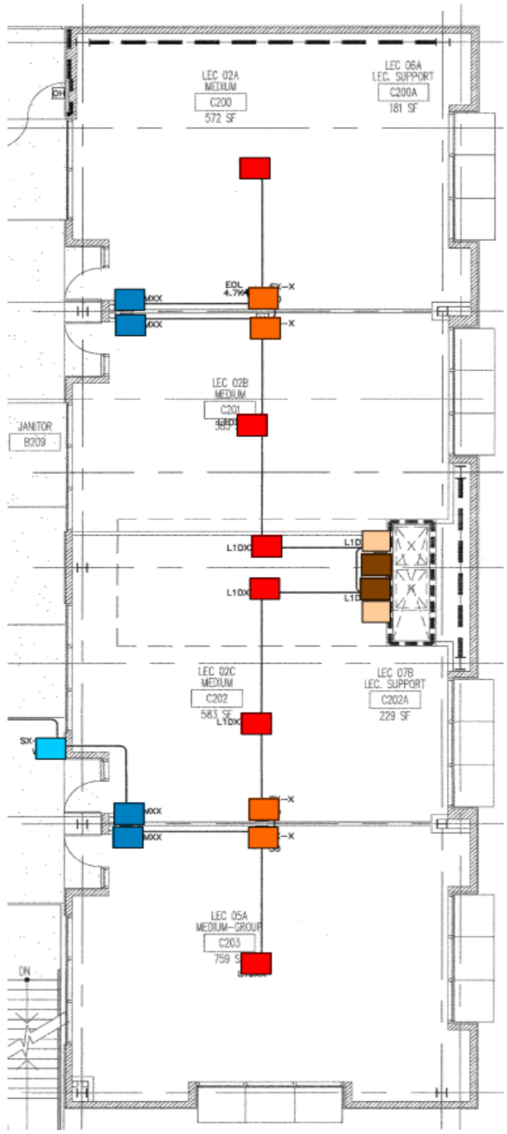
Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

Floor 1 Building C



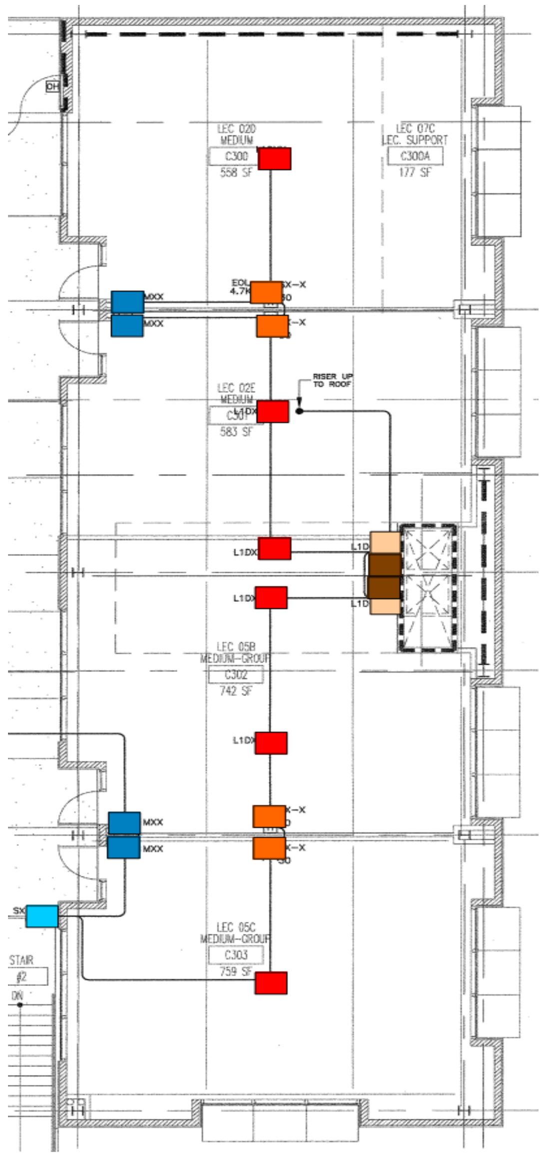
Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

Floor 2 Building C



Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

Floor 3 Building C

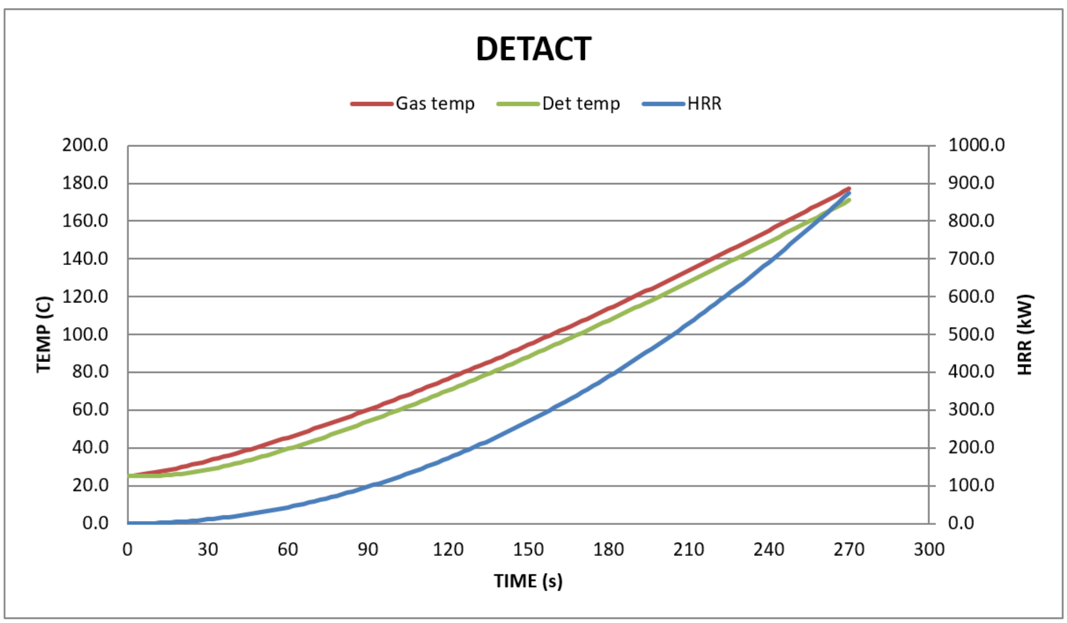


Strobe		Fire Alarm Control Panel		Waterflow Bell	
Horn		Valve Tamper Switch		Fire Smoke Damper	
Pull Down Station		Horn/Strobe		Duct Smoke Detector	
Horn with Gasket		Annunciator		Multi- Sensor Detector	
Heat Detector		Waterflow Switch			

F: Detact for Fire Alarms

I selected Room 206 in the Construction Innovation Center for this fire Scenario. The room is in building B of the facility on the second floor. The room has a 10-ft. ceiling and I modeled the fire as starting on the floor in a corner the furthest point from a heat detector. This gives the longest response time for a detector. I modeled the fire as a medium growth fire with alpha equal to .047. I modeled ambient temperature as 25 degrees Celsius and actuation temperature 21.1 degrees Celsius above that at 46.1 degrees. NFPA 72-ANEX B Table B.4.7.5.3 Temperature Rise for Detector Response says that the average temperature rise for scattering is 21.1 degrees Celsius. I used a low RTI of 15 for this model. The results show that it would take between 62-64 seconds to activate a heat detector in room 206. At the actuation time the heat release rate would be between 46.1-49.2 kW

INPUT PARAMETERS			CALC. PARAMETERS	
Ceiling height (H)	3.048	m	R/H	0.328
Radial distance (R)	1.0	m	dT(cj)/dT(pl)	0.631
Ambient temperature (To)	25	C	u(cj)/u(pl)	0.506
Actuation temperature (Td)	46.1	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



Calculation time (s)	HRR	Gas temp	Gas velocity	Det temp	dT/dt
62	46.1	46.4	1.25	40.34	0.4515
64	49.2	47.3	1.28	41.25	0.4580

G: Voltage Drop Calculations

The notification devices in the Construction Innovation Center are connected using normal 12 AWG wire and 24 VDC. The Circuits of the wires can be seen in the Fire alarm plans in the appendix I have attached. The Voltage drop calculations are seen below

Circuit Number	S1	S2	S1	S1	S1	S2	S3	S1	S2	S3	S1	S2
Building	A1	AB	A2	A3	B1	B1	C1	B2	B2	C2	B3	C3
Wire	12	12	12	12	12	12	12	12	12	12	12	12
Panel	NFS-640	NFS-640	FCPS	FCPS	FCPS	FCPS	FCPS	FCPS	FCPS	FCPS	FCPS	FCPS
Length	340	109	353	175	195	445	139	197	440	109	442	142
Resistance (ohm/1000 ft.)	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98
Total Current Amp	1.208	0.084	1.176	0.608	1.422	0.588	0.552	1.422	0.56	0.524	1.358	0.0524
Voltage drop	1.63	0.04	1.64	0.42	1.1	1.04	0.3	1.11	0.98	0.23	2.38	0.29
VD %	6.78	0.15	6.85	1.76	4.58	4.32	1.27	4.62	4.07	0.94	9.89	1.23

Circuit Number	S1	S2	S1	S1	S1	S2	S3	S1	S2	S3	S1	S2
Strobe 15 cd	1	0	2	2	1	4	0	1	4	0	1	0
Strobe 30 cd	1	0	1	0	1	2	0	1	2	0	3	0
Strobe 75 cd	1	0	0	0	0	0	0	0	0	0	1	0
Interior Horn	0	3	0	0	0	0	0	0	0	0	0	0
Exterior Horn	3	0	3	1	0	3	2	0	2	1	2	1
Horn/Strobe 15 cd	1	0	4	4	0	0	0	0	0	0	0	0
Horn/Strobe 30 cd	2	0	0	0	0	0	4	0	0	4	0	4
Horn/Strobe 75 cd	2	0	2	0	6	0	0	6	0	0	0	0
Horn/Strobe 110 cd	0	0	0	0	0	0	0	0	0	0	3	0
Total	11	3	12	7	8	9	6	8	8	5	10	5

VOLTAGE DROP FORMULAS

VD = VOLTAGE DROP
L = ONE WAY LENGTH OF CIRCUIT (IN FEET)
R = CONDUCTOR RESISTANCE (IN OHMS/FEET)
I = LOAD CURRENT (IN AMPS)

$$VD = \frac{2 \times L \times R \times I}{1000}$$

$$\%VD = \frac{VD}{24} \times 100$$

(DEVICE VOLTAGE)

H: Battery Calculations

Floor 1 Building A

BATTERY CALCULATION

NFS-640 - Building A 1st Floor

	EQUIPMENT		QUANTITY	SUPERVISORY CURRENT (IN AMPS)		ALARM CURRENT (IN AMPS)	
				UNIT	TOTAL	UNIT	TOTAL
1	CPU-640		1	0.2300	0.2300	0.2300	0.2300
2	KDM-2		1	0.0400	0.0400	0.0940	0.0940
3	NCM-W, NCM-F		1	0.1100	0.1100	0.1100	0.1100
4	SLC1 DEVICE ACTIVATION CURRENT		1	0.2000	0.2000	0.2000	0.2000
6	LCD-80		1	0.0500	0.0500	0.1000	0.1000
7	NBG-12LX		10	0.0003	0.0030	0.0003	0.0030
8	FAPT-851		71	0.0003	0.0213	0.0003	0.0213
10	FSD-751PL		10	0.0003	0.0030		
13	FMM-1		1	0.0003	0.0003	0.0003	0.0003
14	FDM-1		1	0.0008	0.0008	0.0057	0.0057
A1	NOTIFICATION CIRCUIT S1		1			1.2080	1.2080
AB	NOTIFICATION CIRCUIT S2		1			0.0840	0.0840
	SUB-TOTALS (IN AMPS)				0.6584		2.0563
	TIME FACTOR: 24 HOUR STANDBY				X 24		
	5 MINUTES IN ALARM						X 0.083
	SUB-TOTALS (IN AMPHOURS):				15.8004		0.1714
	STANDBY AMPHOURS		15.8004				
	ALARM AMPHOURS	+	0.1714				
	SYSTEM AMPHOURS	=	15.9718				
	+25% DERATING	+	3.9929				
	TOTAL AMPHOURS	=	19.9647				
	BATTERIES PROVIDED		55.00				
	TOTAL AMPHOURS	-	19.9647				
	AVAILABLE SPARE CAPACITY	=	35.04				

Floor 2 Building A

BATTERY CALCULATION

FCPS-24S - Building A 2nd Floor

	EQUIPMENT		QUANTITY	SUPERVISORY CURRENT (IN AMPS)		ALARM CURRENT (IN AMPS)	
				UNIT	TOTAL	UNIT	TOTAL
5	FCPS-24S		1	0.0650	0.0650	0.1450	0.1450
A2	NOTIFICATION CIRCUIT S1		1			1.1760	1.1760
	SUB-TOTALS (IN AMPS)				0.0650		1.3210
	TIME FACTOR: 24 HOUR STANDBY				X 24		
	5 MINUTES IN ALARM						X 0.083
	SUB-TOTALS (IN AMPHOURS):				1.5600		0.1101
	STANDBY AMPHOURS		1.5600				
	ALARM AMPHOURS	+	0.1101				
	SYSTEM AMPHOURS	=	1.6701				
	+25% DERATING	+	0.4175				
	TOTAL AMPHOURS	=	2.0876				
	BATTERIES PROVIDED		7.20				
	TOTAL AMPHOURS	-	2.0876				
	AVAILABLE SPARE CAPACITY	=	5.11				

Floor 3 Building A

BATTERY CALCULATION						
FCPS-24S - Building A 3rd Floor						
EQUIPMENT		QUANTITY	SUPERVISORY CURRENT (IN AMPS)		ALARM CURRENT (IN AMPS)	
			UNIT	TOTAL	UNIT	TOTAL
5	FCPS–24S	1	0.0650	0.0650	0.1450	0.1450
A3	NOTIFICATION CIRCUIT S1	1			0.6080	0.6080
	SUB–TOTALS (IN AMPS)			0.0650		0.7530
	TIME FACTOR: 24 HOUR STANDBY			X 24		
	5 MINUTES IN ALARM					X 0.083
	SUB–TOTALS (IN AMPHOURS):			1.5600		0.0628
	STANDBY AMPHOURS	1.5600				
	ALARM AMPHOURS +	0.0628				
	SYSTEM AMPHOURS =	1.6228				
	+25% DERATING +	0.4057				
	TOTAL AMPHOURS =	2.0284				
	BATTERIES PROVIDED	7.20				
	TOTAL AMPHOURS –	2.0284				
	AVAILABLE SPARE CAPACITY =	5.17				

Floor 1 Building B and C

BATTERY CALCULATION						
NFS-640 - Building B 1st Floor						
	EQUIPMENT	QUANTITY	SUPERVISORY CURRENT (IN AMPS)		ALARM CURRENT (IN AMPS)	
			UNIT	TOTAL	UNIT	TOTAL
1	CPU-640	1	0.2300	0.2300	0.2300	0.2300
2	KDM-2	1	0.0400	0.0400	0.0940	0.0940
3	NCM-W, NCM-F	1	0.1100	0.1100	0.1100	0.1100
4	SLC1 DEVICE ACTIVATION CURRENT	1	0.2000	0.2000	0.2000	0.2000
7	NBG-12LX	30	0.0003	0.0090	0.0003	0.0090
8	FAPT-851	77	0.0003	0.0231	0.0003	0.0231
9	FST-851	2	0.0003	0.0005	0.0003	0.0005
10	FSD-751PL	28	0.0003	0.0084		
12	FRM-1	5	0.0002	0.0010	0.0002	0.0010
14	FDM-1	2	0.0008	0.0015	0.0057	0.0114
	SUB-TOTALS (IN AMPS)			0.6235		0.6790
	TIME FACTOR: 24 HOUR STANDBY			X 24		
	5 MINUTES IN ALARM					X 0.083
	SUB-TOTALS (IN AMPHOURS):			14.9650		0.0566
	STANDBY AMPHOURS	14.9650				
	ALARM AMPHOURS +	0.0566				
	SYSTEM AMPHOURS =	15.0215				
	+25% DERATING +	3.7554				
	TOTAL AMPHOURS =	18.7769				
	BATTERIES PROVIDED	55.00				
	TOTAL AMPHOURS −	18.7769				
	AVAILABLE SPARE CAPACITY =	36.22				

BATTERY CALCULATION						
FCPS-24S - Building B 1st Floor						
	EQUIPMENT	QUANTITY	SUPERVISORY CURRENT (IN AMPS)		ALARM CURRENT (IN AMPS)	
			UNIT	TOTAL	UNIT	TOTAL
5	FCPS-24S	1	0.0650	0.0650	0.1450	0.1450
B1	NOTIFICATION CIRCUIT S1	1			1.4220	1.4220
B1	NOTIFICATION CIRCUIT S2	1			0.5880	0.5880
C1	NOTIFICATION CIRCUIT S3	1			0.5520	0.5520
	SUB-TOTALS (IN AMPS)			0.0650		2.7070
	TIME FACTOR: 24 HOUR STANDBY			X 24		
	5 MINUTES IN ALARM					X 0.083
	SUB-TOTALS (IN AMPHOURS):			1.5600		0.2256
	STANDBY AMPHOURS	1.5600				
	ALARM AMPHOURS +	0.2256				
	SYSTEM AMPHOURS =	1.7856				
	+25% DERATING +	0.4464				
	TOTAL AMPHOURS =	2.2320				
	BATTERIES PROVIDED	7.20				
	TOTAL AMPHOURS −	2.2320				
	AVAILABLE SPARE CAPACITY =	4.97				

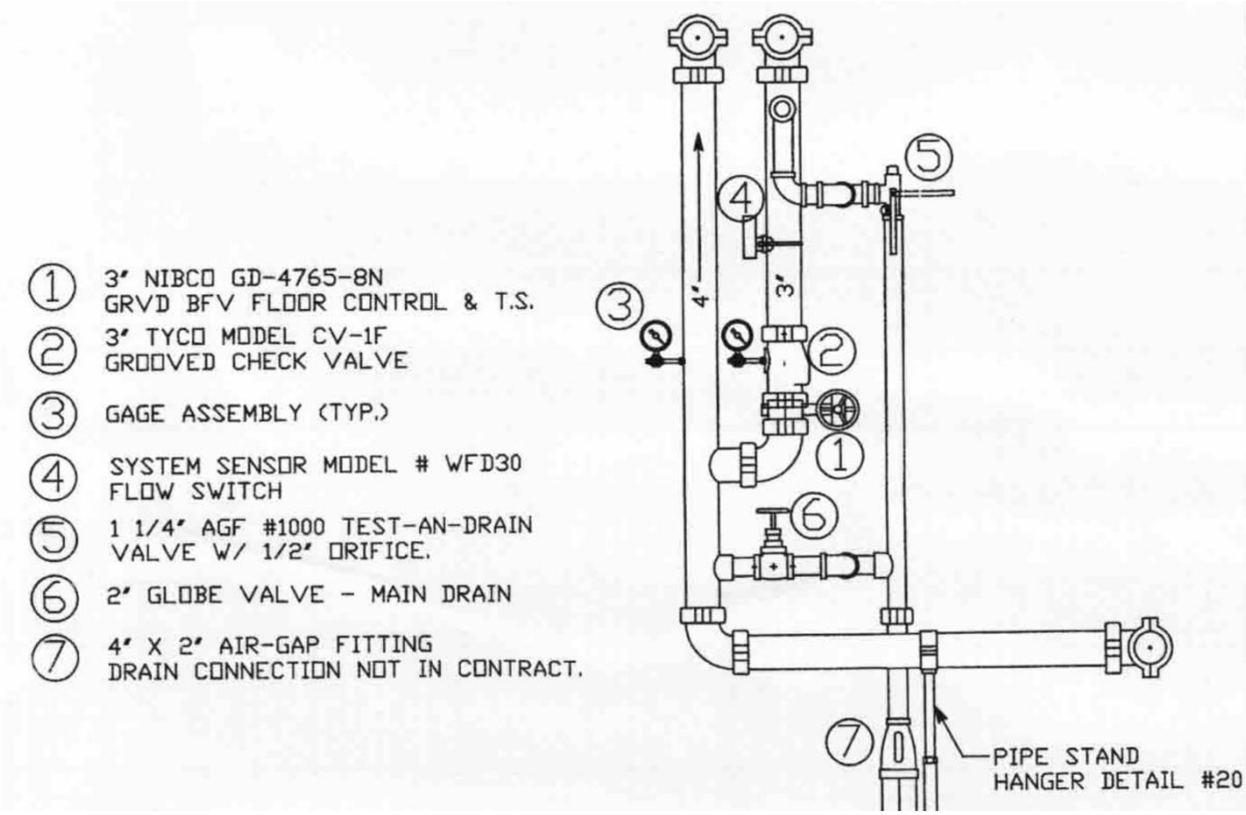
Floor 2 Building B and C

BATTERY CALCULATION							
FCPS-24S - Building B 2nd Floor							
EQUIPMENT		QUANTITY	SUPERVISORY CURRENT (IN AMPS)		ALARM CURRENT (IN AMPS)		
			UNIT	TOTAL	UNIT	TOTAL	
5 FCPS-24S		1	0.0650	0.0650	0.1450	0.1450	
B2 NOTIFICATION CIRCUIT S1		1			1.4220	1.4220	
B2 NOTIFICATION CIRCUIT S2		1			0.5600	0.5600	
C2 NOTIFICATION CIRCUIT S3		1			0.5240	0.5240	
SUB-TOTALS (IN AMPS)				0.0650		2.6510	
TIME FACTOR: 24 HOUR STANDBY				X 24			
5 MINUTES IN ALARM						X 0.083	
SUB-TOTALS (IN AMPHOURS):				1.5600		0.2209	
STANDBY AMPHOURS		1.5600					
ALARM AMPHOURS	+	0.2209					
SYSTEM AMPHOURS	=	1.7809					
+25% DERATING	+	0.4452					
TOTAL AMPHOURS	=	2.2261					
BATTERIES PROVIDED		7.20					
TOTAL AMPHOURS	−	2.2261					
AVAILABLE SPARE CAPACITY	=	4.97					

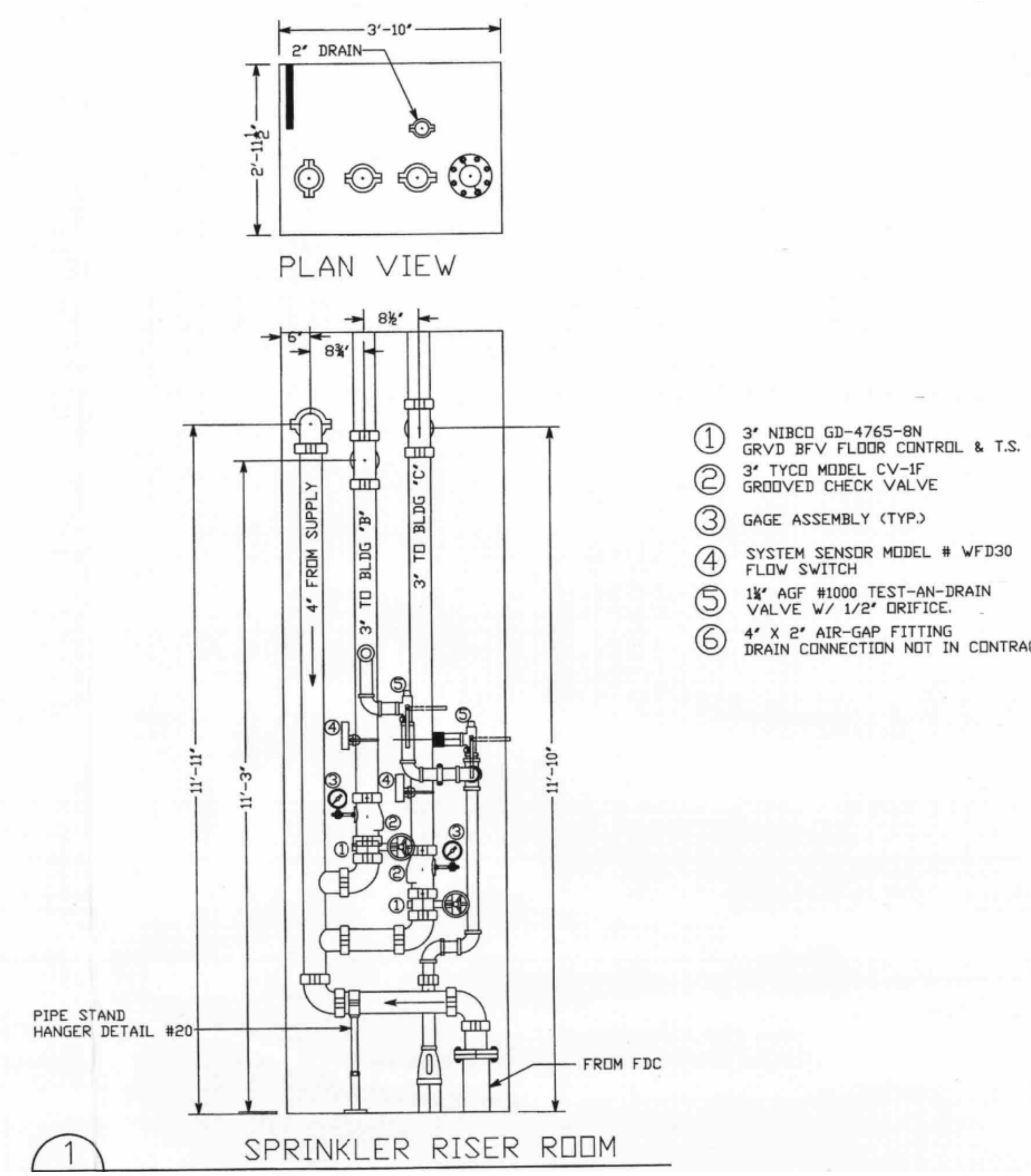
Floor 3 Building B and C

BATTERY CALCULATION						
FCPS-24S - Building B 3rd Floor						
EQUIPMENT		QUANTITY	SUPERVISORY CURRENT (IN AMPS)		ALARM CURRENT (IN AMPS)	
			UNIT	TOTAL	UNIT	TOTAL
5 FCPS-24S		1	0.0650	0.0650	0.1450	0.1450
B3 NOTIFICATION CIRCUIT S1		1			1.3580	1.3580
C3 NOTIFICATION CIRCUIT S2		1			0.5240	0.5240
SUB-TOTALS (IN AMPS)				0.0650		2.0270
TIME FACTOR: 24 HOUR STANDBY				X 24		
5 MINUTES IN ALARM						X 0.083
SUB-TOTALS (IN AMPHOURS):				1.5600		0.1689
STANDBY AMPHOURS		1.5600				
ALARM AMPHOURS	+	0.1689				
SYSTEM AMPHOURS	=	1.7289				
+25% DERATING	+	0.4322				
TOTAL AMPHOURS	=	2.1611				
BATTERIES PROVIDED		7.20				
TOTAL AMPHOURS	−	2.1611				
AVAILABLE SPARE CAPACITY	=	5.04				

I: Riser Building A



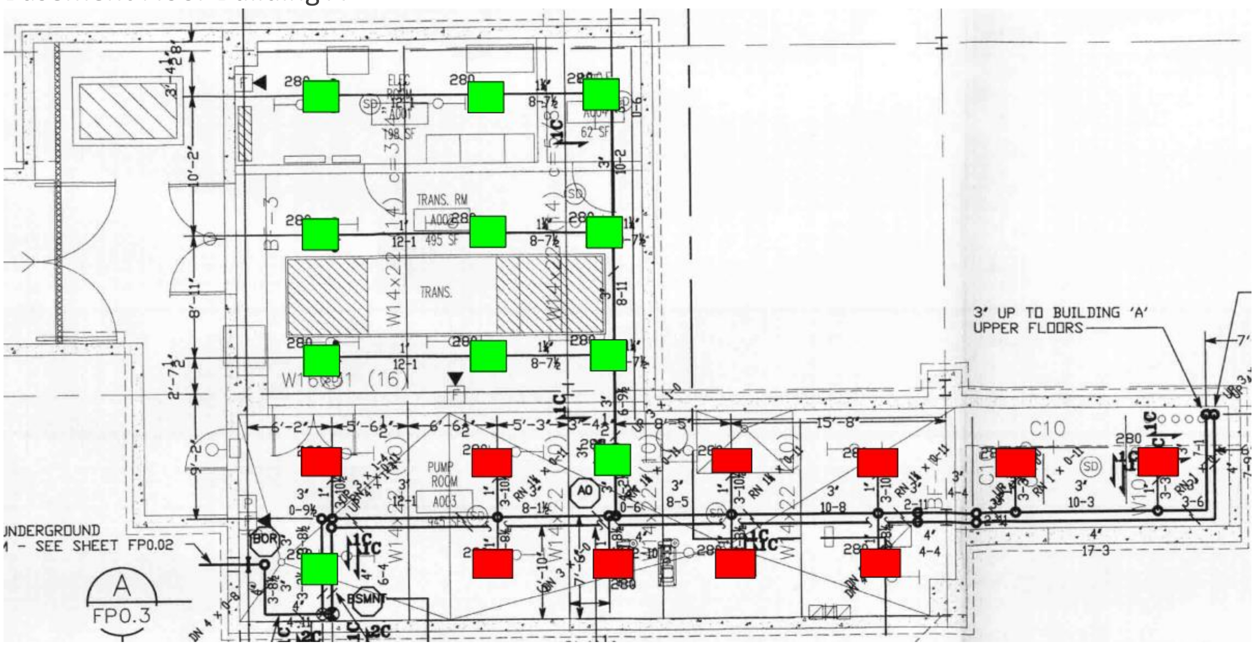
Riser Building B and C



CAL POLY
SAN LUIS OBISPO

J: Sprinkler and Riser Location

Basement Floor Building A



Tyco Sprinkler	Color
Upright Quick Response	
Concealed Response	
Concealed response on Sprig	

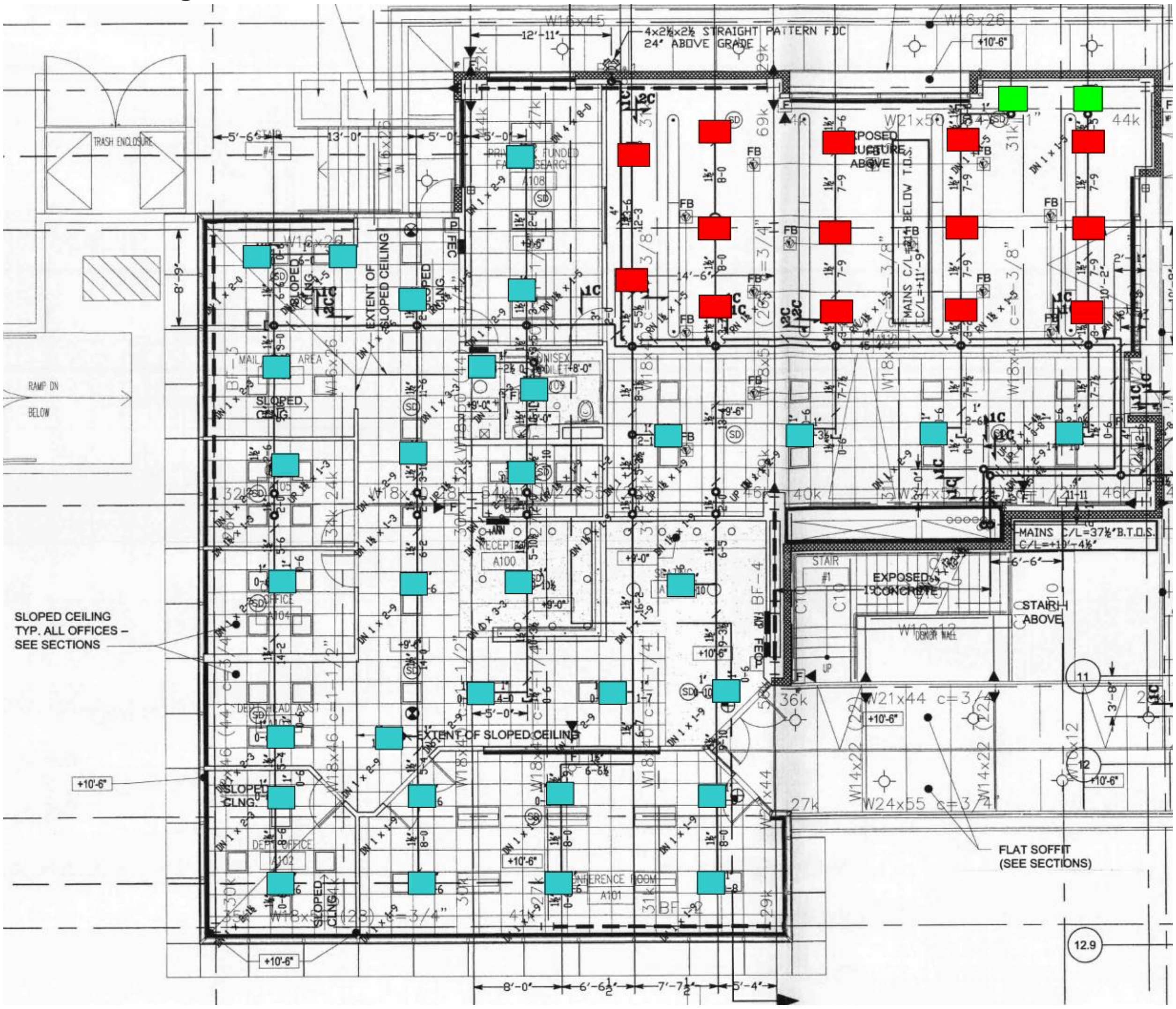
CAL POLY
SAN LUIS OBISPO

Floor 1 Building A

Tyco Sprinkler	Color
Upright Quick Response	
Concealed Response	
Concealed response on Sprig	

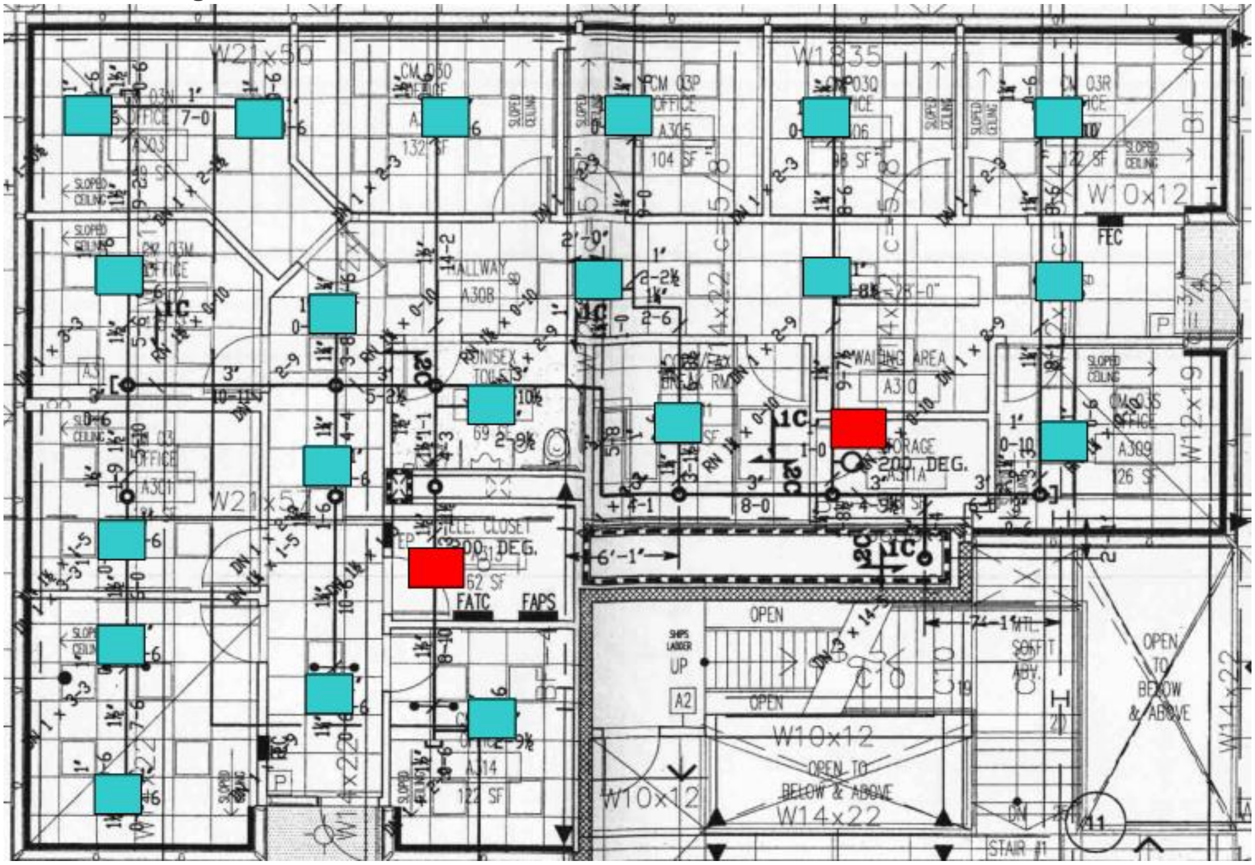
CAL POLY
SAN LUIS OBISPO

Floor 2 Building A



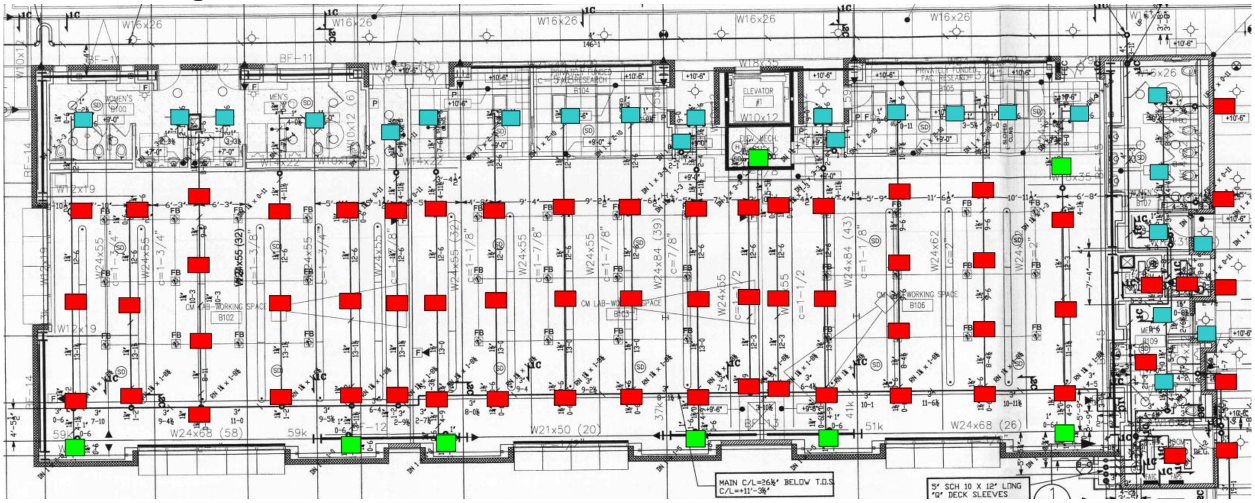
Tyco Sprinkler	Color
Upright Quick Response	
Concealed Response	
Concealed response on Sprig	

Floor 3 Building A



Tyco Sprinkler	Color
Upright Quick Response	Red
Concealed Response	Teal
Concealed response on Sprig	Green

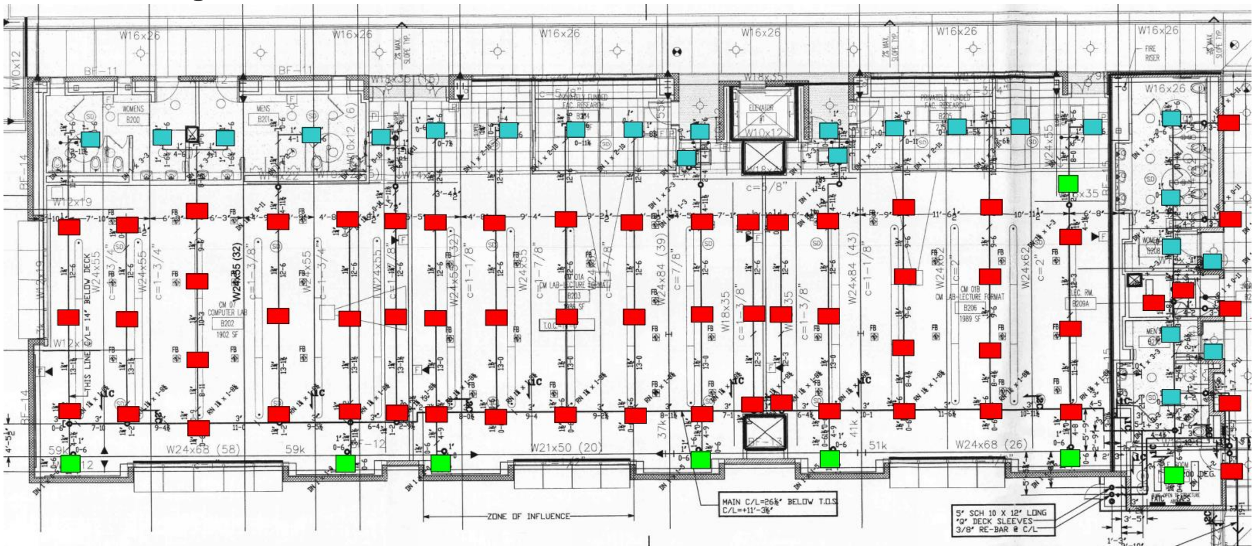
Floor 1 Building B



Tyco Sprinkler	Color
Upright Quick Response	Red
Concealed Response	Teal
Concealed response on Sprig	Green

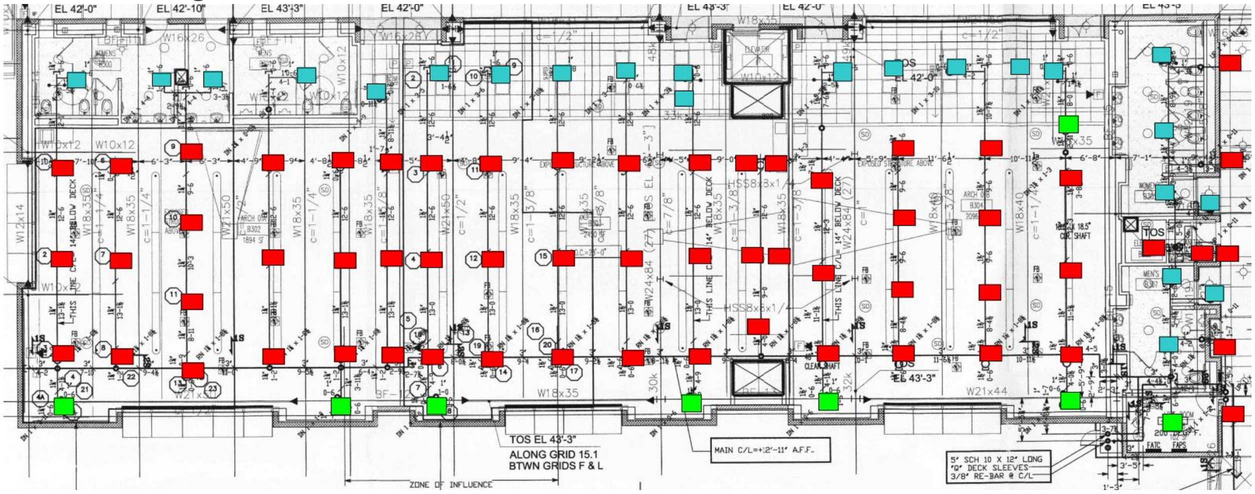
CAL POLY
SAN LUIS OBISPO

Floor 2 Building B



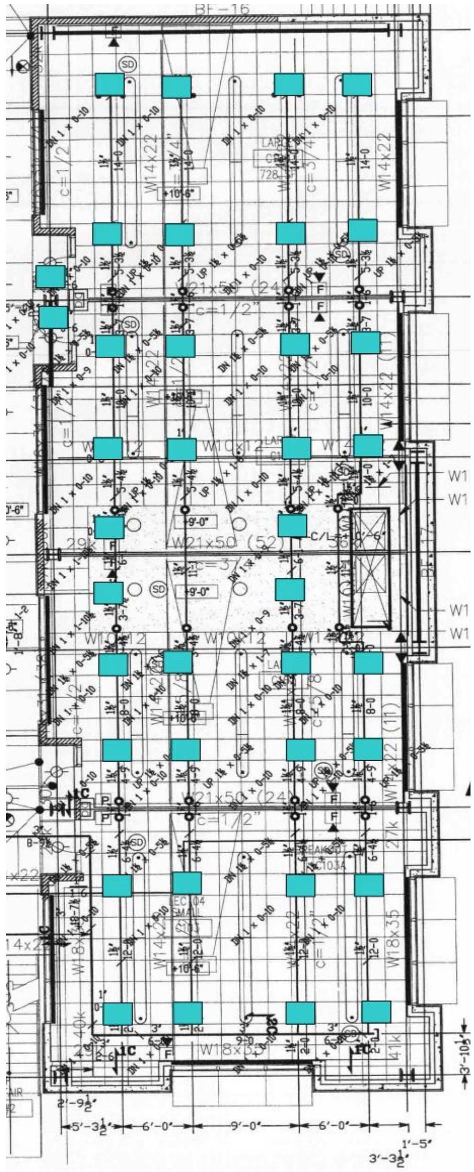
Tyco Sprinkler	Color
Upright Quick Response	
Concealed Response	
Concealed response on Sprig	

Floor 3 Building B



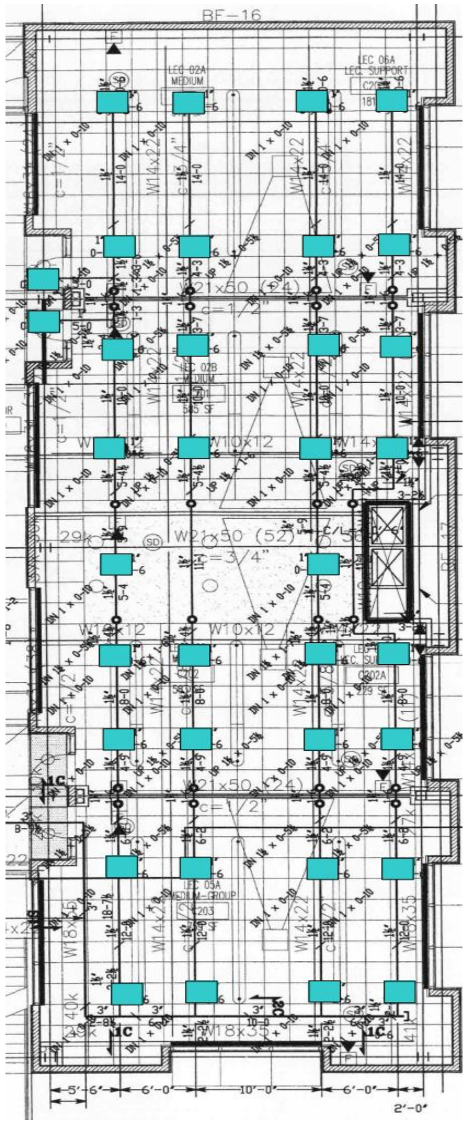
Tyco Sprinkler	Color
Upright Quick Response	
Concealed Response	
Concealed response on Sprig	

Floor 1 Building C



Tyco Sprinkler	Color
Upright Quick Response	
Concealed Response	
Concealed response on Sprig	

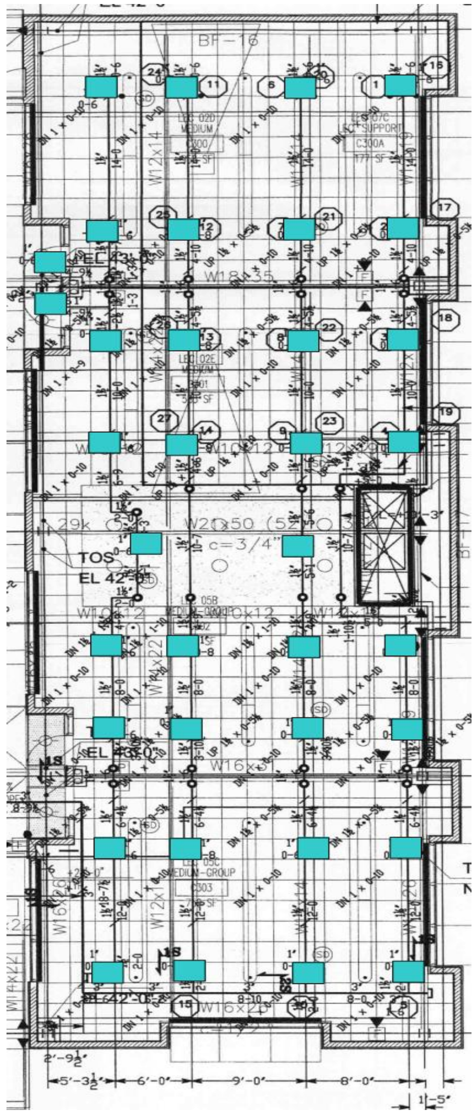
Floor 2 Building C



Tyco Sprinkler	Color
Upright Quick Response	
Concealed Response	
Concealed response on Sprig	

CAL POLY
SAN LUIS OBISPO

Floor 3 Building C



Tyco Sprinkler	Color
Upright Quick Response	
Concealed Response	
Concealed response on Sprig	

K: IBC Occupancy classifications

Floor 1

CAL POLY
SAN LUIS OBISPO

Floor 2

CAL POLY
SAN LUIS OBISPO

Floor 3


B
A-3
S-1
A300
A301
A302
A303
A304
A305
A306
A307
A308
A309
A311
A314
B300
B301
B302
B303
B303A
B304
B304A
B305
B307
B308
C300
C301
C302
C303