Fire Protection and Life Safety Engineering Analysis
-
Center for Science and Mathematics

California Polytechnic State University - San Luis Obispo

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March 20th, 2015

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Keywords:

Fire Protection Engineering, Prescriptive Based Design, Performance Based Design, RSET, ASET, Fire Dynamics Simulation.

Acknowledgments

I would like to thank all the people who contributed to various facets of this project.

I want to express my sincere gratitude to all in the Cal Poly's FPE program, in particular to Frederick W. Mowrer and Christopher C. Pascual for their support during the whole period of study.

Furthermore, I would also like to acknowledge the following persons/companies for providing documentation/information as well as support to this project:

- Kevin Fagan, CAL POLY, SLO
- Rex Wolf, CAL POLY, SLO
- Curtis Streeter, DEEP BLUE INTEGRATION, INC
- Stacey Williams, ZGF ARCHITECTS LLP
- Brian McLaughlin, ARUP
- Antonio Campo, UTSA

I warmly thank my family, especially my wonderful Mother, for their unconditional affection and support in all aspects of my life. In the same context I thank all my friends.

Finally, I want to express my deepest gratitude and appreciation to my inner family. To my wonderful children, Gabriel and Diego, for their great courage and understandings. To my lovely and constantly supportive wife Maytee, who carried me through the FPE program day by day, and always kept intact the fundamental principles of our family. Unquestionably, without their collective support and encouragement, I could not have finished this project.

In sum, I can just express my appreciation for everything and may God give you all the best in return.

Executive Summary

The Life Safety and Fire Protection systems in Cal Poly's Center for Science and Mathematics (CSM) were analyzed and evaluated in this project, according to the requirements of the applicable codes and pertinent standards. The evaluation was conducted through a prescriptive-based approach, in conjunction with a performance-based approach.

On one hand, the prescriptive-based approach considered the analysis of the Structural Fire Protection and Means of Egress in the building and the existing Fire Detection/Alarm and Fire Suppression Systems.

On the other hand, the performance-based approach included an Egress Analysis, which assessed the Required Safe Egress Time (RSET) and the Available Safe Egress Time (ASET) for the occupants to evacuate the building's atrium safely in the event of a fire.

The Egress Analysis was performed using hand calculations and the PATHFINDER computer software, along with data collected from previous studies. The tenability conditions within the building's atrium were evaluated for different fire scenarios and smoke management alternatives, using the Fire Dynamics Simulator (FDS) software.

Finally, some recommendations were appended to improve the performance of the fire safety systems, based upon the outcomes and conclusions obtained in this report.

TABLE OF CONTENTS

List of Figures

List of Tables

Acronyms

ADA	Americans with Disabilities Act
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
ARC	Alarm Receipt Capability
ASET	Available Safe Egress Time
ASME	American Society of Mechanical Engineers
BS	British Standards
Cal Poly	California Polytechnic State University
CBC	California Building Code
CFC	California Fire Code
CMC	California Mechanical Code
CFD	Computational Fluid Dynamics
CIBSE	Chartered Institution of Building Services Engineers
CSFM	California State Fire Marshal
CSM	Center for Science and Mathematics
dBA	Decibel A-weighted filter
DF	Design Fire
EPSS	Emergency Power Supply System
EVAC	Emergency Voice Alarm Communication System
FACP	Fire Alarm Control Panel
FACU	Fire Alarm Control Unit
FATC	Fire Alarm Terminal Cabinet
FD	Fire Department
FDS	Fire Dynamic Simulator
FM	Factory Mutual
GFRG	Glass Fiber Reinforced Gypsum
gpm	Gallons Per Minute
HRR	Heat Release Rate
HVAC	Heating, Ventilation, and Air Conditioning
ICC	International Code Council
IDC	Initiation Device Circuits
IR	Infrared
ITM	Inspection, Testing and Maintenance
LSC	LSC Life Safety Code
NAC	Notification Appliance Circuit
NFPA	National Fire Protection Association
NIST	National Institute of Technology
OSID	Open-area Smoke Imaging Detection
psi	Pounds per Square Inch
RNPS	Remote Notification Power Supply
RSET	Required Safe Egress Time
SFPE	Society of Fire Protection Engineers
SLC	Signal Line Circuit
SLO	San Luis Obispo
STEPS	Simulation of Transient Evacuation and Pedestrian Movements
SFRM	Spray-Applied Fire Resistive Material
UL	Underwriter Laboratory
UV	Ultraviolet

1. Introduction

Fire Protection Engineering (FPE), as defined by the Society of Fire Protection Engineers (SFPE), is the application of science and technology to protect people, property and businesses from destructive fires. FPE includes, inter alia, the following topics:

- Design of systems that control fires, alert people to danger and provide means for escape;
- Evaluation of buildings to pinpoint the risks of fires and the means to prevent them;
- Investigation of fires to discover how fire spreads, why protective measures failed, and how those measures could have been designed more effectively;
- Fire safety research on consumer products and construction materials;

The focus in this project is mainly addressed to the first topic stated by the SFPE, specifically to those issues concerning the prescriptive-based and performance-based approaches to fire protection design of passive and active systems. These systems are primarily used in buildings for providing the occupants with a safe environment when exposed to fire.

The building to be analyzed in this report is The Warren J. Baker Center for Science and Mathematics (CSM), located at Cal Poly's campus in San Luis Obispo, CA, which is a Type 1B construction, classified as Group B, Business Occupancy.

The CSM is equipped throughout with an automatic sprinkler system and possesses a fire detection and alarm system to detect and alert people through visual and audio appliances when smoke or fire is present.

All information for this project was obtained from the documentation generated by the building/systems designers (provided by Cal Poly), and from direct observations performed during several visits to the CSM.

2. Objectives and Scope

The global objective of this project is to evaluate the Life Safety and Fire Protection Systems available to the CSM, regarding the prescriptive and performance-based requirements stated by the applicable codes and standards.

The specific objectives are summarized below:

- Identify the relevant fire safety codes, standards and regulations related to the construction and operation of the building under study.
- Evaluate the prescriptive requirements for fire protection according to the building's characteristics.
- Determine the fire safety performance objectives and criteria related to the building, and to evaluate them using available state-of-the-art computer-based models.
- Recommend possible actions to be taken into account for the building operation in the future, based upon the conclusion obtained.

An important goal[1] to be assessed in this project, is to provide a reasonably safe environment from fire in the building, by protecting the occupants not intimate with the initial fire development and improving the survivability of those occupants intimate with the initial fire development. To achieve this goal, the buildings must be designed for protecting occupants; maintaining structural integrity; and retaining adequate system reliability for the time needed to evacuate, relocate, or defend in place, as specified in NFPA 101-2006, Section 4.2.

The scope of this project was demarcated on the basis of the above goal/objectives, and the compliance options to meet them, both through a prescriptive-based and a performance-based approach (NFPA 101-2006, Section 4.2.2). The scope is subject to the data and documentation gathered for the analysis of the building (provided by Cal Poly), and the information collected during several visits to the building.

[1] As stated in Life Safety Code, 2006, Section 4.1

3. Building Characteristics and Regulatory Framework

3.1 Building Details[2]

The Center for Science and Mathematics consists of a six-level central structure devoted to offices and student spaces with wings on either side that house classrooms and laboratories. The central entrance on Level Two connects to Centennial Park on the South side and to a major pedestrian artery on the North. These entrances access offices and conference rooms for chemistry and biochemistry, physics, and earth and soil science.

Staked above in Levels Three through Six are faculty offices and student study spaces. In addition to this main entrance, there are two additional entrances, Level One on the West end for the University classrooms and Level Three on the East end.

Total Gross Area of the building is 188,372 ft^2. Table 1, shows the gross square footage (G.S.F) per floor in the building.

Table 1- Gross square footage per floor

Floor	G.S.F (ft^2)
Level 1	23,146
Level 2	43,458
Level 3	43,209
Level 4	33,307
Level 5	25,294
Level 6	19,958
TOTAL	188,372

Ref. ZGF, 2009

Figure 1 shows the location of CSM on campus and Figure 2 illustrates a general view from the Southeast.

2 *Ref. http://cosam.calpoly.edu/content/center_sci_math*

Figure 1 - Location of CSM at Cal Poly – SLO

Ref. Google Earth

Figure 2 – Southeast view of CSM at Cal Poly - SLO

3.1.1 Building Occupancy Classification and Height

The general building occupancy classification is **Group B** (**Business Occupancy**[3]), containing the uses detailed in Table 2.

Table 2- Building occupancies and uses

Use	Occupancy	Floor area by occupancy (ft^2)
Lobbies/Lecture	A-3	12,748
Offices	B	108,281
Conference Rooms	B	
Laboratories	B	
Electrical and Telephone Data	S-1	6,456
Mechanical Rooms	S-1	
Storage	H-3	985
Storage	S-2	1,284
Ref. ZGF, 2009		

The actual building height is 108'-0'' (6 stories) and the defined building height is 64'-0", which corresponds to the top highest occupied floor/level above the "building access[4]". Therefore, according the actual height, the building is not classified as a high-rise building[5].

Table 3 shows the allowable heights and building areas for non-separated occupancies and the actual values for the CSM.

<table>
<tr><th colspan="7">Table 3- Allowable height and building areas for non-separated occupancies</th></tr>
<tr><th rowspan="2">Parameter</th><th colspan="5">Allowable for occupancies
(With automatic sprinkler increase)</th><th rowspan="2">Actual in CSM</th></tr>
<tr><th>B</th><th>S-1</th><th>A-3</th><th>H-3</th><th>S-2</th></tr>
<tr><td>Maximum Height (ft)</td><td>160'</td><td>180'</td><td>180'</td><td>180'</td><td>180'</td><td>108'-0"</td></tr>
<tr><td>Maximum Stories</td><td>11</td><td>12</td><td>12</td><td>7</td><td>12</td><td>6</td></tr>
<tr><td>Maximum Area (ft^2)/Story</td><td>Unlimited</td><td colspan="4">96,000</td><td>43,458</td></tr>
<tr><td colspan="7">Ref. CBC-2007, Section 503 and 504</td></tr>
</table>

3 According to NFPA 101, 2006, Section 6.1.11.1 a "*Business Occupancy*" is defined as *an occupancy used for the transaction of business other than mercantile* and according to CBC, 2007, Section 304, a "*Business Occupancy*" is defined as a *building used for offices, professionals or service-type transactions including educational occupancies for students above the 12th grade*.

4 The definition for "building access" comes from CBC-2007, 403.1, exemption 403.1.2, which states: For the purposes of this section, "*building access*" shall mean an exterior door opening conforming to all of the following: 1) Suitable and available for fire department use. 2) Located not more than 2 feet (610 mm) above the adjacent ground level. 3) Leading to a space, room or area having foot traffic communication capabilities with the remainder of the building. 4) Designed to permit penetration through the use of fire department forcible-entry tools and equipment unless other approved arrangements have been made with the fire authority having jurisdiction.

5 A "high rise building or high-rise structure" means *every building of any type of construction or occupancy having floor used for human occupancy located more than 75 feet (22 860 mm) above the lowest floor level having building access (see Section 403.1.2), except building used as hospitals as defined in Health and Safety Code Section 1250* (CBC-2007, section 202*)*

3.1.2 Fire Department Access

The requirements for the Fire Department (FD) access are stated in California Fire Code (CFC), Section 503, which specifies that FD access must extend to within 150 feet of all the portions of the facility and all portions of the exterior walls of the first story of the building, as measured by an approved route around the exterior of the building facility.

The FD access for the CSM are provided within 150 feet through the public way around three sides (North, East and West) of the building as shown in Figure 3.

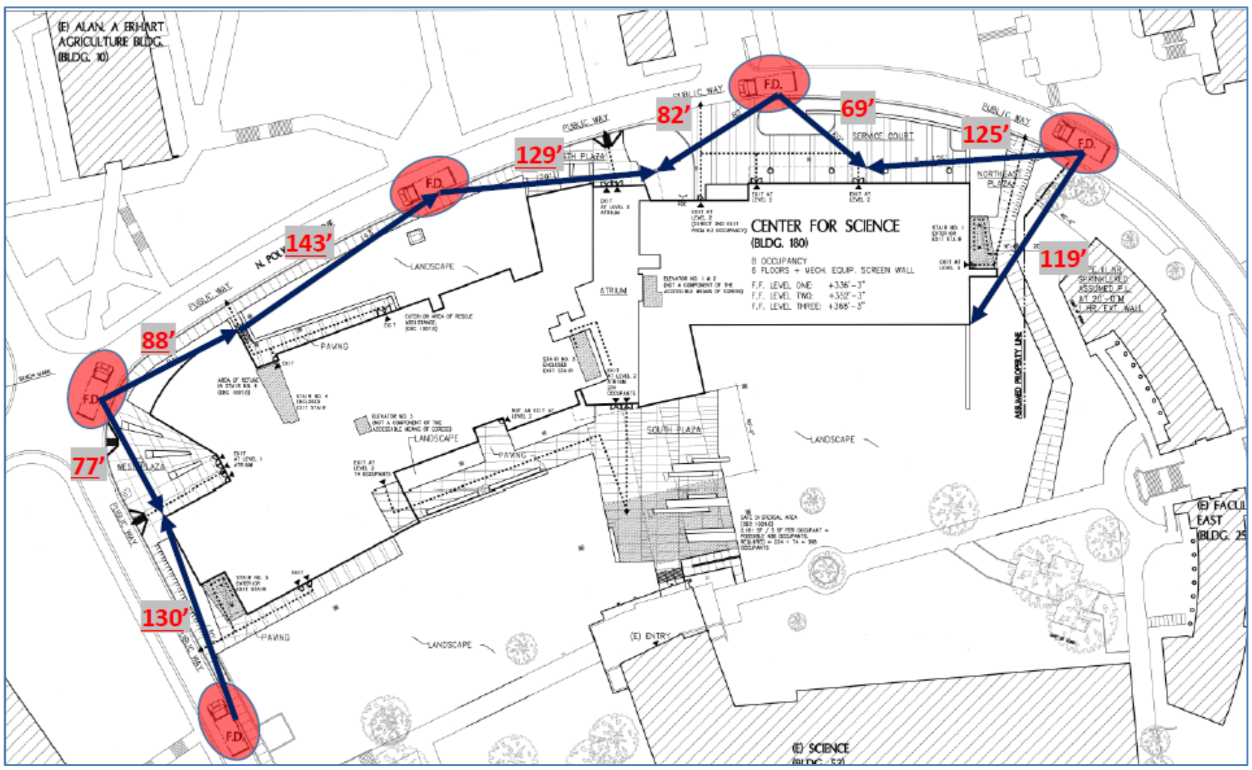

Figure 3 – FD access to the CSM

Ref. ZGF, 2009

South facing side required approval from the fire code official. According to CFC-2007, Section 503.1.1, Exception 1, fire code official is authorized to increase the dimension of 150 feet when the building is equipped throughout with an approved automatic sprinkler system, as the one existing in the CSM.

3.2 Regulatory Framework

The applicable codes and regulations for the CSM (ZGF, 2009) are listed below.

California Code of Regulations

- Building Standards Administrative Code - 2007, Title 24, Part 1.
- California Building Code (CBC) - 2007, Title 24, Part 2.
- California Electrical Code (CEC) - 2007, Title 24, Part 3.
- California Mechanical Code (CMC) - 2007, Title 24, Part 4.
- California Plumbing Code (CPC) - 2007, Title 24, Part 5.
- California Energy Code - 2007, Title 24, Part 6.
- California Elevator Safety Construction Code - 2010, Title 24, Part 7.
- California Historical Building Code – 2007, Title 24, Part 8.
- California Fire Code (CFC) – 2007, Title 24, Part 9.
- California Referenced Standards Code – 2007, Title 24, Part 12.

Applicable Standards and Guides

- NFPA 13 – 2007: Standard for the Installation of Sprinkler Systems.
- NFPA 20 – 2007: Standard for the Inst. of Stationary Pumps for Fire Protection.
- NFPA 70 – 2005: National Electric Code
- NFPA 72 – 2007: National Fire Alarm Code.
- NFPA 90A – 2002: Standard for Installation of Air-Conditioning.
- NFPA 90B – 2006: Standard for Installation of Warm Air Heating.
- NFPA 101 – 2006: Life Safety Code (LSC).

Federal codes

- ADA Standards for Accessible Design.
- ADA Accessibility Guidelines for Buildings and Facilities (28 CFR Part 38, App.A).

The foundations for the regulatory framework related to the fire safety and fire protection issues in this project are is supported on the primary goal stated in the Life Safety Code-2006, section 4.1, which is: “to provide building occupants with a reasonably safe environment from fire by protecting the occupants not intimate with the initial fire development and improving survivability of those occupants intimate with the initial fire development”.

4. Prescriptive–based Approach

According to NFPA 101-2006, Section 4.2.2.1, a prescriptive-based life safety design must be in accordance with Chapters 1 - 4, 6 - 11, and the applicable occupancy chapters from 12 to 42. As the CSM is classified as Group B, Business Occupancy, the applicable chapter is 38 – New Business.

Where specific requirements contained in Chapter 38 differ from general requirements contained in Chapters 1-4 and 6-11, the requirements of Chapter 38 must govern.

The prescriptive approach in this project includes the analysis of the following issues/systems:

- Structural Fire Protection
- Means of Egress
- Fire Detection and Alarm Systems
- Fire Suppression Systems

4.1 Structural Fire Protection

The structural fire protection in a building is intended to limit the spread of fire and smoke to as small an area as reasonable, by evaluating and specifying fire endurance capabilities of structural elements. The main goals of structural fire protections are summarized below:

- Prevent the total or partial collapse of a building (maintain structural integrity).
- Limit the spread of fire within a building (provide compartmentation).
- Limit the spread of fire between buildings (provide exposure protection).

A proper design of structural fire protection in a building must assure a greater fire resistance than the expected fire severity, where the fire severity is a measure of the destructive impact of a fire, and fire resistance is measure of the ability of a structure or element to resist collapse, fire spread or other failure during exposure to a fire of specified severity.

This section analyzes the most important topics related to the structural fire protection elements installed in the CSM.

4.1.1 Fire Resistance Ratings

The CSM is a Type 1B construction[6] fully sprinklered. Because the building has two or more classes of occupancy types, it is considered a Multiple Occupancy and is classified as a Separated Occupancy because the existing occupancy types are separated by fire resistance-rated assemblies, (NFPA 101- 2006, Section 6.1.14.1.1(2) and 6.1.14.2.3).

Table 4 shows the fire-rating requirements for building elements according to CBC-2007, as well as the fire-resistance rating specified in the CSM project.

Table 4- Fire-resistance rating requirement for building elements

Building Element	Fire resistance rating (hours)
Primary Structural Frame	2*
Bearing Walls (Exterior)	2
Bearing Walls (Interior)	2*
No Bearing Walls (Interior)	0
Floor Construction and Associated Secondary Members	2
Roof Construction and Associated Secondary Members	1

Ref. CBC- 2007 Table 601

*1 hour permitted where only supporting a roof.

<u>Fire-resistance rating specified in CSM project</u>

STRUCTURAL FRAME	2–HOUR (1–HR WHERE ONLY SUPPORTING ROOF)
EXTERIOR BEARING WALLS	2–HOUR
INTERIOR BEARING WALLS	2–HOUR (1–HR WHERE ONLY SUPPORTING ROOF)
EXTERIOR NONBEARING WALLS & PARTITIONS	1–HOUR < 30'; NON–RATED N/C ≥ 30'
INTERIOR NONBEARING WALLS & PARTITIONS	NON–RATED
FLOOR CONSTRUCTION INCL. SUPPORTING BEAMS & JOISTS	2–HOUR
ROOF CONSTRUCTION INCL. SUPPORTING BEAMS & JOISTS	1–HOUR

Ref. ZGF, 2009

For fully Sprinklered B occupancies, non-rated corridors are permitted according to CBC-2007.

The design for floor and ceiling assemblies in the CSM is based upon UL Design No. U438 for 2 hour rating. The primary structure is comprised of I (or W) shapes fire proofed with Spray-Applied Fire Resistive Material (SFRM), Glass Fiber Reinforced Gypsum (GFRG) and concrete encased. Girders and beams are designed according to UL Design No. 917 and columns according to UL Design No. X772 and SFRM boxed with steel channels and

[6] In Type 1B construction, building element are considered of noncombustible material.

gypsum wallboard. Retaining walls on levels 1 and 2 are made of reinforced concrete and comply with dimensions specified in CBC-2007, Table 721.1(2) to meet a 2-hour fire rating.

The fire-rating requirements for different occupancy separations according CBC-2007 are illustrated in Table 5, as well as the fire-rating specified for the CSM project.

Table 5- Fire-resistance rating requirement for occupancies separation

Building Element	Fire resistance rating (hours)
B to A-3	1
B to H-3	1
B to S-1	No separation required
B to S-2	1
S-1 to H-3	1
S-1 to S-2	1

Ref. CBC- 2007 Table 508.3.3

Fire-rating specified in the CSM project

B TO A–3: 1–HOUR
B TO H–3: 1–HOUR
B TO S–1: NO SEPARATION REQUIRED
B TO S–2: 1–HOUR
S–1 TO H–3: 1–HOUR
S–1 TO S–2: 1–HOUR

Ref. ZGF, 2009

Appendix 9.1 shows the building's floor plans and fire-resistance ratings between occupancies.

The separation between the atrium and the adjoining spaces must be of 1-hour, but according CBC 405.5, Exception 3, a Fire Barrier is not required between the atrium and the adjoining spaces of any three floors of the atrium, provided such spaces are accounted for in the design of the smoke control system

The atrium in the CSM is separated from adjacent spaces by fire barriers of 2 hour fire resistance rating, in accordance with CBC - 2007, Section 714.2.4, and is considered a Control Area.

Figure 4 shows a picture of the building under construction with the primary structure in sight. Some examples of beams and columns are illustrated in Figure 5 and Figure 6.

Figure 4 – CSM under construction

Ref. http://www.flickr.com//photos/calpolyscience/sets/72157628917516905/show/

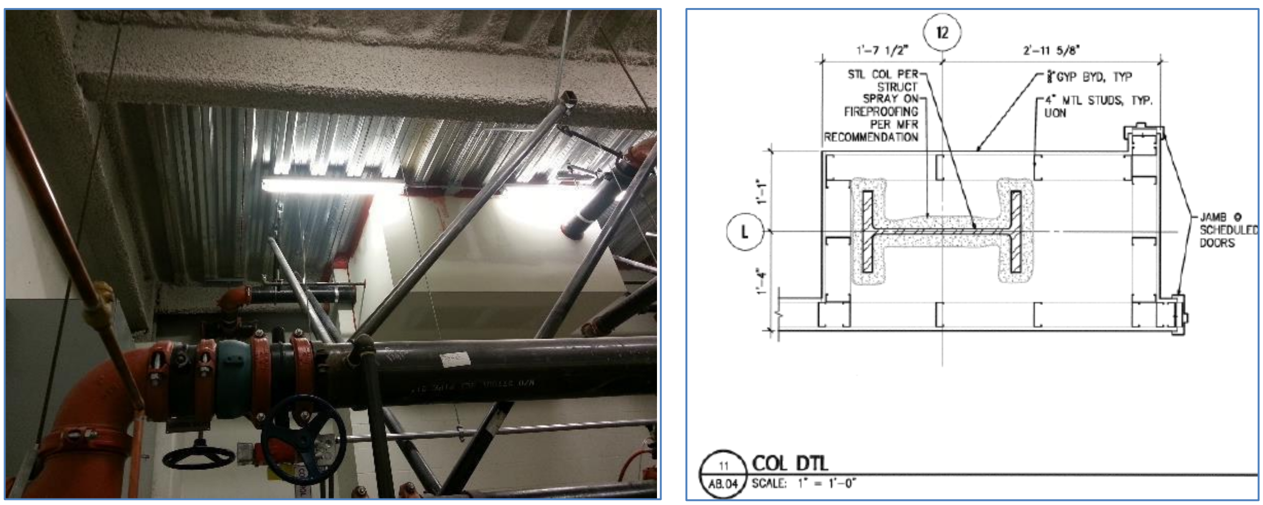

Figure 5 – Beam (left) and column (right) fire proofed with SFRM

Ref. ZGF, 2009

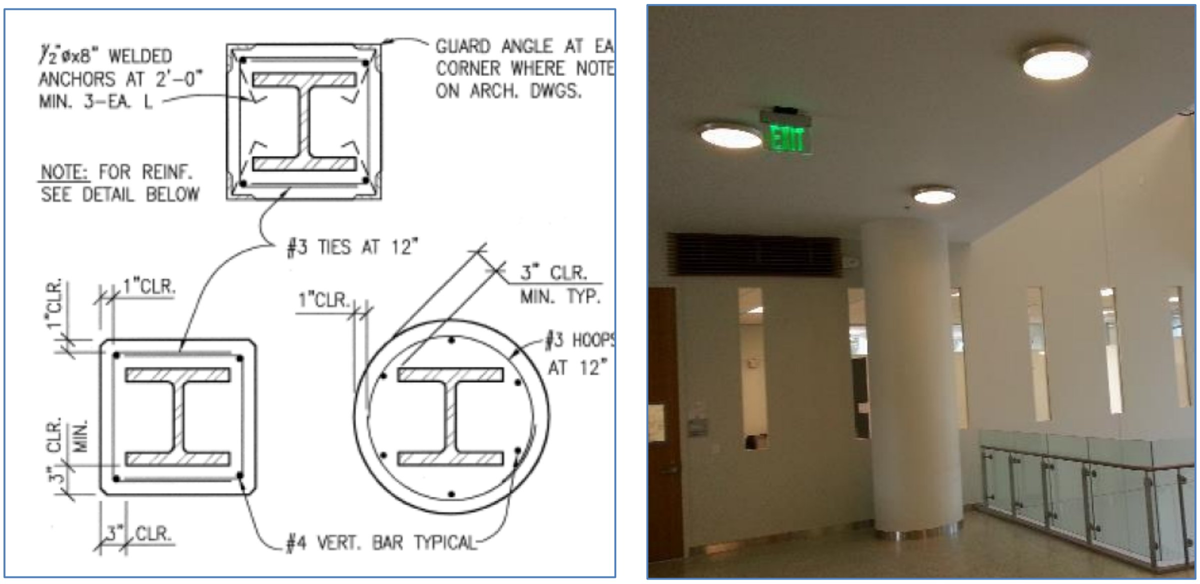

Figure 6 – W Columns concrete encased

Ref. ZGF, 2009

4.1.2 Smoke and Fire Barriers

A Smoke Barrier is a continuous membrane, or a membrane with discontinuities created by protected openings, designed and constructed to restrict the movement of smoke (NFPA 5000-2006; NFPA 101-2006, Section 3.3.24.2). Smoke barriers must be continuous from an outside wall to an outside wall, from a floor to a floor, or from a smoke barrier to a smoke barrier, or by use of a combination thereof.

In the CSM, except for the atrium openings[7], vertical openings separating stories are required as a smoke barrier. In addition, every floor that separates stories is required to be constructed as a smoke barrier in accordance with NFPA 101-2006, Section 8.5.

A Fire Barrier is a continuous membrane or a membrane with discontinuities created by protected openings with a specified fire protection rating, where such membrane is designed and constructed with a specified fire resistance rating to limit the spread of fire, that also restricts the movement of smoke (NFPA 101-2006, Section 3.3.24.1)

A Fire Barrier must be permitted to be used as a smoke barrier, provided that it meets the requirements for smoke barriers (NFPA 101-2006, Section 8.5.3).

[7] Atrium space is permitted to have openings in accordance with Section NFPA 101 -2006, Section 8.6.1.

The design of CSM consider the use of fire barriers, instead of smoke barriers, to comply NFPA 101-2006, Section 8.5.3. Fire barriers used in CSM, which includes barrier penetrations, ducts and air-transfer openings, doors, windows, expansion joints, etc., must be designed and installed to maintain continuity and protect openings in order to meet the requirements of smoke barriers as defined in Section 8.5 of the Life Safety Code.

4.1.3 Vertical Opening

As defined in NFPA 101- 2006, Section 3.3.254, a Vertical Opening is opening through a floor or roof. Openings through floors must be enclosed with fire barrier walls, must be continuous from floor to floor, or floor to roof, and must be protected as appropriate for the fire resistance rating of the barrier. The CSM contains vertical openings protected in accordance with Section 8.6 of the Life Safety Code, 2006 Ed.

4.1.4 Penetrations and Joints

Penetrations for cables, cable trays, conduits, pipes, tubes, vents, wires, and similar items to accommodate electrical, mechanical, plumbing, and communications systems that pass through a wall, floor, or floor/ceiling assembly constructed as a smoke barrier, or through the ceiling membrane of the roof/ceiling of a smoke barrier assembly, must be protected by a system or material capable of restricting the transfer of smoke (NFPA 101-2006, Section 8.5.6.2).

The penetrations installed in CSM must comply with provisions of (NFPA 101-2006, Section 8.5.6, related to the materials and methods of construction used to protect through-penetrations and membrane penetrations of smoke barriers.

Figure 7 and Figure 8 show some examples of penetrations installed in CSM.

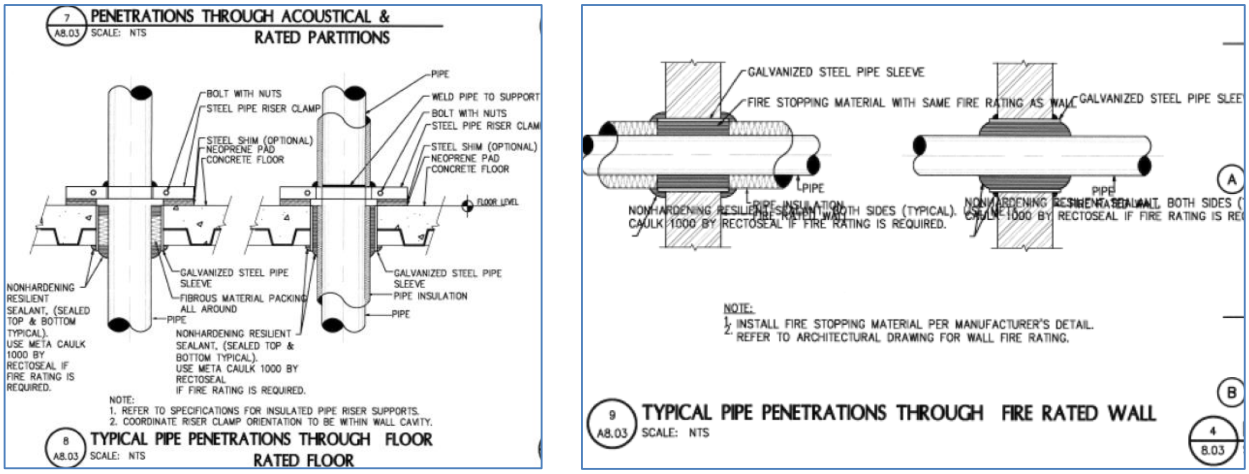

Figure 7 – Details of penetrations through walls and floors

Ref. ZGF, 2009

Figure 8 –Examples of penetrations for ducts and conduits

Smoke barriers that are also constructed as fire barriers must be protected with a joint system designed and tested to resist the spread of fire for a time period equal to the required fire resistance rating of the assembly and restrict the transfer of smoke (NFPA 101-2006, Section 8.5.7.4).

The design of the CSM considers an expansion joint intended to prevent the penetration of fire, and for this building, according to NFPA 101- 2006 Section 8.6.2, the openings through floors must be continuous from floor to floor, or floor to roof and enclosed with a 2 hour fire resistant barriers. Therefore, the expansion joint used in CSM must be proved to have a fire resistance rating not less than 2 hours , tested in accordance with UL 2079, Standard for Tests of Fire Resistance of Building Joint Systems, (NFPA 101- 2006, Section 8.6.3(4)).

4.1.5 Interior Finishes

Interior Finishes are the exposed surfaces of walls, ceilings, and floors within buildings (NFPA 101- 2006, Section 8.6.3, NFPA 5000-2006)

Interior finishes of the CSM must comply with Section 803.5 of the CBC-2007 regarding to the flame spread required for walls and ceilings in exits, corridors, rooms and enclosed spaces, according to the group and location designated.

Interior walls and ceiling finishes other than textiles, must be tested in accordance with NFPA 286 *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth*, with the acceptance criteria stated in CBC-2007, section 803.2.1, as detailed below:

- Flames cannot spread to the ceiling during the 40 kW exposure.
- During the 160 kW exposure, flames cannot spread to the outer extremities of the sample on the 8 x 12 foot wall and flashover cannot occur.
- The peak heat release rate throughout the test cannot exceed 800 kW.
- The total smoke release throughout the test cannot exceed 1,000 m^2.

Flame spread and smoke development test requirements for Class A, Class B and Class C interior wall and ceiling finishes are shown in Table 6.

Table 6- Fire-resistance rating requirement for occupancies separation

Classification (Class)	Flame Spread	Smoke Development	Notes
A	0-25	0-450	No continued propagation of fire in any element thereof when tested
B	26-70	0-450	-
C	76-200	0-450	-

Ref. NFPA 101-2006, Section 10.2.3.4

Table 7 shows the flame spread classifications required for interior finishes in the CSM, according the specifications stated on Section 803.5 of the CBC-2007 and the occupancies groups and location designated. Because the building is fully sprinklered, Class A materials are not required for exits, corridors, rooms and enclosed spaces.

Table 7- Flame spread classification required and specified for the CSM

Group	Exit enclosures and exit passageways*	Corridors*	Rooms and enclosed spaces*
A-3	B	B	C
B	B	C	C
S-1	C	C	C
S-2	C	C	C

Ref. CBC-2007, Table 803.5

**Sprinklered*

Flame Spread Classification specified for the CSM

GROUP	EXIT ENCLOSURES AND EXIT PASSAGEWAYS SPRINKLER	CORRIDORS SPRINKLED	ROOMS AND ENCLOSED SPACES SPRINKLED
A–3	B	B	C
B	B	C	C
S–1	C	C	C
S–2	C	C	C

Ref. ZGF, 2009

4.2 Mean of Egress

A mean of egress is an exit path that occupants may use to safely exit a building. It is designed to provide safe and easy travel during a fire or other emergency so that the risk of injury or death is minimized. Once in place, exit paths must be carefully maintained to ensure they are not blocked or compromised during normal building operation.

There are three separate components that make up each means of egress. The first is the exit access, or egress path. This is the path of travel that takes occupants from their room or place to a safe exit. It may include corridors, offices, or any other types of space that the occupant must pass through to reach the exit. The path must be well-marked with illuminated exit signs to guide occupants during an emergency.

The second component, the exit door, is located at the end of the exit access path. This door must lead out towards the public space, but may not necessarily exit to the outdoors. It may consist of interior doors leading to a vestibule, doors leading to an exterior pathway, or a door leading to an exit ramp.

After passing through the exit door, occupants will arrive at the exit discharge, which provides access to the public way, and may include a street, alley, or sidewalk. The area beyond the exit discharge must be kept free of obstacles at all times, including dumpsters, tools, and other equipment.

The specifications for the means of egress in this section are based on the requirements stated in NFPA 101-2006 and the CBC-2007.

4.2.1 Occupancy Classification and Occupant Load

As explained in 3.1.1, the general classification of CSM is Group B, Business Occupancy. Table 2 illustrates the different uses within the building and the related occupancies in each case.

The occupant load per floor can be estimated by dividing the floor area assigned to each occupancy use by the occupant load factor corresponding to that area.

Table 8 shows the occupant load factors prescribed and used for calculating the occupant load in the building. It is important to note that Occupant Load Factors used for calculating the Occupant Load of the building are based on use of the space, not on occupancy classification.

Table 8- Occupant Loads Factors prescribed and used in CSM
(Maximum Floor Area Allowances per Occupant)

Occupancy	CBC – 2007	Used in CSM
Business	100 GSF	100 GSF (For business use) 15 Net (For assembly use) 50 Net (For educational use: Labs and Shops)
Assembly	15 net (Unconcentrated - tables and chairs)	15 Net (For assembly use)
Hazard	200 GSF	100 GSF (For Industrial Areas use)
Storage	300 GSF (Mercantile) 500 GSF (Warehouse)	300 GSF (For Storage use)
Ref.	*Table 1004.1.1*	*According to the use of the occupancy*

Appendix 9.2 illustrates floor plans showing the different occupancy classifications in the CSM.

Table 9 shows the occupant load calculated for each floor, based upon the occupant load factors specified in Table 8 and the architectural plans.

Table 9- Occupant Loads per floor in the CSM	
Level	**Occupant Load**
1	703
2	523
3	701
4	463
5	263
6	252
TOTAL	2905
Ref. ZGF, 2009	

4.2.2 Means of Egress Components

The specifications for the means of egress of the CSM are stated in Chapter 7 of the Life Safety Code, as specified in Section 38.2.2, and in Chapter 10 of the CBC-2007.

The exits discharges and the area of refuge of the CSM were designed according to the requirements in Section 1024.1 and section 1007.6 of CBC-2007, respectively.

4.2.3 Capacity of Means of Egress

Egress capacity for the CSM is based on the egress width per occupant served requirements, for buildings with sprinkler systems (CBC- 2007, Table 1005.1).

In Table 10 are detailed the egress width prescribed by the code and used in CSM project.

<table>
<tr><th colspan="5">Table 10- Egress width prescribed[8] and used in CSM</th></tr>
<tr><th rowspan="2">Occupancy</th><th colspan="2">Stairs</th><th colspan="2">Other</th></tr>
<tr><th>CBC – 2007 (Table 1005.1)</th><th>CSM</th><th>CBC – 2007 (Table 1005.1)</th><th>CSM</th></tr>
<tr><td>Business (B):</td><td rowspan="4">0.2</td><td rowspan="5">0.2</td><td rowspan="4">0.15</td><td rowspan="5">0.15</td></tr>
<tr><td>Assembly (A-3)</td></tr>
<tr><td>Storage (S-2)</td></tr>
<tr><td>Storage (S-1)</td></tr>
<tr><td>Hazard (H-3)</td><td>0.7</td><td>0.4</td></tr>
</table>

Table 11 shows the minimum mean of egress width prescribed by the code and the compliance in CSM project.

[8] With Sprinkler System.

Table 11- Minimum mean of egress width prescribed and used in CSM		
Mean of Egress	**CBC – 2007 (Inches)**	**CSM Status**
Door	34 (CBC 1008.1)	OK
Stair	44 (CBC 1009.1.1)	OK
Exit Stair	48 (CBC 1007.8.2)	OK
Corridor	44 (CBC 1017.2)	OK

4.2.4 Number of Exits

As shown in Table 9, the occupant load in Levels 1-3 is greater than 500 and less than 1000, therefore, according to NFPA 101-2006, Sections 7.4.1.2 and 7.4.1.4, for each one of these levels at least 3 exits are required.

For Levels 4-6, as the occupant load is less than 500, no less than two separate exits must be provided on every story (NFPA 101-2006, Section 38.2.4.1). The terraces located on Levels 3-6 also comply with the minimum number of two exits required (NFPA 101-2006, Section 38.2.4.1 and Section 7.4.1.1).

For elevator lobbies, NFPA 101-2006, Section 7.4.1.6 requires the access to at least one exit, and such exit access must not require the use of a key, a tool, special knowledge, or special effort. The two elevators lobbies available in the CSM (one in the atrium and another in the west wing) comply with this requirement.

Table 12 summarizes the compliance of the CMS with respect to the number of exits, according to the requirements of the Life Safety Code.

Table 12- Number of exits in CSM				
Zone	**Number of exits required**	**Number of exits available in CSM**	**Occupant Load**	**Compliance Status**
Level 1	3	5	703	OK
Level 2	3	7	523	OK
Level 3	3	4	701	OK
Level 4	2	2	463	OK
Level 5	2	2	263	OK
Level 6	2	2	252	OK
Elevators N.1 and N.2				
Lobby - Level 2	1	2	-	OK
Lobby - Level 3	1	1	-	OK
Lobby - Level 4	1	1	-	OK
Lobby - Level 5	1	1	-	OK
Lobby - Level 6	1	1	-	OK
Elevators N.3			-	
Lobby - Level 1	1	3	-	OK
Lobby - Level 2	1	2	-	OK
Lobby - Level 3	1	1	-	OK
Terrace - Level 3	2	2	64	OK
Terrace - Level 4	2	2	48	OK
Terrace - Level 5	2	2	50	OK
Terrace - Level 6	2	2	13	OK
Ref. NFPA 101-2006, Section 7.4 and Section 38.2.4.1; Radle, L., 2013				

4.2.5 Arrangement of Means of Egress

The arrangement of Means of egress in the CSM is in compliance with Section 7.5 of the Life Safety Code.

The CSM is fully sprinklered, therefore according to NFPA 101- 2006, Section 7.5.1.3.3 and 7.5.1.3.6, the minimum separation distance between two exits or exit access doors must be not less than one-third the length of the maximum overall diagonal dimension of the building or area to be served. This requirement is also stated in CBC-2007, Section 1015.2.1.

There are no dead-end corridors in the CSM that exceed 50 feet (with sprinklers), and common path of travel exceeding 100 feet as required by NFPA 101-2007, Section 38.2.5 and CBC-2007, Table 1017.3, Exception 3 and Section 1014.3, exemption 1 & 2.

The area of refuge existing in the CSM (located on Levels 2-6) complies with section 1007.6 of CBC-2007, therefore it is considered part of an accessible means of egress.

4.2.6 Travel Distance to Exits

The CSM is equipped throughout with an automatic sprinkler system, therefore the travel distance cannot exceed the maximum allowable values stated in CBC-2007, Table 1016.1, as shown in Table 13.

Table 13- Minimum allowable travel distance in CSM

Occupancy	Minimum allowable travel distance (Feet)
B	300
A-3	150
H-3	150
S-1	250
S-2	400
Ref. CBC – 2007, Table 1016.1	

As the CSM is Group B (Business Occupancy), the maximum travel distance allowed is 300 feet. For atriums with sprinklers, according to CBC-2007, Section 404.8, the exits access maximum travel distance is 200 ft. The maximum travel distances to exits in the CSM are detailed in Appendix 9.2 for Levels 1-6, and Table 14 shows the compliance with this requirement.

Table 14- Travel Distance to exit in CSM

Level	Maximum Allowable (Feet)	Maximum existing (Appendix 9.2)	Compliance Status
1	300	149	OK
2		184	OK
3		207	OK
4		185	OK
5		207	OK
6		207	OK
Ref. CBC – 2007, Table 1016.1			

4.2.7 Discharge from Exits

Exit discharge from the CSM complies with NFPA 101-2006, Section 7.7.1 since exits terminate at an exterior exit discharge that leads directly to public way as shown in Figure 9.

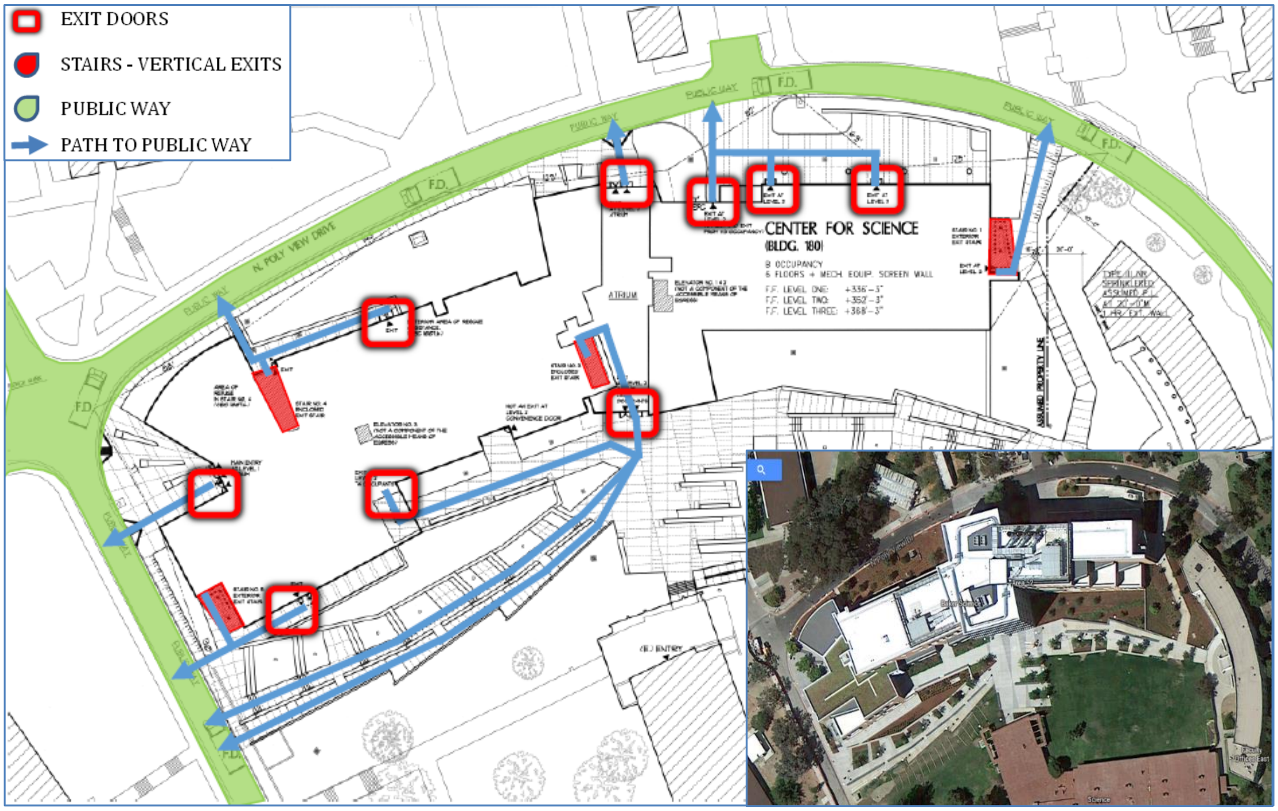

Figure 9 – Exit Discharge to Public Way

Ref: ZGF, 2009; Google Earth

4.2.8 Illumination of Means of Egress

Means of egress in the CSM must comply with the NFPA 101- 2006, Section 7.8, which stablishes the illumination requirements for this kind of buildings.

The following specifications must be considered in the illumination of all stairs, aisles, corridors, ramps, passageways and walkways leading to an exit and/or public way during the time of building use:

- Illumination must be continuous during the time that the conditions of occupancy require that the means of egress be available for use (Section 7.8.1.2).
- Automatic, motion sensor–type lighting switches equipped with fail-safe operation must be installed, with the illumination timers set for a minimum 15-minute duration, and the motion sensor activated by any occupant movement in the area served by the lighting units (Section 7.8.1.2.2).
- The floors and other walking surfaces within an exit and within the portions of the exit access and exit discharge must be illuminated as follows (Section 7.8.1.3):

- During conditions of stair use, the minimum illumination for new stairs must be at least 10 ft-candle (108 lux), measured at the walking surfaces.
- The minimum illumination for floors and walking surfaces, other than new stairs during conditions of stair use, must be to values of at least 1 ft-candle (10.8 lux), measured at the floor.
- In assembly occupancies, the illumination of the floors of exit access must be at least 0.2 ft-candle (2.2 lux) during periods of performances or projections involving directed light.
- The minimum illumination requirements must not apply where operations or processes require low lighting levels.

4.2.9 Emergency Lighting

Emergency lighting in the CSM must comply with Section 7.9 of NFPA 101-2006. The following specifications must be considered:

- Emergency illumination must be provided for not less than 1.5 hours in the event of failure of normal lighting.
- Emergency lighting facilities must be arranged to provide initial illumination that is not less than an average of 1 ft-candle (10.8 lux) and, at any point, not less than 0.1 ft-candle (1.1 lux), measured along the path of egress at floor level.
- Illumination levels must be permitted to decline to not less than an average of 0.6 ft-candle (6.5 lux) and, at any point, not less than 0.06 ft-candle (0.65 lux) at the end of the 11⁄2 hours.
- A maximum-to-minimum illumination uniformity ratio of 40 to 1 must not be exceeded.

The emergency lighting system in the CSM must be of at least Type 10, Class 1.5, Level 1 in accordance with NFPA 110, Standard for Emergency and Standby Power Systems, (NFPA 101-2006, Section 7.9.2.2). A Level 1 system is required because failure of the equipment to perform could result in loss of human life, (NFPA 110- 2005, Chapter 4).

4.2.10 Marking of Means of Egress

The Markings of means of egress in the CSM must comply with Section 7.10 of the Life Safety Code, (NFPA 101-2006, Section 38.2.10).

The following specifications must be considered in the design and installation of Marking of Means of Egress for the CSM:

- Exits, other than main exterior exit doors that obviously and clearly are identifiable as exits, must be marked by an approved sign that is readily visible from any direction of exit access.
- Access to exits must 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.
- Exit access corridors must have approved exit signs every 100 feet.
- Exit signs must provide contrast with decorations, interior finish, or other signs and no decorations, furnishings, or equipment is permitted to impair visibility of the exit sign.
- Exit signs must be mounted at a vertical distance less than 6 feet 8 inches above the top edge of the egress opening intended for designation by that marking.
- Exit signs must be mounted at a horizontal distance less than the required width of the egress opening, as measured from the edge of the egress opening intended for designation by that marking to the nearest edge of the marking.
- Externally Illuminated Signs (Section 7.10.6)
  - Must contain letters not less than 6 inches high, with the principal strokes of letters not less than ¾ inches wide.
  - Must be illuminated by at least 5 foot-candles (54 lux) at the illuminated surface and have a contrast ratio of at least 0.5.
  - The word “EXIT” must be written in letters of a width not less than 2 inches, except the letter I, and the minimum spacing between letters must be greater than 3/8 inches.
  - Exit signs that are larger than the minimum established requirements must use letter widths, strokes, and spacing in proportion to their height.
  - A directional sign is required at every location where the direction of travel to reach the nearest exit is not apparent. Directional indicators must be located outside of the EXIT legend and not less than 3/8 inches from any letter. The directional indicator must be a chevron-type.
- Internally Illuminated Signs (Section 7.10.7)
  - Internally illuminated signs must be listed in accordance with UL 924, Standard for Emergency Lighting and Power Equipment, unless: (1) they are approved existing signs; (2) they are existing signs having the required wording in legible letters not less than 4 in high; (3) they are signs that are in accordance the requirements for eternally illuminated sigs and the tactile signage stated by ICC/ANSI A117.1, American National Standard for Accessible and Usable Buildings and Facilities.

- Elevator Signs (Section 7.10.8.4 and 7.2.13.1)
  - Elevators that are a part of a means of egress must have signs with a minimum letter height of 5⁄8 in posted in every elevator lobby that indicate that the elevator can be used for egress, including any restrictions on use and the operational status of elevators.

4.3 Fire Alarm and Detection System

A Fire Alarm and Detection system consists of a set of electric/electronic devices/equipment working together to detect and alert people through visual and audio appliances when smoke/fire situation is present.

These alarms may be activated from automatic (smoke detectors, heat detectors, water flow sensors, etc.) or manual (fire alarm pull station) devices. The definitions, design criteria and requirements for these systems are stated in NFPA 72 - National Fire Alarm and Signaling Code.

The Fire Alarm and Detection system for this building was designed by the company Deep Blue Integration, Inc. (http://www.deepblueintegration.com/)

4.3.1 System Requirements

The main requirements for the Fire Alarm and Detection system installed in the CSM are stated in CBC-2007, CMC-2007 and NFPA 72-2007. The most important issues related to these requirements are summarized in Appendix 9.3.

Key factors for defining the requisites for the Fire Alarm and Detection system in CSM are as follows :

- It is classified as Group B, Business Occupancy, with an occupant load of 2905 persons.
- It is not classified as a high-rise building.
- It is equipped throughout with an automatic sprinkler system.

Based in the above features, the requirements for the Fire Alarm and Detection system installed in the CSM are summarized below:

General requirements:
- Partial or Selective Coverage. Where codes, standards, laws, or authorities having jurisdiction require the protection of selected areas only, the specified areas shall be protected in accordance with this Code (NFPA 72-2007, Section 5.5.2.2)
- A fire alarm system[9] for occupancies with an atrium that connects more than two stories (CBC-2007, Section 907.2.13)

[9] According to CBC-2007, Section 907.6, where an alarm notification system is required by another section of the code, it shall be activated by an automatic fire alarm system, sprinkler water-flow devices and manual fire alarm boxes.

- A fire-fighter's smoke control panel (CBC-2007, Section 909.16)
- A two-way FD communication system (CBC-2007, Section 907.2.12.3)

Detectors requirements:

- Detectors for Elevator Recall for Fire Fighters' Service (NFPA 72-2007, Section 6.3.5)
- Detectors for Door Releasing Service (NFPA 72-2007, Section 5.16.6.5.1.1).
- Detectors for Automatic Shutoffs of Air-Moving systems (CMC-2007, Section 609.0)

As the building is equipped throughout with an automatic sprinkler system and the alarm notification appliances will activate upon sprinkler water flow, the following initiating devices are not required:

- Manual[10] fire alarm boxes (CBC- 2007, Section 907.2).
- Automatic heat detection (CBC- 2007, Section 907.2)
- Smoke detectors above the RNPS in the electrical room (NFPA 72- 2007, Section 4.4.5 Exception No. 2)

According to NFPA 101- 2006, Section 9.6.1.7, a complete fire alarm system must provide functions for initiation, notification, and control, as follows:

- The initiation function provides the input signal to the system.
- The notification function is the means by which the system advises that human action is required in response to a particular condition.
- The control function provides outputs to control building equipment to enhance protection of life.

4.3.2 System Characteristics

The system installed in CSM is a Fire Alarm with In-building Fire Emergency Voice Alarm Communication System (EVACS), which according to NFPA 72, is a dedicated manual or automatic equipment for originating and distributing voice instructions, as well as alert and evacuation signals pertaining to a fire emergency, to the occupants of a building. The system is designed to assist emergency response personnel in managing the movement of both building occupants and fire fighters during a fire or other emergency.

The EVACS installed in the building has a One-way Emergency Communication System with In-building fire emergency voice/alarm communications, as well as a Two-way

[10] Manual fire alarm boxes, (i.e. pull stations), are used for fire protective signaling purposes only. If used, manual pull stations must be provided in the natural exit access path near each required exit from an area. Each manual pull station must be accessible, unobstructed and visible.

Emergency communication System (Telephone System). The telephone system is used to facilitate the exchange of information and the communication of instructions in buildings, primarily for emergency services personnel.

The Fire Alarm Control Unit (FACU) installed is Honeywell Notifier Model : NFS2-640 (see Figure 10).

Figure 10 – FACU installed in CSM, Room 122

The requirements and specifications for EVACS and Two-way Emergency communication System, according to CBC-2007 and 72-2007 are summarized in Appendix 9.4. The Two-way Communication System installed in the building has 12 telephone jacks installed and 5 telephone[11] handsets stored on site (see Table 20 and Figure 11).

Figure 11 –Telephones jack and portable handsets located at fire pump room

[11] Type: Sound powered.

As the signals from the EVACS are sent to the University Police Department's Communications Center, which is staffed 24 hours a day, 7 days a week with certified, professionally trained dispatchers[12] (supervising station), the building may be considered a Protected Premise.

NFPA 72 -26.1.1 states that "where a protected premises Fire Alarm System has its signals sent to a supervising station, the entire system becomes a supervising station alarm system". In this context, according to the fire alarm classification described in NFPA 72, Section 1.3.1, the fire alarm system of the CSM may be classified as a Proprietary Supervising Station Alarm Systems[13].

4.3.3 Signal Initiation

The building counts on the following types of automatic and manual detection devices:

- Automatic smoke detectors:
  - Spot type smoke detectors.
  - Duct smoke detector.
  - Beam smoke detectors.

- Automatic supervisory signal devices:
  - Sprinkler[14] water flow device (Paddle- or vane-type switches).

- Pump activation.
  - Supervisory signal devices : Control valve tamper switch.
  - Manual devices:
  - Manual fire alarm boxes (pull station).

The control functions related to the activation of the above devices are mainly related to hold-open doors releasing devices, smoke management, HVAC shutdown, F/S dampers and elevator recall.

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12 https://afd.calpoly.edu/police/services_communications.asp?pid=1

13 This kind of systems typically involve the fire alarm systems of those protected premises where the signals are monitored by a supervising station under the same ownership as the protected premises. The property may consist of a single building, such as a high-rise building, or several buildings, such as at a college campus, where the dormitories and other buildings report to a single proprietary supervising station at the campus police department or campus fire department.

14 The fire alarm system initiates a signal when the sprinkler system provides automatic detection that the flow of water is equal to or greater than that from a single automatic sprinkler, (NFPA 101,2006, Section 38.3.4 and 9.6.2).

Smoke alarms in the CSM receives their operating power from the Fire Alarm Control Panel (FACP), which is powered by the building's electrical system, (NFPA 101-2006, Section 9.6.2.9.2).

Appendix 9.5 shows features of the devices used in the Fire Alarm Systems and Annex 10.1 shows the location and symbols of fire detection devices installed throughout the CSM. These plans show that, aside from the detectors required for Elevator Recall for Fire Fighters' Service, Door Releasing Service, and Automatic Shutoffs of Air-Moving systems, the building has also the following initiating devices:

- Manual initiator devices in exit access paths.
- Smoke detectors in Electrical rooms (located at the rooms containing the FACP, RNPS and FATC), elevators hoistway, elevators machine room, and storage rooms)
- Beam detectors in the atrium.

As drawings in Annex 10.1 are shown in a small scale, Figure 12 depicts the details of the location of initiating devices installed in one of the floors of the building.

Smoke Detector	Smoke Detector - Duct
Beam Smoke Detector - Transmitter	Beam Smoke Detector - Receiver
Manual Pull Station	

Figure 12 – Initiating devices installed in Level 2 of the CSM

Ref. Deep Blue Integration, 2013

Beam Detectors

As of February 2012 when the design was reviewed by the Fire Official at Cal Poly for the first time, the design did not include any beam detection. As of March 2013, the design was updated to include an open-area smoke imaging detector (OSID), also known as a beam detector. OSID smoke detection is a new technology that is still pending major agency approvals (Radle, L., 2013).

The bean detectors installed in CSM were provided by the company Xtralis[15]. In this section are summarized the main aspects related to the operation of the bean detectors installed in the CSM.

OSID system measures the level of smoke entering beams of light projected over an area of projection. A single OSID Imager can detect up to seven Emitters to provide a wide coverage area. Two innovations in smoke detection technology have been developed for the revolutionary OSID smoke detector (Xtralis,2011).

- Dual Wavelength Particle Detection- The beam projected from each Emitter contains a unique sequence of ultraviolet (UV) and infrared (IR) pulses that are synchronized with the Imager and enable the rejection of any unwanted light sources. By using two wavelengths of light to detect particles, the system is able to distinguish between particle sizes. The shorter UV wavelength interacts strongly with both small and large particles while the longer IR wavelength is affected only by larger particles. Dual wavelength path loss measurements enable the detector to provide repeatable smoke obscuration measurements, while rejecting the presence of dust particles or solid intruding objects. Figure 13 shows an schematic representation of this capability.

- Optical Imaging with a CMOS[16] Imaging Chip- An optical imaging array in the OSID Imager provides the detector with a wide viewing angle to locate and track multiple Emitters. Consequently, the system can tolerate a much less precise installation and can compensate for the drift caused by natural shifts in building structures. Optical filtering, high-speed image acquisition and intelligent software algorithms also enable the OSID system to provide new levels of stability and sensitivity with greater immunity to high level lighting variability. Figure 14 shows an schematic representation of this capability.

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15 A complete information about this technology can be found in http://xtralis.com/p.cfm?s=22&p=459

16 Complementary metal–oxide–semiconductor

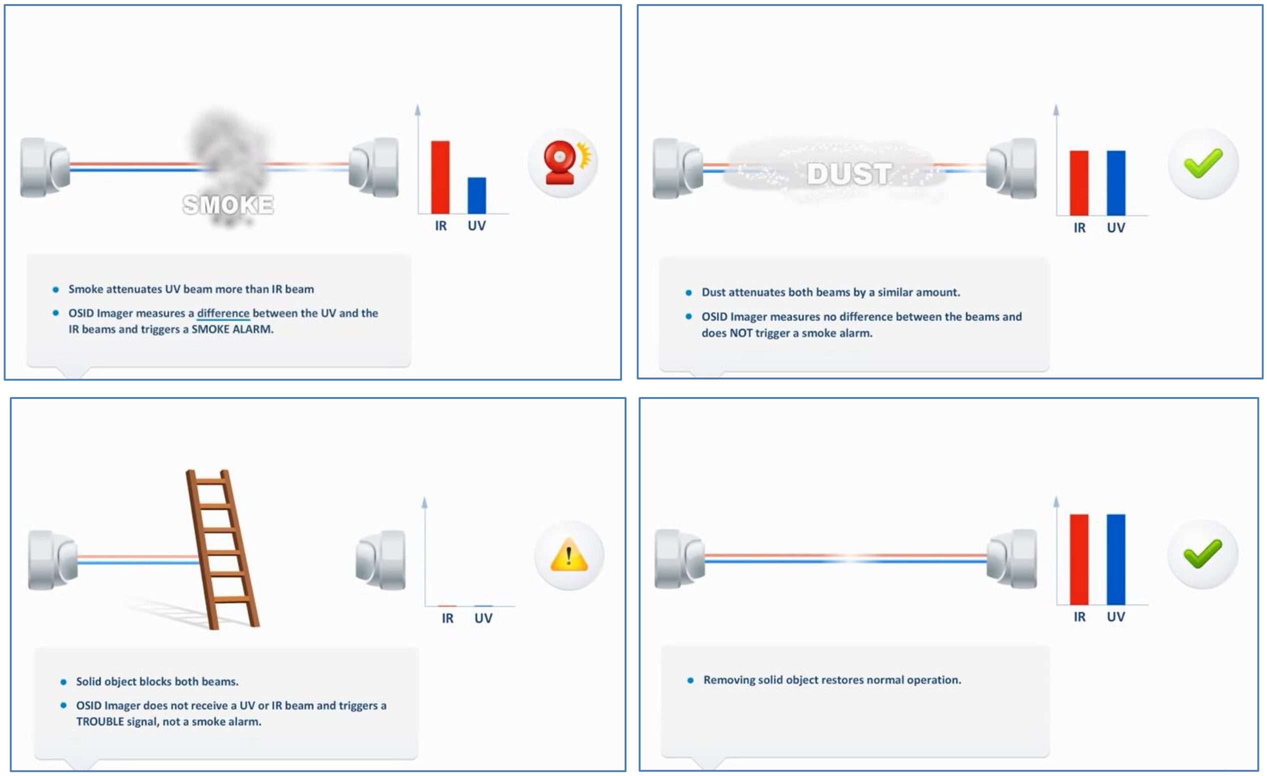


Figure 13 – OSID Dual Wavelength Particle Detection

Ref. http://xtralis.com

The placement of the detector components must consider the following specifications:

- Provide a stable and secure surface for mounting the Emitter and Imager.
- Include no obstructions between the Emitter and Imager.
- Ensure the system is mounted well above the head height of a person.
- Avoid direct sunlight into the Imager and Emitter components.
- Ensure Emitters for the same Imager are not placed within one meter of each other or lighting.
- Consider effects like stratification and other parameters that may affect the performance of the detector (e.g. room geometry, ceiling height, ceiling shape, fuel sources and location)
- Comply with spacing and location requirements for applicable codes and standards.

The location and spacing of components of the detector system should comply with national and regional installation codes. In any OSID system, the line of protection between the Imager and an Emitter is recognized by many standards to be equivalent to a traditional beam detector. For areas that require multiple lines of protection, the Emitters should be located and spaced according to the following recommendations to provide full coverage of the protected space.

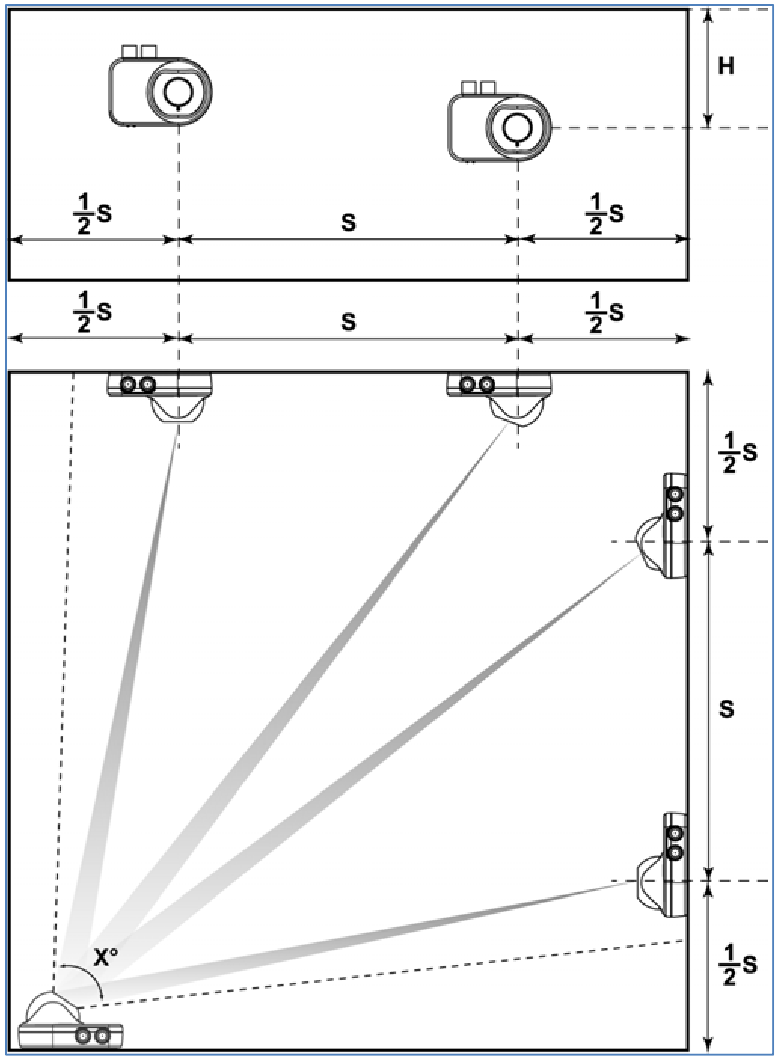


Figure 14 –OSID Horizontal spacing requirements

Ref. Xtralis,2011

Emitters should be positioned within a distance of H below the ceiling. For flat ceilings, this value is generally between 25 to 600 mm (1 to 23.6 in.). The value of H will vary according to regional specifications, geometry of the ceiling and specific requirements of the installation for the protected space (see Table 15).

Table 15- Mounting Distance from Ceiling for Flat Ceilings	
International Standard	**Distance from Ceiling (H)**
NFPA72	-
AS1670.1	25 to 600 mm (1 to 23.6 in.)[1]
BS5839.1	25 to 600 mm (1 to 23.6 in.)[2]
GB50166	300 to 1000 mm (11.8 to 39.4 in.)
NFS 61.970 et R7	300 to 3000 mm (11.8 to 118 in.)
Ref. Xtralis,2011	

Measured horizontally, Emitters can be spaced a maximum distance of S apart, with one half of that spacing from beams and the sidewall. The value of S varies according to local codes and standards, and is summarized in Table 16.

Table 16- Maximum Emitter Spacing	
International Standard	**Maximum Spacing (S)**
NFPA72	18.3 m (60 ft)[1]
AS1670.1	14 m (45.9 ft)[2]
BS5839.1	15 m (49.2 ft)[3]
GB50166	14 m (45.9 ft)[4]
NFS 61.970 et R7	10 m (39.4 ft)[5]
Ref. Xtralis,2011	

OSID systems may be configured to suit a range of detection spaces by selecting the number of Emitters and type of Imager. Each type of Imager differs by the lens used in the unit, which determines the field of view and range of the system. Appendix 9.6 shows the configuration options, available field of view and detection ranges for OSID.

Annex 10.1 shows details and installation specifications of initiation and notification devices.

4.3.4 Occupant Notification

Occupant notification in CSM is provided by the following appliances (see Appendix 9.5 and Table 20 for more detailed information):

- Strobes

- Speakers
- Speaker/Strobe combination
- Bells
- Annunciators.

<u>Audibility</u>

Occupant Notification must comply with the following requirements according to NFPA-2006, Section 9.6.3.

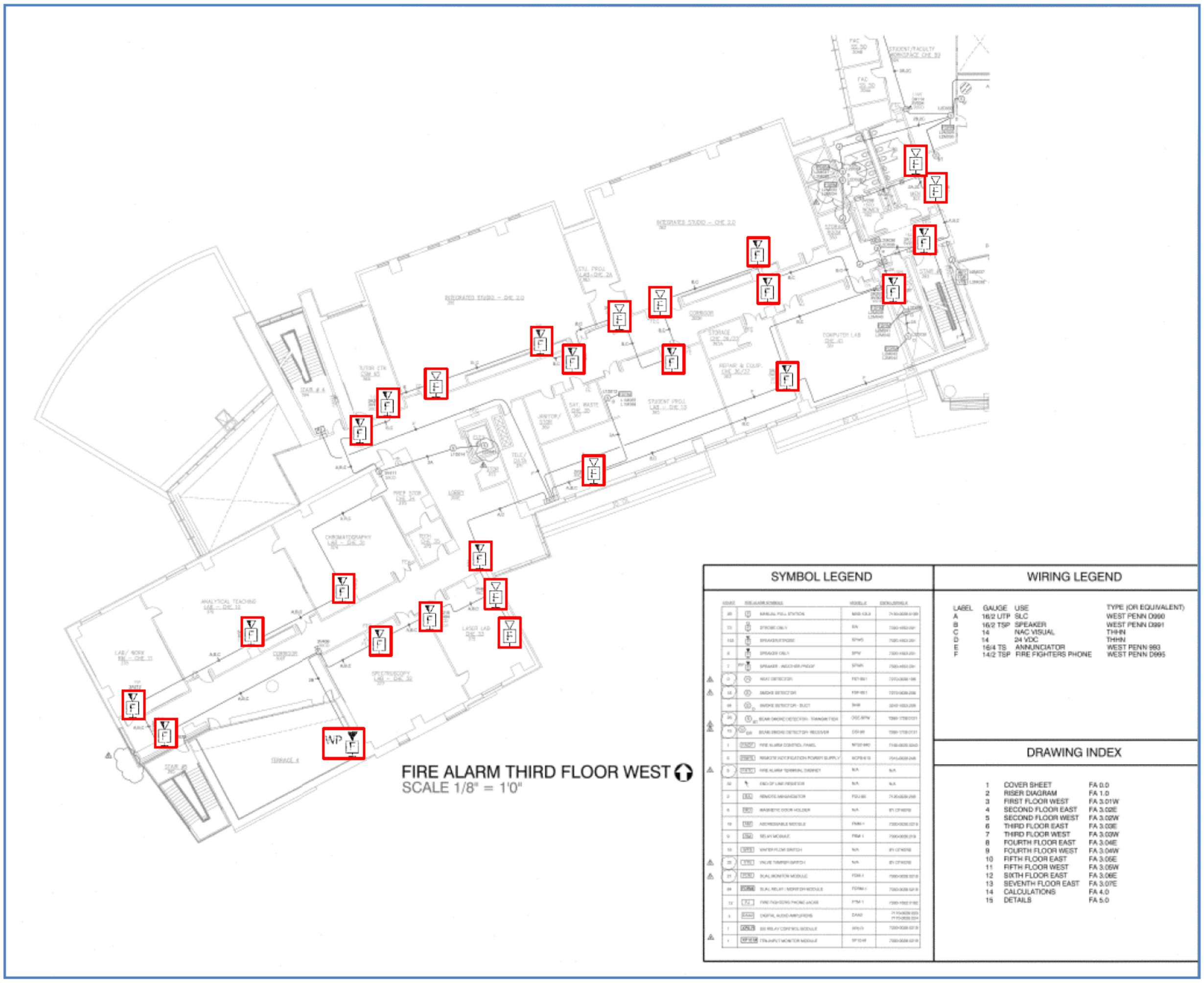
- Notification signals for occupants to evacuate must be audible and visible signals in accordance with NFPA 72, National Fire Alarm Code, and ICC / ANSI A117.1, American National Standard for Accessible and Usable Buildings and Facilities.
- The general evacuation alarm signal must operate throughout the entire building with the exception of exit stair enclosures and elevator cars.
- Audible alarm notification appliances must be distributed so they are effectively heard above the average ambient sound level that exists under normal conditions of occupancy. Business occupancies and places of assembly are assumed to have an average ambient sound level of 55 decibels (dBA), (NFPA 72-2007, Table A.7.4.2).
- To ensure that audible signals are clearly heard, a sound level of at least 15 dB above the average ambient sound level or 5 dB above the maximum sound level having a duration of at least 60 seconds, whichever is greater, measured 1.5 meters (5 feet) above the floor in the area required to be served by the system using the A-weighted scale (dBA), (NFPA 72-2007, Section 7.4.2.1).
- The audible alarm signal must be distinctive from audible signals used for other purposes in the CSM.
- Automatically transmitted evacuation or relocation instructions are permitted to be used to notify occupants and must be in accordance with NFPA 72, National Fire Alarm Code.
- Audible and visible fire alarm notification appliances must be used exclusively for fire alarm system or other emergency purposes unless the AHJ approves the system to be used for other purposes, in which case the fire alarm system takes precedence over all other signals, (NFPA 1012006, Section 9.6.3).
- During all times that the CSM is occupied, the required fire alarm system, once initiated, must activate an alarm signal in a continuously attended location for the purpose of initiating emergency action, by personnel trained to respond to emergencies.

As mentioned above, the average ambient sound level for Group B (Business) occupancies should be 55 dBA, according to NFPA 72-2007. In this context, the sound level in the CSM rooms must be at least 70 dBA (15 dB + 55 dB = 70 dB).

Regarding the location of the audible and visible appliances NFPA -2007 specifies :

- If ceiling heights allow, wall-mounted appliances shall have their tops above the finished floors at heights of not less than 2290 mm and below the finished ceilings at distances of not less than 150 mm (Section 7.4.7.1).
- Wall-mounted appliances shall be mounted such that the entire lens is not less than 2030 mm and not greater than 2440 mm above the finished floor or at the mounting height specified using the performance-based alternative (Section 7.5.4.1).

The locations of alarm notifications appliances installed in the building are shown in Annex 10.1. Figure 15 shows an example of the notifications appliances installed in the second floor.



	Strobe Only		Speaker Only
	Speaker/strobe	WP	Speaker – Water Proof

Figure 15 – Location of notification appliances in the third floor (West) of CSM

Deep Blue Integration, 2013

<u>Intelligibility</u>

As mentioned in 4.3.2, the system installed in CSM is a Fire Alarm with In-building Fire Emergency Voice Alarm Communication System (EVACS).

NFPA 72-2007, Section 7.4.1.4 requires voice intelligibility for voice communications systems, but this code doesn't specify the requirements for achieving the voice intelligibility in the systems.

NFPA 72-2013 clarifies some situations where voice intelligibility can be achieved inside specific construction configurations as explained below:

- Intelligibility must be determined by ensuring that all areas in the building have the required level of audibility. In an Acoustically Distinguishable Space (ADS) that is a non-acoustically challenging area, designing for audibility will typically result in an intelligible system provided minimum speaker guidelines are followed. Areas typically considered to be non-acoustically challenging include traditional office environments, hotel guest rooms, dwelling units, and spaces with carpeting and furnishings (NFPA 13 -2013, Section 24.4.2.2.2.1(2).
- Buildings and areas of buildings that are not acoustically challenging such as traditional office environments, hotel guest rooms, dwelling units, and spaces with carpeting and furnishings generally meet intelligibility levels if the audibility levels are consistent with the requirements of NFPA 72, National Fire Alarm and Signaling Code. Performing intelligibility testing might not be necessary in these areas (NFPA 13 -2013, Section D.3.6.1)

As the CSM is mainly used for business occupancies, it could be considered as an ADS that is a non-acoustically challenging area. Accordingly, the assumption that designing for audibility will typically result in an intelligible system, provided that minimum speaker guidelines are followed and that audibility levels are consistent with the requirements of NFPA 72-2013, might be applicable.

<u>Annunciation and staged (phased) evacuation</u>

According to NFPA 101-2006, Section 9.6.3.6.2, where total evacuation of occupants is impractical due to building configuration, only the occupants in the affected zones must be notified initially, and provisions must be made to selectively notify occupants in other zones to afford orderly evacuation of the entire building. In this case, to approve an evacuation plan to selectively notify building occupants, the authority having jurisdiction should consider several building parameters, including building compartmentation, detection and suppression system zones, occupant loads, and the number and arrangement of the means of egress.

CBC-2007, Section 907.2.12.2 states that the operation of any automatic fire detector, sprinkler water-flow device or manual fire alarm box must automatically sound an alert tone, followed by voice instructions giving approved information and directions for a general or staged evacuation on a minimum of the alarming floor, the floor above and the floor below in accordance with the building's fire safety and evacuation plans required by Section 404 of the California Fire Code.

In the CSM, depending on the location of a fire, the building configuration may inhibit total evacuation of occupants and the atrium space contains a horizontal exit and area of refuge that is suitable to be used as staged evacuation in the event of a fire, as specified NFPA 101-2006, Section 9.6.3.6.2.

According to NFPA 101-2006, Section 9.6.7.4, the floor area of each zone may not exceed 22,500 ft^2 and the length of any single fire alarm zone may not exceed 300 ft in any direction. In this case, as the CSM is protected throughout by an automatic sprinkler system, the area of the fire alarm zone is permitted to coincide with the allowable area of the sprinkler system and therefore the sprinkler system is permitted to be annunciated on the fire alarm system as a single zone.

Figure 16 shows an example of recommended building zones within the CSM. A fire located within the atrium space would initially evacuate all occupants, Levels 2 through Levels 6 from the atrium area of the building, (Zone 1) and the entirety of Level 1, (Zone 4) simultaneously, since the evacuation paths of travel do not overlap. After evacuation of personnel in Zones 1 & 4, the remainder of the building should be evacuated, including the East and West wings, (Zones 2 & 3).

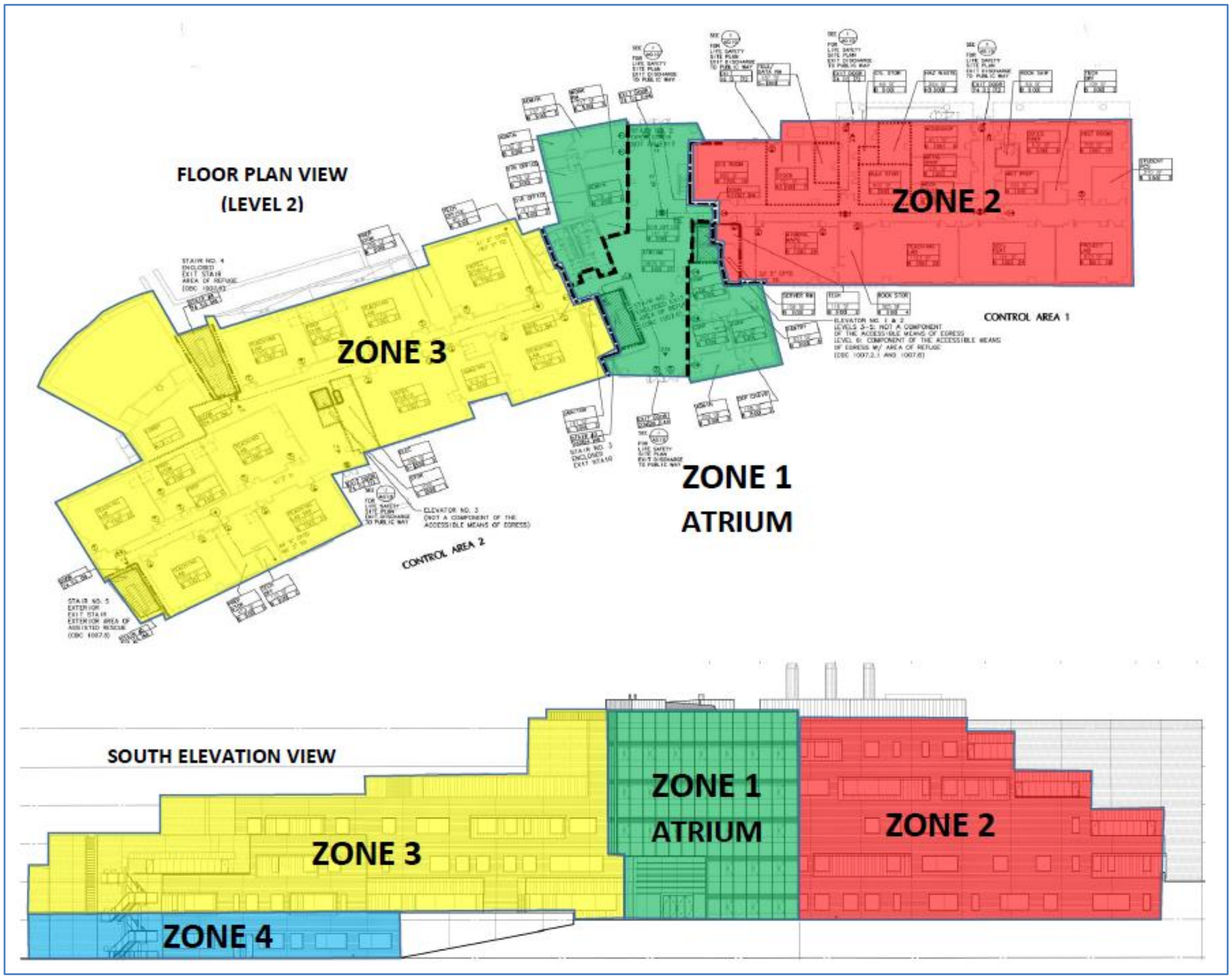


Figure 16 – Recommended building zones for staged evacuation

Ref. NFPA 106-2006, Section 9.6.3.6.2; ZFG 2009; Radle, L., 2013

4.3.5 System Design

This system is classified as Class B, addressable and manual, and complies with Section 9.6 of the Life Safety Code, (NFPA 101- 2006, Section 38.3.4) since it is designed to be installed, tested, and maintained in accordance with NFPA 70, National Electrical Code, and NFPA 72, National Fire Alarm Code, (NFPA 101- 2006, Section 9.6.1.3).

Class B circuits, according to NFPA 72 -2007, Section 6.4.2.1.1(2)), do not transmit an alarm or supervisory signal for signaling line circuits and do not allow connected devices to operate during a single open or a simultaneous single ground fault on any circuit conductor for the Notification Appliance Circuit (See Figure 17).

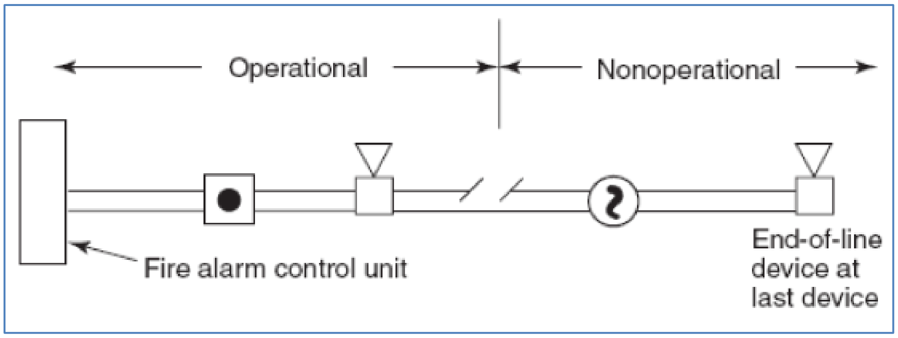


Figure 17 – Schematic drawing of a Class B circuit for IDC and NAC

Ref. NFPA 72 -2007, Section 6.4.2.1.1(2))

The circuit designations for the alarm system are as follows:

- Signaling Line Circuit (SLC): Class B and Survivability level 1.
- Notification Appliances Circuit (NAC): Class B and Survivability level 1.

Table 17 and Table 18 show the Alarm, Trouble, and Alarm Receipt Capability (ARC) during abnormal conditions for Class B Signaling Line Circuits (SLCs) and Notification Appliance Circuits (NACs).

Table 17-Performance of Notification Appliance Circuits (NACs)

Class	B	
	Trouble Indication at Protected Premises	Alarm Capability During Abnormal Conditions
Abnormal Condition	1	2
Single open	X	—
Single ground	X	R
Wire-to-wire short	X	—

Source: NFPA 72-2007, Section 6.4.2.1.1

Table 18-Performance Signaling Line Circuits (SLCs)

Class	B		
Style	4		
	Alm	Trbl	ARC
Abnormal Condition	1	2	3
Single open	—	X	—
Single ground	—	X	R
Wire-to-wire short	—	X	—
Wire-to-wire short & open	—	X	—
Wire-to-wire short & ground	—	X	—
Open and ground	—	X	—
Loss of carrier (if used)/channel interface	—	X	—

Source: NFPA 72-2007, Section 6.4.2.1.1

A pathway survivability Level 1 consists of pathways in buildings that are fully protected by an automatic sprinkler system in accordance with NFPA 13 - Standard for the Installation of Sprinkler Systems, with any interconnecting conductors, cables, or other physical pathways installed in metal raceways.

The fire alarm systems provide three types of signals:

- Alarm : warning of fire danger that requires immediate action (alarm signals initiated by manual fire alarm boxes, automatic fire detectors, water flow from the automatic sprinkler system, or actuation of other fire suppression systems or equipment)
- Supervisory: action is needed in connection with the operation of other fire protection systems that are being monitored by the fire alarm system
- Trouble: fault in a monitored circuit or component of the fire alarm system or the disarrangement of the primary or secondary power supply

The operation matrix of the alarm system of the building upon the receipt of signal is shown in Figure 18.

ACTION

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

Figure 18 – Operation Matrix of the Fire Alarm ad Detection System in CSM

Ref. Deep Blue Integration, 2013

Annex 10.1 shows the Fire Alarm and Voice Evacuation System designed by the company Deep Blue Integration Inc. The system includes the audible and visible devices distributed throughout the building and their associated decibel and candela ratings required per square foot of area covered.

4.3.6 Power Requirements for Fire Alarm and Communication Systems

The main requirements for Secondary Power Supply, according to NFPA 72-2007 are summarized below:

- The secondary power supply must consist of one of the following (Section 4.4.1.5.2.1):
  - Storage batteries dedicated to the supervising station equipment arranged in accordance with 4.4.1.8
  - A dedicated branch circuit of an automatic-starting, engine-driven generator arranged in accordance with 4.4.1.9.3.2 and storage batteries dedicated to the supervising station equipment with 4 hours of capacity arranged in accordance with 4.4.1.8
  - A dedicated branch circuit of multiple engine-driven generators, at least one of which is arranged for automatic starting in accordance with 4.4.1.9.3.2

- The secondary power supply for emergency voice/alarm communications service must be capable of operating the system under quiescent load for a minimum of 24 hours and then shall be capable of operating the system during a fire or other emergency condition for a period of 15 minutes at maximum connected load. 4.4.1.5.3

Battery supplies are installed in the CSM at the following equipment:

- Fire Alarm Control Panel (FACP)
- Remote Notification Power Supply (RNPS): 3-5th Floor East.
- RNPS1: 2nd Floor East
- RNPS2: 3rd and 4th Floor East
- RNPS3: 5th Floor East
- RNPS4: 6th Floor East
- RNPS5: 4th Floor West

The secondary power supply requirements calculation for the fire alarm system are shown in Annex 10.1.

Table 19 illustrates calculations details for the Fire Alarm Control Panel (FACP) with the Standby and Alarm Current per unit, according to the manufacturer and the quantities of devices supplied by design.

Required Standby Time is stated as 24 hour operation under quiescent load, and Alarm Time is calculated for 15 minutes (0.250 hour) at maximum connected load, according the requirements stated by NFPA 72 for this kind of systems (EVACS).

Table 19- Secondary Power Supply calculations for FACP

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

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

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

Ref. Deep Blue Integration, 2013

In this case the adjusted battery capacity requirement for the FACP, including a 20 % safety margin, is 35.6 Amp-Hour and the battery capacity installed, as shown in Table 19, is 55 Amp-hours, so the system complies with the NFPA 72 requirements for secondary power supply.

4.3.7 Commissioning and ITM

The inspection, testing and maintenance (ITM) requirements for the fire alarm system and components installed in the building according to NFPA 72-2007 are summarized in Appendix 9.7.

4.3.8 Fire Alarm and Detection system – Summary Table

Table 20 summarizes the amount, model and CSFM Listing # of the devices, appliances and equipment installed in the fire alarm system.

Table 20- Fire Alarm System Details

System Devices			# of Devices	CSFM Listing #
Fire Alarm Control Panel (FACP)			1	7165-0028:0224
Remote Notification Power Supply (RNPS)			5	7315-0028:248
Fire Alarm Terminal Cabinet (FATC)			3	N/A
End of Line Resistor (EOL)			32	N/A
Circuit	**Wire (or equivalent)**	**Device Description**	**# of Devices**	**CSFM Listing #**
SLC, Class B, Style 4	16/2 Gauge West Penn D990	**Smoke Detector**	30	7272-0028:206
		Duct Smoke Detector	62	3242-1653:209
		Beam Detector[17]	11	7260-1728:0121
		Manual Pull Station	30	150-0028:0199
		Addressable Module	29	150-0028:0199
		Relay Module	6	150-0028:0199
		Dual Monitor Module	18	150-0028:0199
		Digital Audio Amplifier	4	7170-0028:223
		Bell	1	BY OTHERS
		Magnetic Door Holder	8	BY OTHERS
		Water Flow Switch	16	BY OTHERS
		Water Flow Alarm	7	BY OTHERS
		Fire Pump Supervisory	3	BY OTHERS
		Sprinkler System Supervisory	12	BY OTHERS
		Smoke Damper Position Indicators	52	BY OTHERS
		Valve Tamper Switch	16	BY OTHERS
NAC Visual	14 Gauge THHN	**Strobe**	223	7320-1653:201
NAC Speaker Class B	16/2 Gauge West Penn D991	**Speaker**	172	7320-1653:201
Annunciator	16/4 Gauge West Penn 993	**Remote Annunciator**	2	7120-0028:209
Fire Fighter Phone	14/2 Gauge West Penn D995	**Fire Fighters Phone Jack**	12	7300-1652:0182
Reference: Deep Blue Integration, 2013, Radle, L.2013				

[17] Imagers and Emitter

4.4 Fire Suppression System

A sprinkler system consists of an integrated network of piping designed in accordance with fire protection engineering standards that includes a water supply source, a water control valve, a water-flow alarm, and a drain. It is commonly activated by heat from a fire, discharging water over the fire area. The definitions, design criteria and requirements for these systems are stated in NFPA 13 - Standard for the Installation of Sprinkler Systems.

The fire suppression system installed in CSM was designed by Aero Automatic Sprinkler Company (http://www.aerofire.com/). The hydraulic calculations were performed with the software Hydracad.

4.4.1 Fire Suppression Requirements

As specified in 3.1.1, the CSM is Classified a Group B, Business Occupancy, but it is not classified as a high-rise building. There is no specific fire suppression requirements in CBC-2007 for non-high-rise buildings classified as Group B. Nonetheless there are other features in the CSM that makes the entire building to have an automatic sprinkler system. These features are as follows:

- There is an atrium that connects Level 2-6.
- There are incidental uses in the building that requires sprinklers (A-3, CBC-2007, Section 903.2.1.3; H-3, CBC-2007, Section 903.2.4.1; S-2 and S-2, CBC-2007, Section 903.2.8)
- The actual height of the building is 64 ft.

For atriums, CBC-2007, Section 404.3 requires an approved automatic sprinkler system to be installed throughout the building[18] and for buildings 55 ft or more in height with a floor level having an occupant load of 30 or more, CBC-2007, Section 903.2.10.3 also requires an automatic sprinkler system installed throughout the building.

In addition to the foregoing requirements, NFPA 13-2007, Section 4.1 states that a building, where protected by an automatic sprinkler system installation, shall be provided with sprinklers in all areas except where specific sections of this standard permit the omission of sprinklers[19].

[18] This section also cites two exceptions that may be applicable to this building taking in consideration the construction configuration, but theses exceptions are nor pertinent according to NPFA 13-2007, as explained bellow.

[19] The oldest and most important design rule of NFPA 13, as stated in Section 4.1, is that sprinklers should be installed in all areas of a building. Sprinkler systems designed in accordance with NFPA 13 are not intended to prevent a fire in an unsprinklered area from spreading into a sprinklered area.

The CSM is protected throughout by an automatic sprinkler system in accordance with Section 903 of the CBC- 2007. Sprinkler systems must be installed, repaired, operated and maintained in accordance with Section 901.2 of the CBC- 2007.

The automatic sprinkler system of the CSM must comply with NFPA 13, Standard for the Installation of Sprinkler Systems, (CBC, 2007, Section 903.3.1.1).

System size must be designed such that initial water is discharged from the system test connection in not more than 60 seconds, starting at the normal pressure on the system and at the time of fully opened inspection test connection. (NFPA 13-2007, Section 7.2.3.2).

4.4.2 Type and Design Criteria of the Sprinkler System

The fire suppression system installed in the building is a Wet Pipe System, which contains water under pressure at all times and utilize a series of closed sprinklers. When a fire occurs and produces a sufficient amount of heat to activate one or more sprinklers, water immediately discharges from the open sprinklers.

As depicted in Figure 19, the building's sprinkler system is supplied by a public water main from which the water is sucked by a pump located at a fire pump room (inside the building). The fire pump feeds 4 standpipe riser systems[20] and 6 sprinkler systems (one for each floor). Standpipe riser in Stair 3 feeds the sprinkler systems risers located at Levels 2-6. Sprinkler system for Level 1 is fed from a riser located in Pump Room (See Appendix 9.8)

The global wet pipe system counts on a Fire Department Connection (FDC), through which water can be supplied from an external source.

[20] Standpipe systems are Class 1 according to NFPA 14 - Standard for the Installation of Standpipe and Hose Systems

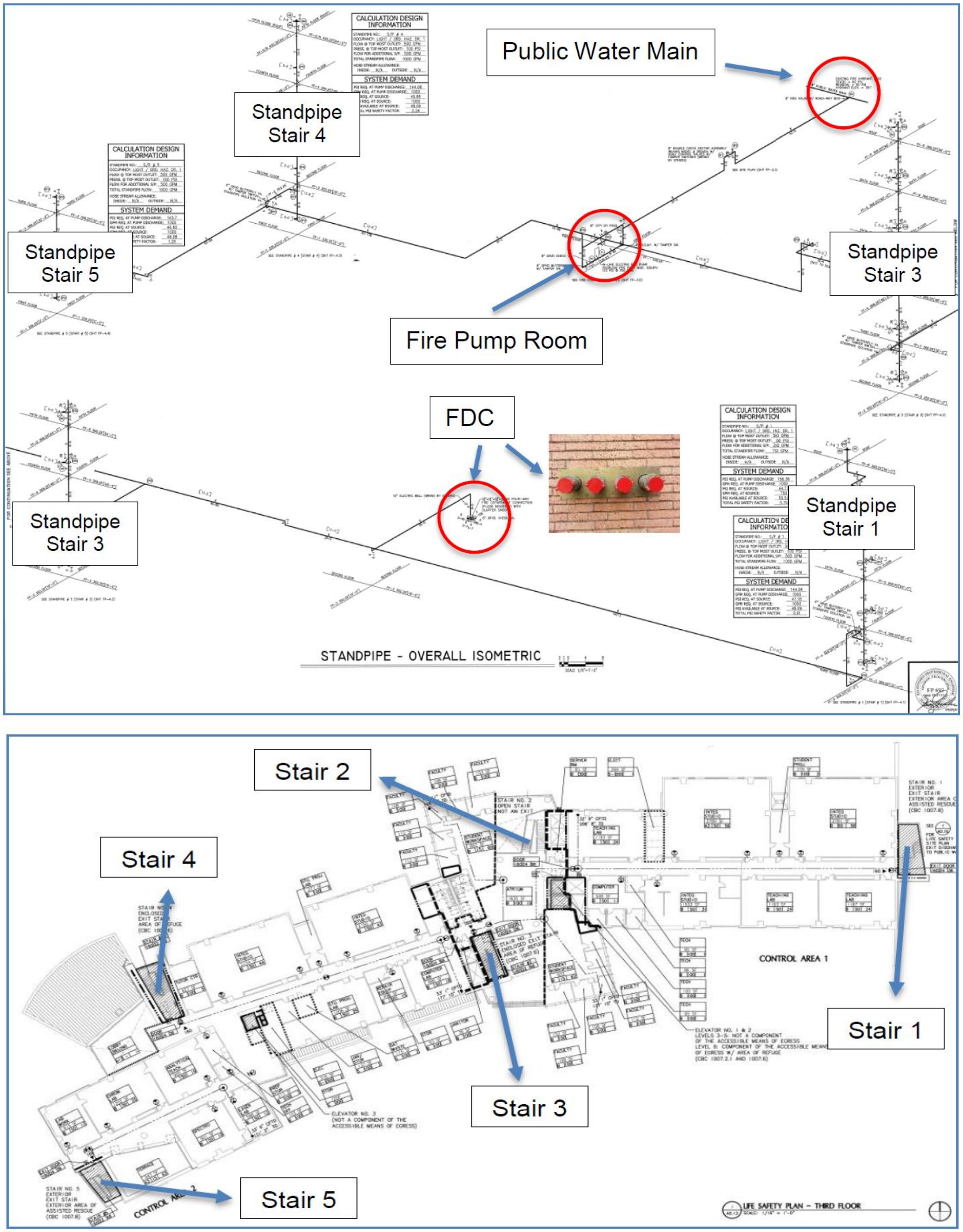


Figure 19 – Isometric Standpipe System and stairs location in the building

The design criteria used for this building is based upon the density/area method and the occupancy classification related to the sprinkler protection. The occupancies were classified as Light Hazard (Lobbies, Lecture, Office, and Conference Rooms) and Ordinary Hazard Group 1 (Laboratories, Mechanical, Storage and Electrical Rooms).

4.4.3 Water Supply

Sprinkler systems may be supplied with water from one source or a combination of sources – street mains, gravity tanks, reservoirs, fire pumps, pressure tanks, rivers, lakes, wells, etc. As explained in previous section, the water supply serving the fire suppression systems installed in the building comes from a Public Water Main.

NFPA 13 states that a water flow test must be performed for each source of water supply, to ensure that a water supply of sufficient flow and pressure is available for a water-based fire protection system. It is essential that accurate water flow availability obtained represents the available water supply under the worst case scenario (water demand at its maximum).

The purpose of a water flow test is to establish that an adequate water supply exists to supply the following requirements:

1. Water to support firefighting activities,
2. Water consumed during the peak domestic demand,
3. Calculated sprinkler system demand.

The water data for designing the extinction system were obtained from a flow test carried out at the public main in August, 2011, as shown in Figure 20 . According to this test, the static pressure obtained was 60 psi (Hydrant 63), and a flow of 914 GPM was measured at a residual pressure of 55 psi (Hydrant 63).

The measurements were subsequently adjusted (10 % of reduction), resulting in a static pressure of 54 psi and a flow of 914 GPM at a residual pressure of 49 psi. These data were used, for determining the flow and pressure availability for the sprinkler system.

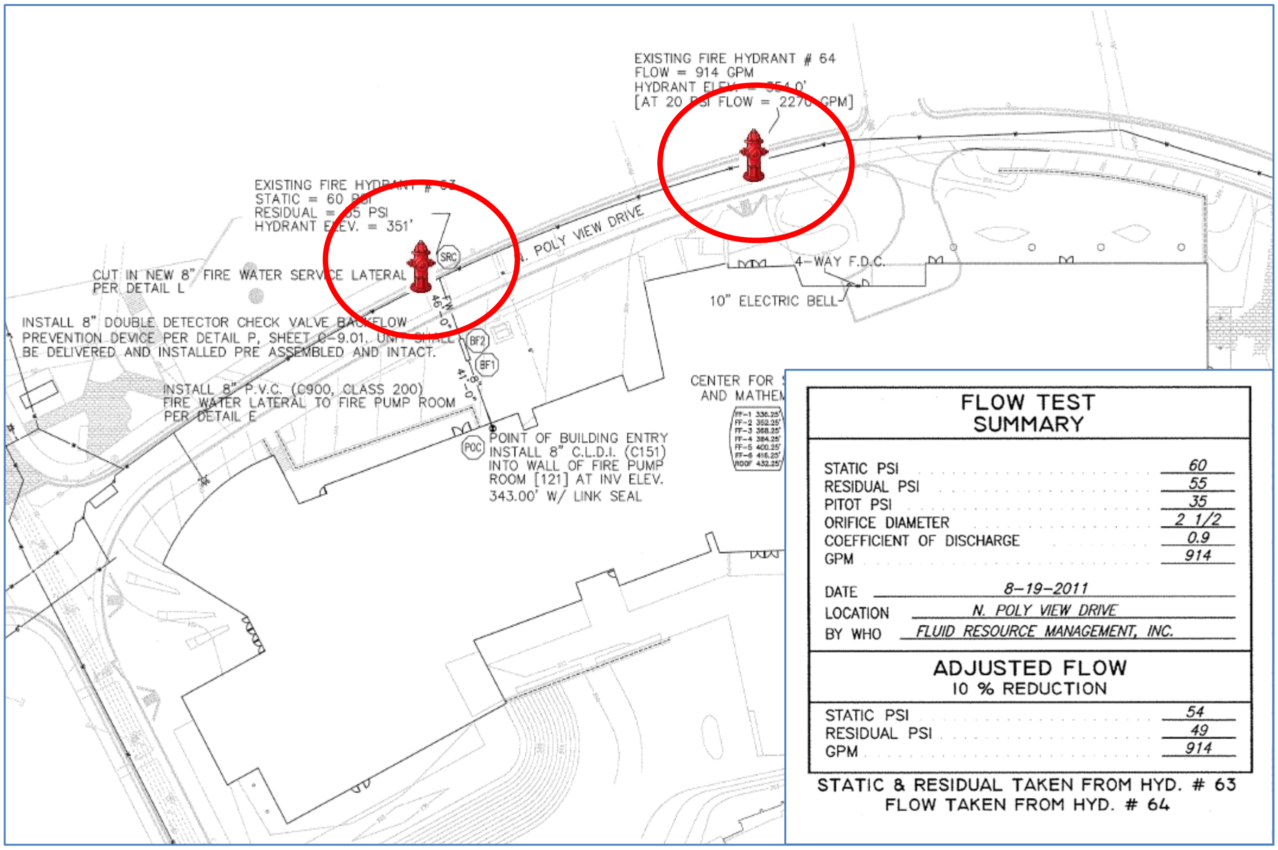


Figure 20 – Test Flow for the building and locations of hydrants used

Ref. Aero Automatic Sprinkler Co. 2011-SD

4.4.4 Design Criteria for Automatic Sprinkler Systems

As explained in 3.1.1, the building is mainly comprised of lecture rooms, lobbies/corridors (circulation), office/conference rooms and laboratories. There are also some rooms for storage and electrical/mechanical equipment. Based in these occupancy characteristics, the design criteria was established as detailed in Table 21.

Table 21- Design criteria for sprinkler systems					
Occupancy		Hazard	Protection Area Sprinkler (ft^2)	DESIGN (gpm/ft^2/ 1500 ft^2)	Hose Stream Allowance (I/O) (gpm)
A-3	Lobbies/Lectures	Light Hazard[21]	225	0.10	100/0
B	Office/ Conference Room	Light Hazard	130	0.10	100/0
B	Laboratories	O.H. GR. 1[22]	130	0.15	100/150
S-1	Storage/Mechanical / Electric Room	O.H. GR. 1	130	0.15	100/150
Ref	*NFPA 2007 5.2 and 5.3*		*NFPA 2007 TABLE 8.6.2.2.1(a)*	*NFPA 2007 FIGURE 11.2.3.1.1*	*NFPA 2007 12.8*

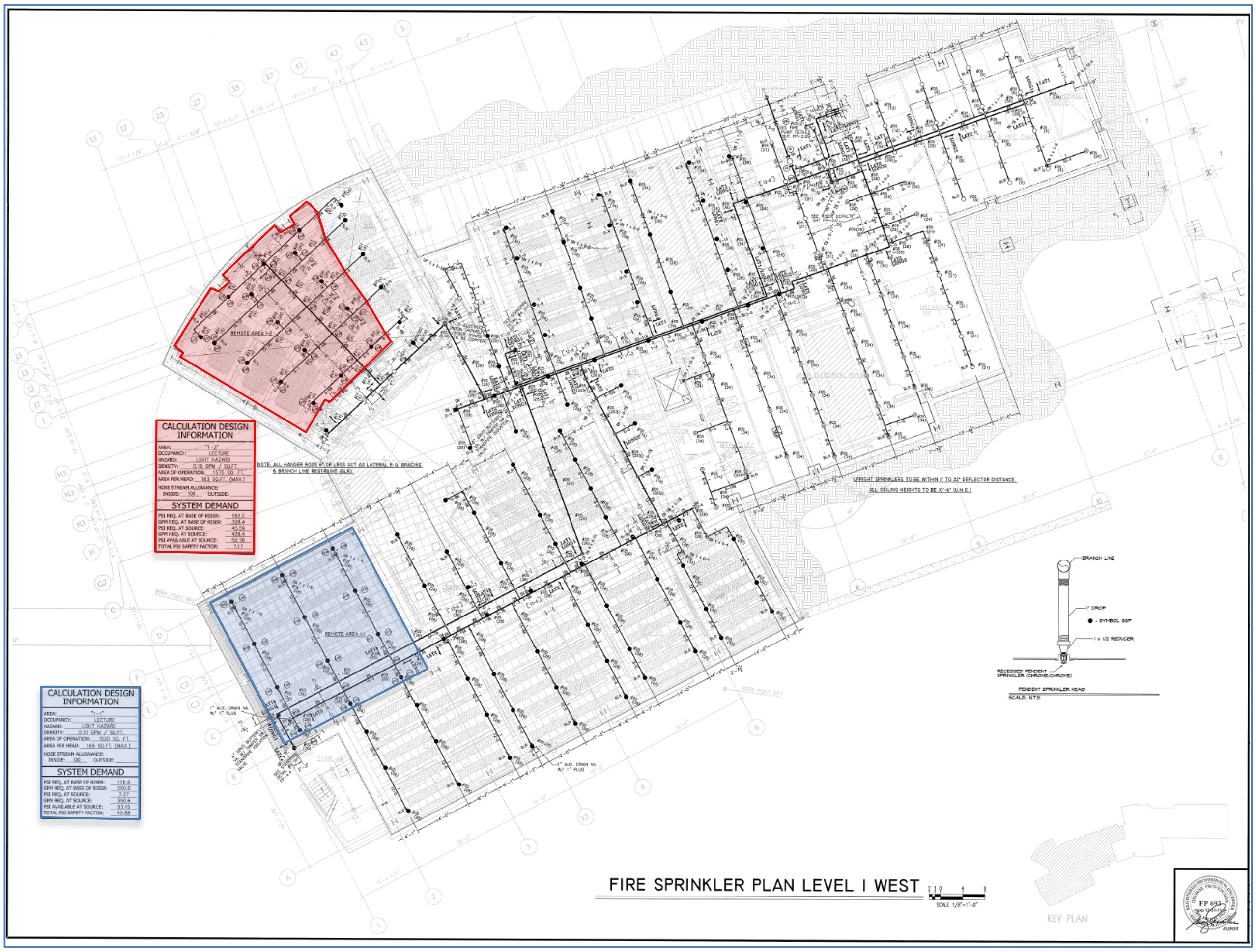
Hydraulic calculations were performed at different levels and areas because the floors were not symmetric and the hazards were not homogeneous. The calculations were performed taking in consideration the demand of the sprinklers systems and also the standpipe systems located at the stairs.

An important objective of this calculations was to determine the worst condition for selecting/evaluating the pump capable of supplying the higher flow and pressure demand in the building.

The hydraulic demand for the standpipes system were calculated based upon the flow and pressure requirements for this systems combined with sprinklers system, according NFPA 14 Standard for the Installation of Standpipe and Hose Systems. Figure 21 illustrates an example of the hydraulic calculations performed in Level 1 for two remotes areas (“1-1” and “1-2”).

21 Occupancies or portions of other occupancies where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected.

22 Occupancies or portions of other occupancies where combustibility is low, quantity of combustibles is moderate, stockpiles of combustibles do not exceed 8 ft and fires with moderate rates of heat release are expected.



CALCULATION DESIGN INFORMATION	
AREA:	"1–1"
OCCUPANCY:	LECTURE
HAZARD:	LIGHT HAZARD
DENSITY:	0.10 GPM / SQ.FT.
AREA OF OPERATION:	1520 SQ. FT.
AREA PER HEAD:	168 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE: INSIDE:	100
OUTSIDE:	
SYSTEM DEMAND	
PSI REQ. AT BASE OF RISER:	126.6
GPM REQ. AT BASE OF RISER:	250.6
PSI REQ. AT SOURCE:	7.27
GPM REQ. AT SOURCE:	350.6
PSI AVAILABLE AT SOURCE:	53.15
TOTAL PSI SAFETY FACTOR:	45.88

CALCULATION DESIGN INFORMATION	
AREA:	"1–2"
OCCUPANCY:	LECTURE
HAZARD:	LIGHT HAZARD
DENSITY:	0.10 GPM / SQ.FT.
AREA OF OPERATION:	1575 SQ. FT.
AREA PER HEAD:	163 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE: INSIDE:	100
OUTSIDE:	
SYSTEM DEMAND	
PSI REQ. AT BASE OF RISER:	162.2
GPM REQ. AT BASE OF RISER:	328.4
PSI REQ. AT SOURCE:	45.59
GPM REQ. AT SOURCE:	428.4
PSI AVAILABLE AT SOURCE:	52.76
TOTAL PSI SAFETY FACTOR:	7.17

Figure 21 – Hydraulic Calculations on Level 1 for remotes areas "1-1" and "1-2"

Ref. Aero Automatic Sprinkler Co. 2011-SD

For Quick-Response Sprinklers, including Extended Coverage Quick Response Sprinklers, NFPA 13-2007, Section 11.2.3.2.3, permit to reduce the system area of operation (see Figure 22) when all of the following conditions are satisfied:

- Wet pipe system
- Light hazard or ordinary hazard occupancy
- 20 ft (6.1 m) maximum ceiling height

Based on the foregoing permit, remotes areas of the building having Quick-Response Sprinklers and complying the above conditions, were calculated with the reduction allowed (see Annex 10.2 and Appendix 9.9). This is the case for Remote Areas 3-1, 3-2, 6-2 and 6-3 where the design criterion is reduced 39.25%.

These Remote Areas are classified as Ordinary Hazard Group 1 (Laboratories) with ceiling heights of 10'6", (x = 10.5 feet) and have no unprotected ceiling pockets. Therefore, using the equation (or graph) presented in Figure 22, the design area reduction can be calculated (Y = -15.75 + 55 = 39.25% reduction to design area).

This issue is relevant for the approval of the building because the permit stated in NFPA 13-2007 regarding the reduction of the system area of operation, is no longer accepted in CBC -2013 for ordinary hazard occupancy. This is clarified in CBC-2013, Section 35 – Referenced Standards (Page 635), where the reduction permit is only specified for Light Hazard.

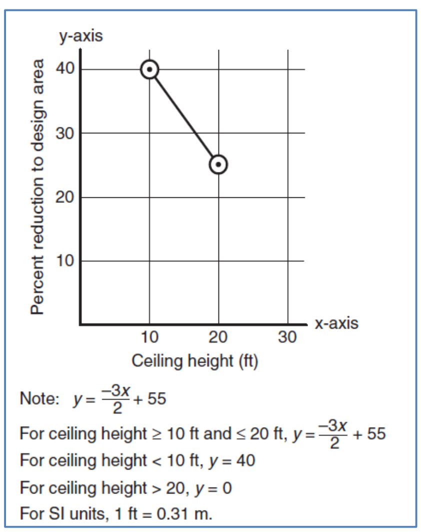
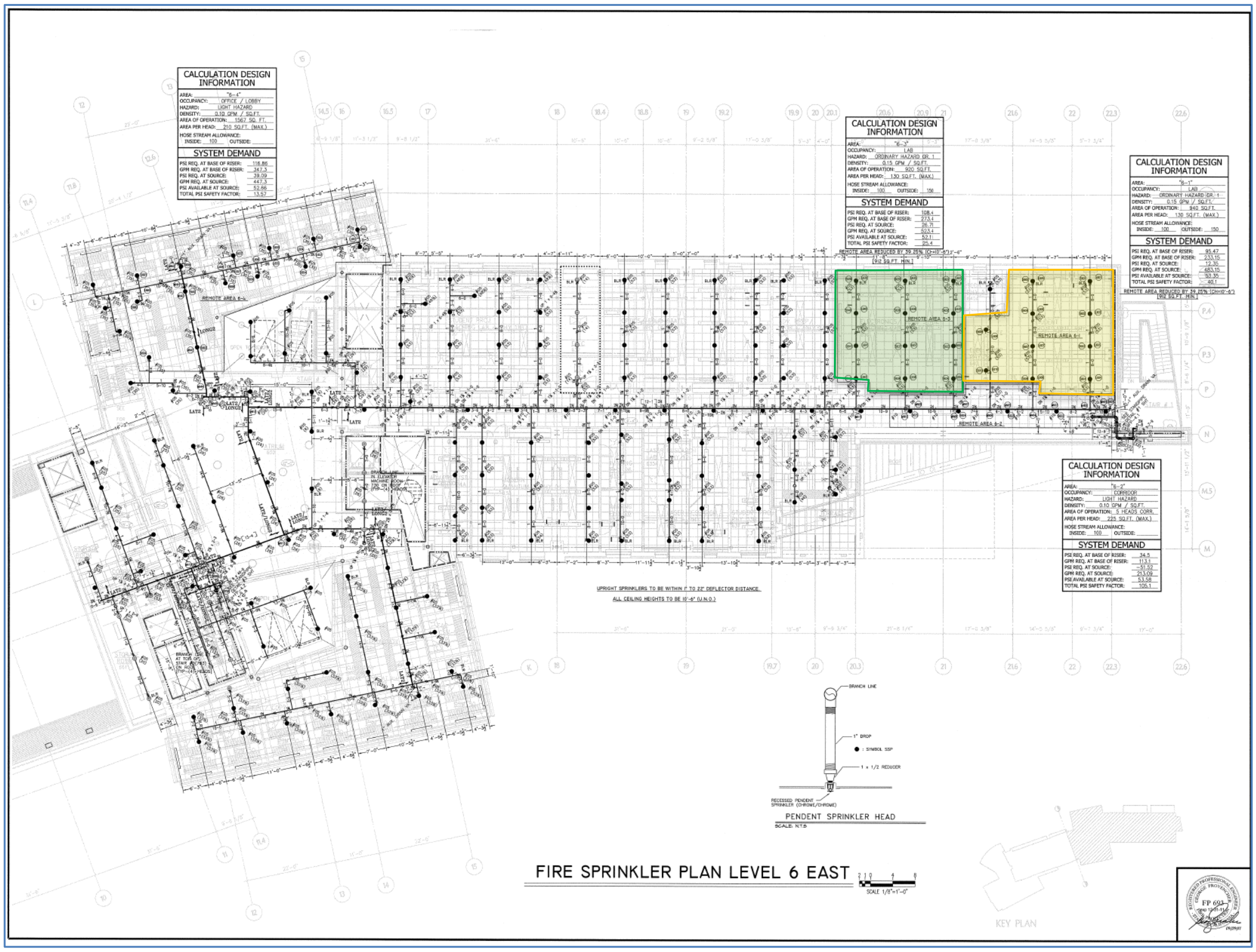


Figure 22 – Design area reduction for Quick-Response Sprinklers - NFPA 13-2007

Figure 23 shows an example of the hydraulic calculations performed in Level 6 for two remotes areas ("6-1" and "6-3"), where the design criterion is reduced 39.25%.

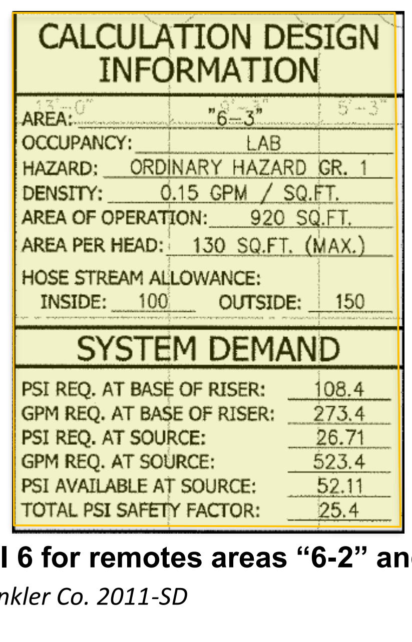


CALCULATION DESIGN INFORMATION

AREA: "6–2"
OCCUPANCY: CORRIDOR
HAZARD: LIGHT HAZARD
DENSITY: 0.10 GPM / SQ.FT.
AREA OF OPERATION: 5 HEADS CORR.
AREA PER HEAD: 225 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE:

SYSTEM DEMAND

PSI REQ. AT BASE OF RISER: 34.5
GPM REQ. AT BASE OF RISER: 113.1
PSI REQ. AT SOURCE: –51.52
GPM REQ. AT SOURCE: 213.09
PSI AVAILABLE AT SOURCE: 53.58
TOTAL PSI SAFETY FACTOR: 105.1



CALCULATION DESIGN INFORMATION

AREA: "6–3"
OCCUPANCY: LAB
HAZARD: ORDINARY HAZARD GR. 1
DENSITY: 0.15 GPM / SQ.FT.
AREA OF OPERATION: 920 SQ.FT.
AREA PER HEAD: 130 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE: 150

SYSTEM DEMAND

PSI REQ. AT BASE OF RISER: 108.4
GPM REQ. AT BASE OF RISER: 273.4
PSI REQ. AT SOURCE: 26.71
GPM REQ. AT SOURCE: 523.4
PSI AVAILABLE AT SOURCE: 52.11
TOTAL PSI SAFETY FACTOR: 25.4

Figure 23 – Hydraulic Calculations in Level 6 for remotes areas "6-2" and "6-3"

Ref. Aero Automatic Sprinkler Co. 2011-SD

As explained above, the hydraulic calculations for the CSM were performed with the software HydraCad. Some hand calculations were conducted for this project in order to check the results generated with Hydracad. The evaluation for verifying the hydraulic calculations was conducted on remote Area 1-1, Level 1. The methodology and details of this hand calculation are described in Appendix 9.10 and summarized in Table 44.

Table 44 shows that results obtained by the designer company for the System Demand Pressure in remote area “1-1 (130.16 psi, see Figure 24) is very similar to the one obtained with the hand calculations (131.9 psi). Minor differences are mainly due to the use of different equivalent lengths for some fittings and the assumption of some different elevations of the pipes.

Figure 24 shows the Public Main Supply curve (Blue), the Combined[23] curve (Black) and the system demand curve (Green) for the remote area and riser calculated. In this case (Level 1: Area 1-1) the system demand (356.5 gpm at 130.16 psi) is readily satisfied by the Combined curve, even considering the HSA required for Light Hazard Classification.

Curves for the other remote areas are illustrated in Appendix 9.11, which also shows that the system demand is always satisfied by the Combined curves for all cases. This guarantees the adequacy of the water supply.

Annex 10.2 shows the sprinkler design calculations and shop drawing for each floor plan, and Table 22 and Table 23 summarize the results of these calculations.

[23] Public Supply + Pump.

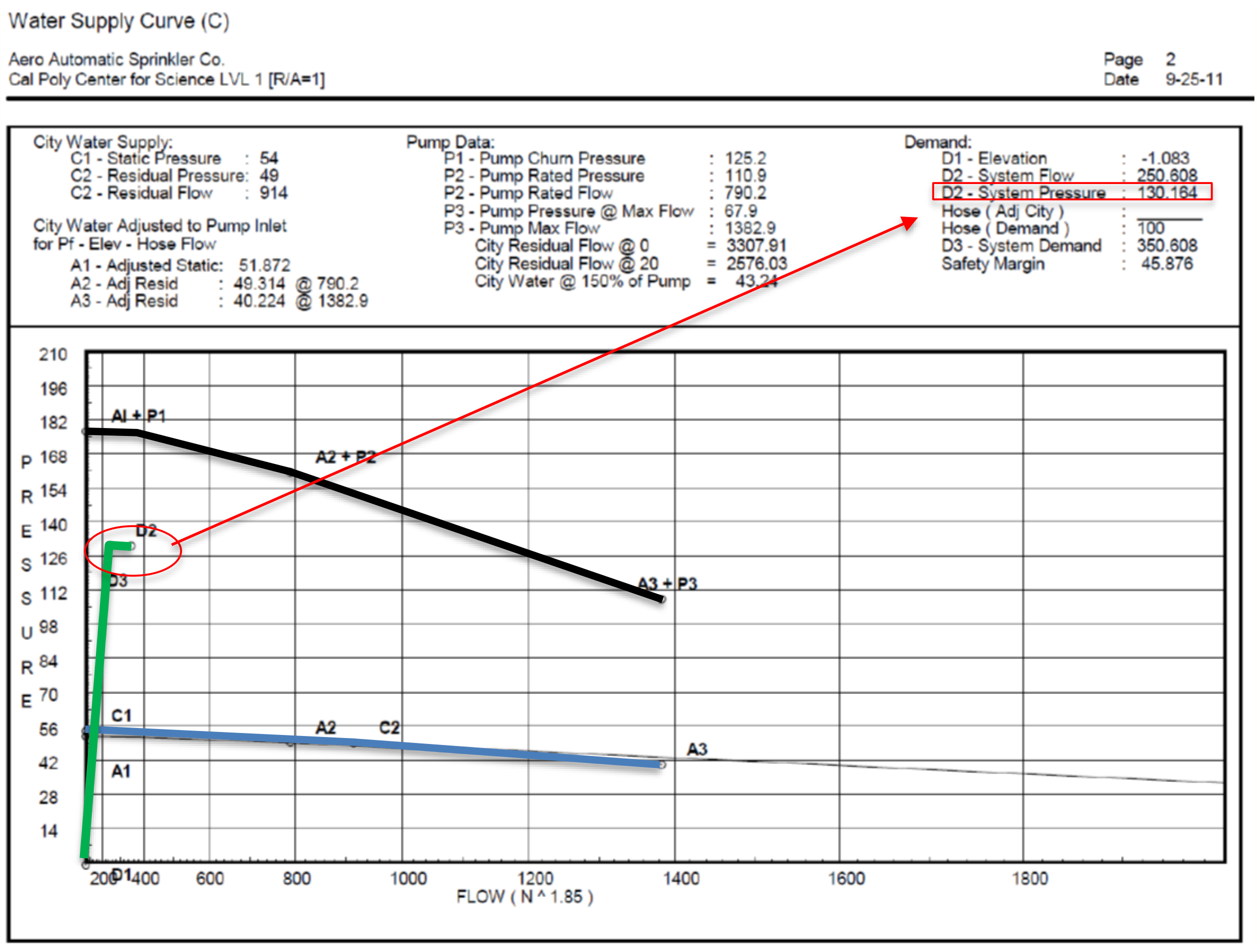


Figure 24 – System demand curve for the remote area A 1-1

Ref. Aero Automatic Sprinkler Co. 2011-SD

Table 22- Standpipes locations details

Standpipe	Location* See Figure 19.	Size	From/To	Pressure required at source (PSI)	Pressure available at source* (PSI)
Standpipe Riser 1	Stairway #1, East	6”	Level 3 to roof level	44.73	50.52
Standpipe Riser 2	Stairway #3, East	6”	Level 2 to roof level	47.18	48.09
Standpipe Riser 3	Stairway #4, West	4”	Level 1 to Level 5	45.55	48.09
Standpipe Riser 4	Stairway #5, West	4”	Level 1 to Level 3	46.80	48.08

Ref: Aero Automatic Sprinkler Company, 2011-HC; Radle, L.2013

**Includes 10% safety factor for adjusted flow.*

Table 23- Standpipes design details				
Calculation and Design Information	**Standpipe Riser 1**	**Standpipe Riser 2**	**Standpipe Riser 3**	**Standpipe Riser 4**
Occupancy	Light / Ordinary Hazard, Group 1			
Flow @ top most outlet (gpm)	500	500	500	500
Pressure @ top most outlet (psi)	100	100	100	100
Flow for additional standpipes (gpm)	250	500	500	500
Total Standpipe flow (gpm)	750	1000	1000	1000
Pressure required at pump discharge (psi)	156.36	144.06	144.08	143.7
Flow required at pump discharge (gpm)	1000	1000	1000	1000
Pressure required at source (psi)	44.73	47.18	45.85	46.80
Flow required at source (gpm)	750	1000	1000	1000
Pressure available at source (psi)	50.52	48.09	48.09	48.08
TOTAL psi Safety Factor*	5.79	0.91	2.24	1.26
Ref: Aero Automatic Sprinkler Company, 2011-HC; Radle, L.2013 ** Total psi Safety Factor does not include 10% safety factor for adjusted flow.(see Figure 20).*				

4.4.5 Installation Details

Appendix 9.8 describes the installation details of the sprinkler system in the CSM

Figure 25 shows the Fire Pump curve and data.

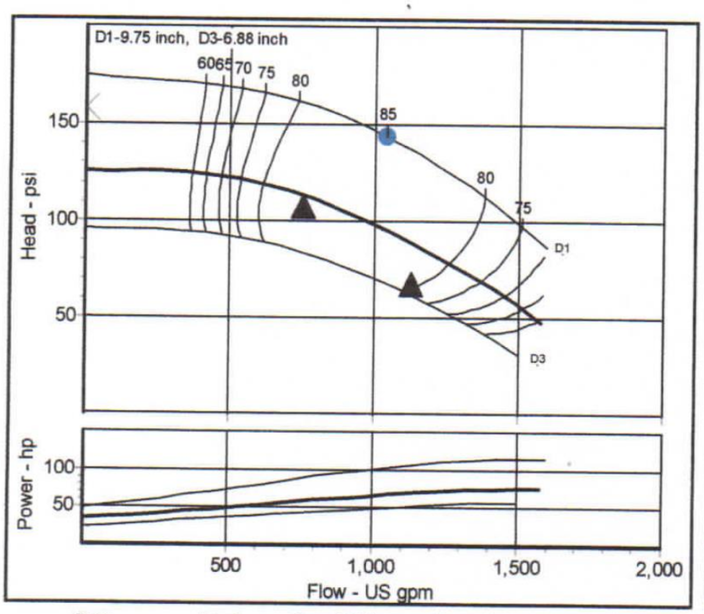
PEERLESS PUMP Reliability | When It Matters

Approved Fire Pumps

1151 N. Pomona Rd., Ste. B Corona, Ca 92882
Dena Mueller
Phone 951-738-9100
Fax 951-7389191

Project :	Cal Poly Center for Science		
Quote Ref. :	UK-999999-1	**Page No :** 1	**Date :** Monday, February 28, 2011

Type:	PG - In-Line Close Coupled Fire	Item :	1
Pump Model:	6PVF10	Impeller No.:	2699332
Pump Op. Speed:	3550 RPM, 60 Hz Electric	Liquid:	Water
Impeller Dia.:	8.24 inch	Temperature:	59 °F
Curve No.:	3116186	Viscosity:	1.14 cSt
Market :	FM/UL/ULC Listed Fire Pump	Sp. Gravity:	1.00
		Your Ref. :	



Rated Flow	750 US gpm
Rated Head	113 psi
Imp. Dia.	8.24 inch
Rated Power Required	58.1 hp
Rated Efficiency	85.3 %

NFPA Limits:

140% Head at shutoff	158.2 psi
65% Head at 150% flow	73.4 psi
Flow at 150%	1125 US gpm
Head at 150	89 psi
Power Req. at 150%	69.3 hp
Efficiency at 150%	84.5 %
Peak Power	75.4 hp
Closed Valve Pressure	125.2 psi
Approval	UL

Comments

Performance curve represents typical performance. NPSH data is

Flow (US gpm)	Head (psi)	Pump Efficiency (%)	Power Required (hp)	NPSH Required (ft)
0.0	125.2	0.0	34.7	
197.6	125.2	36.6	39.5	
395.1	124.2	62.8	45.7	
592.7	119.6	78.8	52.6	
790.2	110.9	86.2	59.5	
987.8	98.9	87.0	65.7	
1185.3	84.4	82.8	70.7	
1382.9	67.9	74.2	74.0	
1580.4	48.2	59.1	75.4	

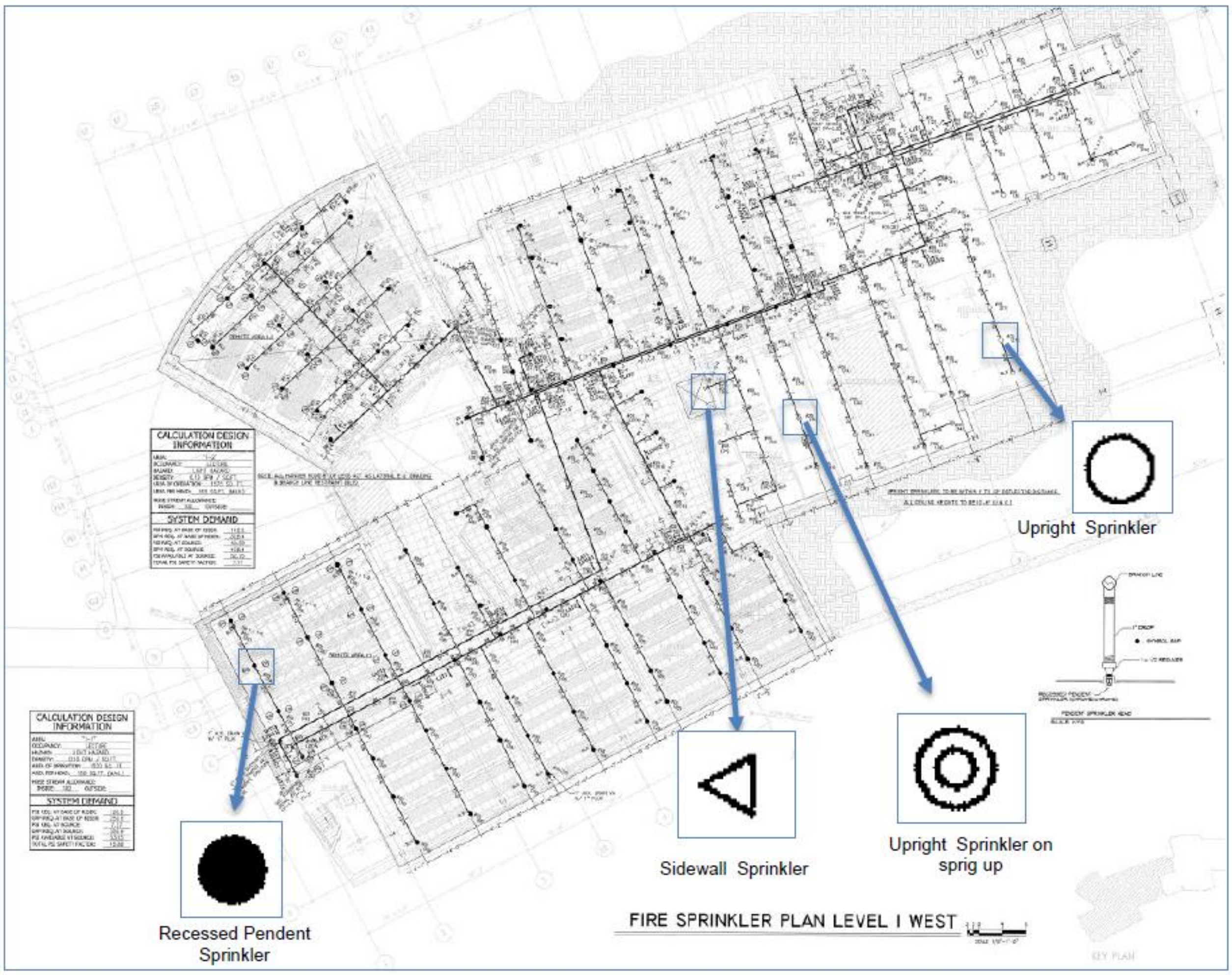
Figure 25 – Fire Pump curves and data

Ref. Aero Automatic Sprinkler Co. 2011-SD

The sprinklers used in the building are Quick Response with K-factor 5.6. Recessed chrome pendent sprinkler were installed in Lecture, Conference, Office and Laboratory Room (finished ceilings). Pendent, upright and upright sprinklers on sprig up were also used in Mechanical rooms, Elevator Mach. Room, Electrical Room, Telecommunication

Rooms and Stairs (exposed areas). Horizontal Sidewall Sprinklers were used in elevator wells.

Figure 26, illustrates an example of the sprinklers located on the first level of the building and the Cross Mains, Branch Lines on which they are installed. Piping is black steel schedule 10 and schedule 40.



SPRINKLER HEAD LEGEND											ESCUTCHEON			
SYM.	MFG.	MODEL	SIN	RESP	STYLE	FINISH	N.P.T.	ORIFICE	K	TEMP.	ESC. TYPE	FINISH	TEMP.	QTY.
●	TYCO	TY-FRB	TY3231	QR	PEND	CHRM	1/2"	1/2"	5.6	155	RECESSED	CHRM	N/A	123
◎/○	TYCO	TY-FRB	TY3131	QR	UPR	CHRM	1/2"	1/2"	5.6	200	–	–	–	66
▷	TYCO	TY-FRB	TY3331	QR	HSW	BRASS	1/2"	1/2"	5.6	200	–	–	–	1
TOTAL SPRINKLERS THIS SHEET														190

Figure 26 – Example of sprinklers in the first level of the building

Ref. Aero Automatic Sprinkler Co. 2011-SD

5. Performance-based Approach

In a Prescriptive-based approach, as analyzed in Section 4 of this report, fire safety is achieved by specifying certain construction materials, limiting dimensions, protection systems, or other features.

In a Performance-based approach, fire safety goals and objectives are translated into performance objectives and performance criteria. Fire models and calculations are used in combination with the building design specifications, specified fire scenarios, and specified assumptions to determine whether the performance criteria are met, in which case there is compliance with the code under the performance-based design option.

Performance-based codes establish acceptable or tolerable levels of hazards or risk for a variety of health, safety, an public welfare issues in buildings. Compliance with these codes is typically attained by using either a prescribed-base code that has been "deemed to comply" as an "acceptable option", or by using a performance-based design approach that provides an "acceptable method" for developing an a acceptable solution (SFPE, 2007 Guide to PBD)

CBC-2007, Section 108.7. discusses provisions for alternative materials, design and method of construction and equipment. It states: *The provisions of this code, as adopted by the Department of Housing and Community Development are not intended to prevent the use of any alternate material, appliance, installation, device, arrangement, method, design or method of construction not specifically prescribed by this code. Consideration and approval of alternates*[24] *shall comply with Section 108.7.2 for local building departments and Section 108.7.3 for the Department of Housing and Community Development*.

It is this provision that permits a performance-based design to be conducted in the CSM and subsequently reviewed by the Authority Having Jurisdiction for compliance with the intent of the California Building Code (Ref. CBC-2007, ARUP 2012) .

[24] Approval of alternates. The consideration and approval of alternates by a local building department shall comply with the following procedures and limitations: (1) The approval shall be granted on a case-by-case basis; (2) Evidence shall be submitted to substantiate claims that the proposed alternate, in performance, safety and protection of life and health, conforms to, or is at least equivalent to, the standards contained in this code and other rules and regulations promulgated by the Department of Housing and Community Development.; (3) The building department may require tests performed by an approved testing agency at the expense of the owner or owner's agent as proof of compliance.; and (4) If the proposed alternate is related to accessibility in covered multifamily dwellings or in facilities serving covered multifamily dwellings as defined in Chapter 11A, the proposed alternate must also meet the threshold set for "Equivalent Facilitation" as defined in Chapter 11A.

The CSM has an atrium that connects the building from Level 2 to 6 (see Figure 27).

Figure 27 – Pictures of the atrium high-bay connecting Level 2-6 in the CSM
Ref. ZGF, 2009

On Levels 2-3 the office and student work places existing in the atrium are protected by 1-hour fire barrier, but the offices on levels 4-6 are not protected by 1-hour fire barrier as shown in Appendix 9.1. Regarding this issue, CBC-2007, Section 405.5, Exception 3 states that a *Fire Barrier is not required between the atrium and the adjoining spaces of any three floors of the atrium, provided such spaces are accounted for in the design of the smoke control system*. Therefore, an engineering analysis (smoke management analysis) which assesses the performance of the smoke control system, has to be conducted in this atrium in order to meet the code.

5.1 <u>Performance-based Design According to NFPA 106-2006</u>

A performance-based approach to life safety design must be in accordance with Chapters 1-5 of the Life Safety Code, (NFPA 101-2006, Section 4.2.3). Chapter 5 focuses on the performance-based approach to life safety design.

5.1.1 Goals, Objectives and Performance Criteria

The performance-based design must meet the same goals and objectives of the Life Safety Code, 2006 (NFPA 101-2006, Section 5.1.2)

The goal is to provide an environment that is reasonably safe from fire and similar emergencies, protecting occupants not intimate with the initial fire development and improving the survivability of occupants intimate with the initial fire development.

The primary objectives used to achieve this goal include protecting occupants, maintaining structural integrity and maintaining system reliability for the time needed to evacuate, relocate, or defend in place.

The criterion for defining the goals and objectives described above is that any occupant who is not intimate with ignition, must not be exposed to instantaneous or cumulative untenable conditions (NFPA 101-2006, Section 5.2).

5.1.2 Retained Prescriptive Requirements

When developing a performance-based design, requirements retained from the prescriptive approach of the Life Safety Code must be considered. These requirements pertain to means of egress and the fire protection systems and features of the building to comply with applicable NFPA standards (NFPA 101-2006, Section 5.3). The most important prescriptive requirements for the CSM are covered in Section 4 of this report.

5.1.3 Design Specifications and Occupant Characteristics

Design specifications and other conditions used in the performance-based design must be clearly stated and shown to be realistic and sustainable (NFPA 101-2006, Section 5.4.1).

The main aspects related to the assumptions, design specification, and occupant characteristics are summarized below:

- Assumptions must be accurately translated into input data specifications, as appropriate for the calculation method or model. Assumptions that are not addressed or that are modified in the input data because of limitations in test methods must be identified and a sensitivity analysis of the consequences must be performed.
- Characteristics of the building or its contents, equipment, or operations that affect occupant behavior or the rate of hazard development, must be explicitly identified.
- The selection of occupant characteristics must provide an accurate reflection of the expected population of building users and be approved by the AHJ.
- The basic occupant response characteristics of sensibility, reactivity, mobility and susceptibility must be evaluated.
- It should be assumed that in every normally occupied room, at least one person is located at the most remote point from the exits.

- The design must be based on the maximum number of people that every occupied room is expected to contain.

5.1.4 Design Fire Scenarios

The Life Safety Code specifies a minimum of eight design fires (DF) scenarios to be included in the performance-based analysis (NFPA 101-2006, Section 5.5.3). These are summarized below:

- *DF Scenario* **1**: Specific fire representative of a typical fire for the occupancy.
- *DF Scenario* **2**: Ultrafast-developing fire, in the primary means of egress, with interior doors open at the start of the fire.
- *DF Scenario* **3**: Fire that starts in a normally unoccupied room, potentially endangering a large number of occupants in a large room or other area.
- *DF Scenario* **4**: Fire that originates in a concealed wall or ceiling space adjacent to a large occupied room.
- *DF Scenario* **5**: Slowly developing fire, shielded from fire protection systems, in close proximity to a high occupancy area.
- *DF Scenario* **6**: The most severe fire resulting from the largest possible fuel load characteristic of the normal operation of the Building.
- *DF Scenario* **7**: Outside exposure fire.
- *DF Scenario* **8**: Fire originating in ordinary combustibles in a room or area with each passive or active fire protection system independently rendered ineffective.

This report analyzes four fire scenarios considered in a Smoke Management Study for the atrium of the CSM developed by Arup North America Ltd (ARUP, 2009), and follows the guidance of the SFPE Engineering Guide to Performance-based Fire Protection Analysis and Design of Buildings. The four fire scenarios considered in the Smoke Management Study were developed with the assumptions detailed in 5.4.2 of this report.

There is no references in this study about the specific type of design covered according to the description used in Section 5.5.3 of the Life Safety Code, 2006. Nevertheless, the characteristics of these four DF scenarios represent design fires analogous to the above Scenarios 1, 3 and 6 and comply with the requirement stated by NFPA 101-2006, Section 5.5.2. This section states that each design fire scenario must be as challenging as any that could occur in the building, but shall be realistic, with respect to at least one of the following scenario specifications: (1) initial fire location; (2) early rate of growth in fire severity; and (3) smoke generation.

5.2 Performance-based Methodology

Where performance-based approaches are used, they must follow the guidelines set out in the Society of Fire Protection Engineers document SFPE Engineering Guide to Performance-based Fire Protection Analysis and Design of Buildings (SFPE Guide to PBD; ARUP, 2009). The conceptual design and steps included in this guide are depicted in Figure 28.

As shown in Figure 28, for a project to comply with the performance-based approach, the selected design has to meet the performance criteria. For the current project, this evaluation is conducted through the assessment of the Available Safe Egress Time (ASET) versus the Required Safe Egress Time (RSET) in the building's atrium (See Figure 29).

The ASET analysis is based upon the general performance criteria stating that any occupant who is not intimate with ignition shall not be exposed to instantaneous or cumulative untenable conditions, according to NFPA 101-2006, Section 5.2.2.

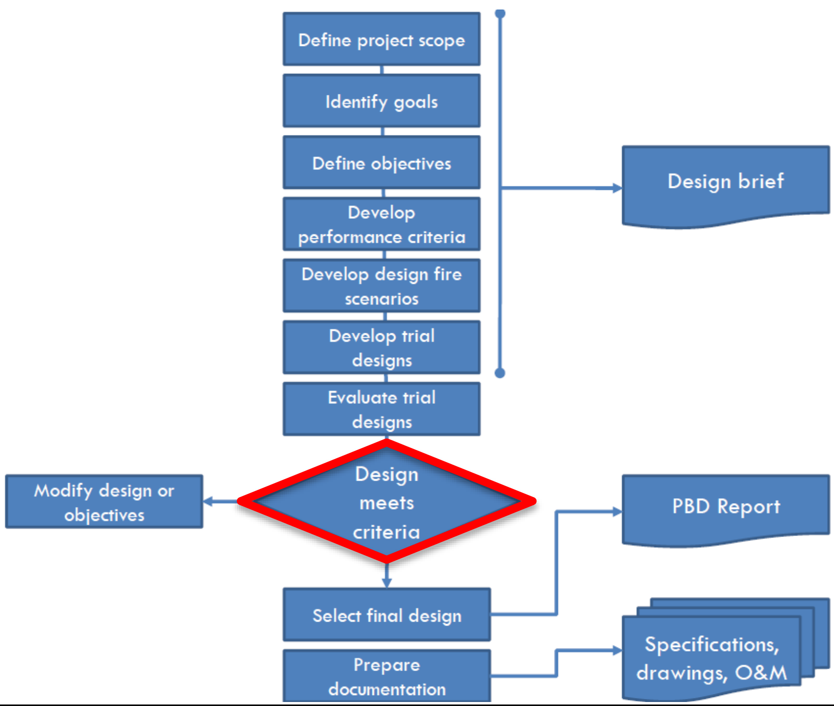


Figure 28 – Steps in Performance-based analysis

Ref. SFPE, 2007 - Guide to PBD

As mentioned in Section 5.1.4 of this report, a Smoke Management Study was conducted by Arup North America Ltd, prior to construction completion of the CSM. This study analyzes four design fire scenarios and their effects on the atrium smoke control, using a natural ventilation system. Two computer software programs, Fire Dynamics Simulator (FDS) and Simulation of Transient Evacuation and Pedestrian movements (STEPS), were used in the study to analyze the effects of each design fire scenario.

For this report, the four design fire scenarios identified in the Smoke Management Study were taken as a baseline for the analysis of ASET vs RSET in the building's atrium, using different evacuation models (Pathfinder and SFPE methodology) and FDS for simulating the fires.

5.3 Required Safe Egress Time (RSET) Analysis

The Required Safe Egress Time is the predicted time necessary to evacuate a building or component. The RSET can be subdivided into a number of discrete time intervals, the sum of which constitute the total RSET (SFPE Handbook, 2008, Section 3):

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

where,

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

The RSET elements t_d and t_n primarily involve a technical solution, including fire detection devices and fire alarm equipment, and also human intervention, such as the discovery of a fire by a staff member.

The element t_{p-e} relates to the individual and collective responses of the occupants; that is, the time between them being notified of the incident and the time to commence the evacuation. This can be prolonged by a number of complex activities. This include receiving a cue, performing pre-evacuation activities; and determining an appropriate response.

The element t_e is the time from when an individual initiate evacuation movement up to the point that she or he reaches safety.

Figure 29 illustrates the sequence of occupant response to fire.

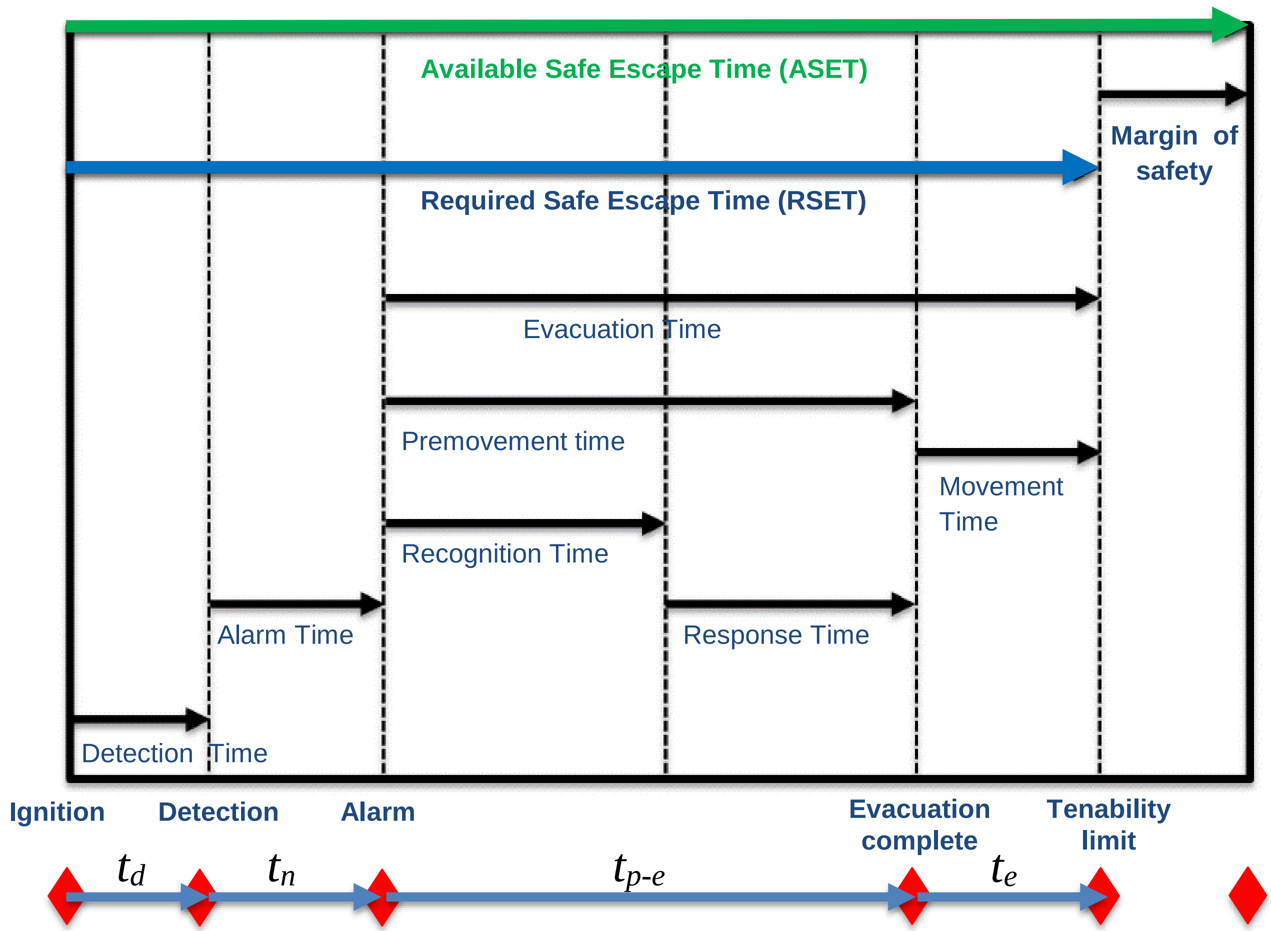


Figure 29 – Egress time model

Ref. SFPE Handbook, 2008, Figure 3-12.1

5.3.1 Detection and Notification Phase

The detection phase, t_d, and notification phase, t_n, is the time from ignition to the time at which the occupants are aware of the fire and the need to evacuate. It is assumed that detection will occur when occupants become aware of smoke through either visual awareness or when smoke detectors, sprinklers, or manual alarms are activated and the building alarm is initiated. Occupants in the room or compartment of the fire and in close proximity can also be alerted to a fire by visual cues from the various fire-induced conditions, such as smoke and heat.

Given the openness of the atrium, the likely source of primary detection is the building occupants seeing smoke rise through the atrium, which would occur quickly in the event of a fire. Based upon the design fire scenarios, it is likely that the detection and notification time would be between 30-60 seconds. For purposes of this egress analysis, a detection and notification time of 60 seconds will be used. Therefore, $t_d + t_n$ = 60 seconds.

5.3.2 Pre-evacuation Phase

Pre-evacuation phase or pre-movement time (t_{p-e}) is the time taken to perform activities that people are engaged in prior to actual evacuation of the area. These activities may include investigating, assessing danger, warning others, collecting belongings, and seeking assistance (Proulx, 2002). This behavior is a complex, cognitive thought process and is not easily characterized.

The SFPE Handbook (SFPE Handbook, 2002, Section 3 – Chapter 13) provides a discussion regarding pre-movement times in various types of buildings for three different emergency notification scenarios (see Table 24).

Table 24- Estimated Delay Time to start evacuation

Occupancy Type	W1 (min)	W2 (min)	W3 (min)
Offices, commercial and Industrial buildings, schools, colleges and universities (Occupants awake and familiar with the building, the alarm system, and evacuation procedure.)	< 1	3	> 4
Shops, museums, leisure-sport centers, and other assembly buildings (Occupants awake but may be unfamiliar with building, alarm system, and evacuation procedure.)	< 2	3	> 6
Dormitories, residential mid-rise and high-rise (Occupants may be asleep but are predominantly familiar with the building, alarm system, and evacuation procedure.)	< 2	4	> 5
Hotels and boarding houses (Occupants may be asleep and unfamiliar with the building, alarm system, and evacuation procedure.)	< 2	4	> 6
Hospitals, nursing homes, and other institutional establishment (A significant number of occupants may require assistance.)	< 3	5	> 8

Reference: Proulx, SFPE Handbook, Table 3-13.1

The three notification scenarios are defined as follows:

- *W1*: live directives using a voice communication system from a control room with closed-circuit television facility, or live directives in conjunction with well-trained, uniformed staff that can be seen and heard by all occupants in the space.

- *W2*: nondirective voice messages (pre-recorded) and/or informative warning visual display with trained staff.
- *W3*: warning system using fire alarm signal and staff with no relevant training.

Pre-movement times for a university building, where occupants are awake and familiar with their surroundings such as the building discussed herein are suggested as follows in conjunction with the type of emergency notification:

- W1: less than 1 minutes
- W2: 3 minutes
- W3: 4 minutes or more

In the Smoke Management Study performed by ARUP, it was assumed that since all of the design fires are in relatively close proximity to occupied spaces, where occupants would be able to see smoke and flames, it is reasonable to consider the W1 condition for pre-movement time. As such, a pre-movement time of 60 seconds was assumed (Section 6.3 of the Smoke Management Study, ARUP, 2009).

The validity of this assumption may be challenged because there are administrative offices and work spaces that subdivide the atrium space on Levels 2-6 in which it may not be reasonable to assume that all occupants would be able to clearly see smoke and flames in case of a fire. In addition, as stated by SFPE Handbook Handbook, Table 3-13.1, W1 scenarios consider *live directives using a voice communication system from a control room with closed-circuit television facility, or live directives in conjunction with well-trained, uniformed staff that can be seen and heard by all occupants in the space*. However, the characteristics of EVAC installed and operated in the building are representative of the system described for scenario W2, with nondirective (pre-recorded) voice messages.

For this report, based upon the above analysis, the pre-evacuation phase or pre-movement time is evaluated for both scenarios (W1 and W2) and the results are analyzed for both cases.

5.3.3 Evacuation Phase - Using SFPE Hydraulic Model

Evacuation phase or travel time, t_e, is the time from the start of evacuation until it is completed. For this report, the occupant travel time was calculated using the hydraulic model of emergency egress from the SFPE Handbook, and the Pathfinder software.

The methodology for the hydraulic model of emergency egress from the SFPE Handbook is detailed in Appendix 9.12 and the results are shown in Table 25, which also includes the results[25] obtained in the In the Smoke Management Study performed in the building.

Table 25- Travel Time with SFPE Hydraulic Model and STEPS

Level	Occupant Load (# persons)	Atrium Exit Area (ft^2)	Density: D^{26} (persons/ft^2)	Movement Speed		Travel Distance (ft)	t_e SFPE Hbk	t_e STEPS
				(ft/min)	m/s			
2	77	3675	0.021	235	1.2	100	26	21
3	155	1835	0.084	209	1.06	117	34	37
4	64	4170	0.015	235	1.2	152	39	34
5	67	4227	0.016	235	1.2	152	39	40
6	68	4213	0.016	235	1.2	152	39	39
Ref	*ZGF, 2009*		*Occupant load /area*	*Figure 17 And Equation 3*		*ZGF, 2009*	*TD /Walking Speed*	*ARUP, 2009*

Notice that, the results obtained with the hydraulic model from the SFPE Handbook are very similar to those obtained with the STEPS evacuation software by ARUP. The movement speed in the SFPE handbook methodology is constant for levels 2, 4, 5, and 6 at 1.2 m/s which is the typical waking speed of a Middle person(see Table 27). For level 3, the movement speed calculated is 1.06 m/s which correspond to an Old person. These results are consistent with the assumption specified for the hydraulic model stating that all or most of the persons involved are free of disabilities. The walking speed for disabled persons is deemed to be 0.5 m/s according to Table 27, which is approximately half the value for an Old person.

5.3.4 Evacuation Phase - Using Pathfinder

The evacuation phase or travel time was also calculated with Pathfinder[27], which is an agent based egress and human movement simulator. This model represents a more realistic approach to building evacuation within the controlled area of the atrium space, when all occupants on Level 2 through Level 6 evacuate simultaneously. Pathfinder simulates travel time based on different walking speeds for four different age demographics, Young, Middle, Old and Disabled, according to the data specified in Table 26 and Table 27.

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25 The Smoke Management Study uses the computer software, Simulation of Transient Evacuation and Pedestrian movements (STEPS) to simulate occupant travel time within the atrium space.

26 Represents the most conservative scenario (maximum D) since the occupant load includes the persons in all rooms on the level, but it is only considered the atrium exit area for the calculations.

27 www.thunderheadeng.com/pathfinder.

Demographics

The characteristics of the building population are based on information provided by study titled, "*Assessment of Photoluminescent Material during Office Evacuation*", conducted by Proulx, G. and Tiller, D., 1999. Table 26 illustrates the demographics used for the above study and the values used in the Smoke Management Study, developed by ARUP.

Table 26- Age demographics baseline

Age	Demographic Classification	Percent from "Assessment of Photoluminescent Material during Office Evacuation"	Percent used by Pathfinder Model and Smoke Management Study
20-30	Young	15 %	15 %
31-50	Middle	66 %	63 %
51-61+	Old	19 %	16 %
All Ages	Disabled	5.6 %	6 %

Ref. Assessment of Photoluminescent Material during Office Evacuation, 1999;
Smoke Management Study- Atrium Smoke Control, ARUP 2009.

Travel Speeds

The horizontal and vertical travel speeds for occupants are dependent on the age and mobility of the occupant. Table 27 indicates the values referred in the Smoke Management Study model for walking speeds of the occupants.

Table 27- Occupant walking speeds

Occupant type	Horizontal	Down Stair	Up Stair	References
Young	1.3 m/sec (4.27 ft/sec)	0.8 m/sec (2.62 ft/sec)	0.6 m/sec (1.96 ft/sec)	*Fruin, 1987; And Fahy, 2001*
Middle	1.2 m/sec (3.94 ft/sec)	0.7 m/sec (2.3 ft/sec)	0.5 m/sec (1.64 ft/sec)	
Old	1.0 m/sec (3.28 ft/sec)	0.6 m/sec (1.96 ft/sec)	0.4 m/sec (1.31 ft/sec)	*Fruin, 1987*
Disabled	0.5 m/sec (1.64 ft/sec)	0.27 m/sec (0.89 ft/sec)	0.216 m/sec (0.71 ft/sec)	*Fruin, 1987; Boyce, Shields; And Silcock, 1999.*

Ref. Smoke Management Study- Atrium Smoke Control, 2009; ZGF, 2009

As mentioned above, the characteristics of the building population are based on information provided by study "*Assessment of Photoluminescent Material during Office*

Evacuation". As the data from this study come from office buildings and the CSM, in addition to offices, also have other kind of occupancies (see 3.1.1), for this report the travel time with Pathfinder is also calculated assuming that the percent of persons with lower velocities are twice as the specified in the baseline study.

The objective of these calculations is to evaluate the sensitivity of this variable with respect to the results obtained for the travel time in the atrium. In order to maintain the same amount of persons specified per floors in the atrium, the percent added to the persons with lower velocity (Old and Disable), was proportionally subtracted to the percent of persons with higher velocities (Middle and Young). Table 28 and Table 29 show the percent and the number of occupants used for each case, respectively.

Table 28- Age demographics used in Pathfinder

Age	Demographic Classification	Percent used based on the Smoke Management Study	Percent used assuming twice the persons with lower velocities
20-30	Young	15 %	**9 %**
31-50	Middle	63 %	**47 %**
51-61+	Old	16 %	**32 %**
All Ages	Disabled	6 %	**12 %**

Ref. Assessment of Photoluminescent Material during Office Evacuation, 1999,
Smoke Management Study- Atrium Smoke Control, 2009

Table 29- Number of Occupants (app.) per Level used in Pathfinder

Atrium Level	Young		Middle		Old		Disabled		Total Occupant Load
	(15 %)	(9 %)	(63 %)	(47 %)	(16 %)	(32%)	(6 %)	(12%)	
1	12	7	49	36	12	25	5	9	77
2	23	14	98	73	25	50	9	19	155
3	10	6	40	30	10	20	4	8	64
4	10	6	42	31	11	21	4	8	67
5	10	6	43	32	11	22	4	8	68

Ref. Smoke Management Study- Atrium Smoke Control, 2009; ZGF, 2009

For Pathfinder model, each Level of the atrium space is designed based on the floor plan layout provided in the architectural plans (ZGF, 2009). The occupant load for each level is based on the occupant load of each individual room specified in the architectural plans. Occupant characteristics are based on distribution of population demographics as shown in Table 28 and the steering mode is used for the simulations.

Two evacuation alternatives were evaluated with Pathfinder. In the first one, Young, Middle and Old occupants are programmed to exit towards the fastest route (*Go to Any Exit*) and Disabled occupants are programmed to exit to the area of refuge (Stairway #3) for Levels 3, 4, 5 & 6. Stairway #2 is not considered an exit because it is an open stairway and is assumed to be affected by fire, therefore is not considered an accessible means of egress.

In the second alternative, the difference is that Disabled occupants are also programed to exit towards the fastest route (*Go to Any Exit*).

Details of the Pathfinder model used are explained in Appendix 9.13. Figure 30 shows a general view of the atrium simulated with Pathfinder and Table 30 summarizes the results obtained for the travel time with Pathfinder, STEPS, and the hydraulic model of emergency egress from the SFPE Handbook.

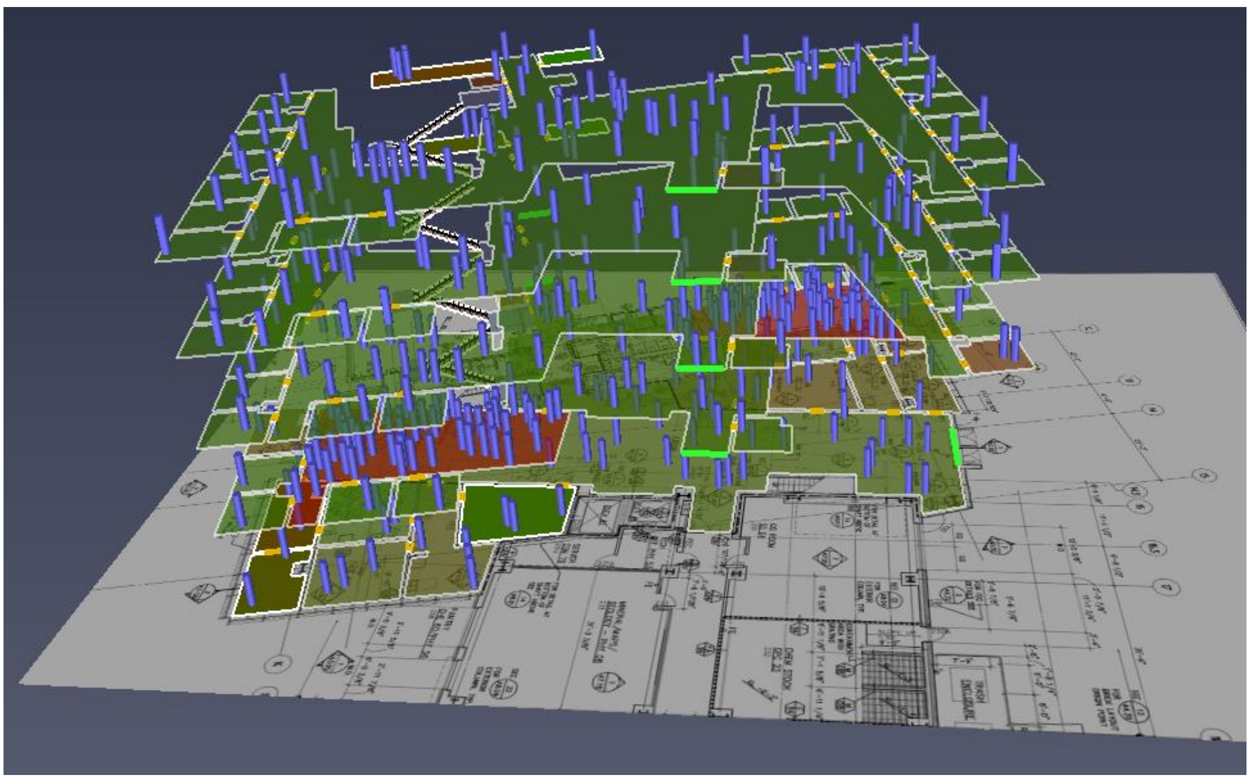

Figure 30 – CSM atrium simulated with Pathfinder

Table 30- Travel time for atrium Levels 2 to 6				
Level	**Occupant Load**	**t_e** SFPE Handbook	**t_e** STEPS	**t_e** Pathfinder
2	77	26	21	24
3	155	34	37	104
3*	21*	-	-	27
4	64	39	34	69
5	67	39	40	51
6	68	39	39	49
** Level 3 in this case excludes the student work spaces from evacuating because a 1- hour fire rated wall separates the atrium space from all other areas on this Level*				

Table 30 shows that the travel times obtained with Pathfinder are different than those obtained with STEPS and the hydraulic model (SFPE Handbook) in all Levels, especially in Level 3. As analyzed in 5.3.3, the differences may be conditioned by the assumptions made in each case, with regards to the waking speed. In Level 3, the big deference may be explained by the bottleneck effect observed in Pathfinder. These effects are not assessed by the hydraulic model from the SFPE Handbook, and it seems that were not predicted by the STEPS model either.

Based upon the above results, the values obtained with Pathfinder are used in this project for the RSET calculation, as shown in Table 31. Table 32 shows the RSET results obtained in the Smoke Management Study, for comparison.

Table 31- RSET calculations (Seconds)						
Atrium Level	**Detection and Notification Time ($t_d + t_n$)**	**Pre-movement time (t_{p-e})**		**Travel Time (t_e)**	**RSET $= t_d + t_n + t_{p-e} + t_e$**	**1.5xRSET[28]** ***(CBC Section 909.4)***
		W1	W2			
2	60	60	180	24	144-264	216-396
3	60	60	180	104	224-344	336-516
3*	60	60	180	27	147-267	221-401
4	60	60	180	69	189-309	284-464
5	60	60	180	51	171-291	257-437
6	60	60	180	49	169-289	254-434
Note: RSET calculations were performed considering pre-movement times of 60 and 180 seconds (W1 and W2).						

[28] The values indicated in the last column (right) of Table 31 consider the safety factor (1.5xRSET) required by CBC, Section 909.4 for the RSET calculations.

Table 32- RSET calculations – Smoke Management Study (Seconds)					
Atrium Level	**Detection and Notification Time ($t_d + t_n$)**	**Pre-movement time (t_{p-e})** W1	**Travel Time (t_e)**	**RSET $= t_d + t_n + t_{p-e} + t_e$**	**1.5xRSET *(CBC Section 909.4)***
2	60	60	21	141	212
3	60	60	37	157	236
3*	60	60	-	-	-
4	60	60	34	154	231
5	60	60	49	160	240
6	60	60	39	159	239
Ref. Smoke Management Study- Atrium Smoke Control, 2009					

5.4 Available Safe Egress Time (ASET) analysis

The ASET analysis is based on the general performance criteria stated by NFPA 101 - 2006 - 5.2.2, which requires that any occupant who is not intimate with ignition must not be exposed to instantaneous or cumulative untenable conditions.

Based upon the above criteria, the ASET may then be defined as the time when fire-induce conditions within an building become untenable.

5.4.1 Tenability Criteria

NFPA 101, Section A.5.2.2 provides different methods for ensuring that occupants are not incapacitated by fire effects and refers to the SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings to establish tenability limits.

For this project, the temperature, visibility, radiant flux, and Carbon Monoxide tenability limits are proposed to serve as design criteria on which to base the level of safety for the atrium. These tenability limits are evaluated at a height of 6 feet above the finished floor level.

Temperature: NFPA 130-2007 – Standard for Fixed Guideway and Passenger Rail Systems suggests that thermal burns to the respiratory tract can occur upon inhalation of air saturated with water vapor above 140ºF (60ºC). Therefore, the tenable design temperature of 140ºF (60ºC) is used for this project.

Visibility: Jin, T., 2002 proposed allowable smoke visibility that permits safe escape ranges from approximately 4 ft to 66 ft, depending on the nature of the space and the awareness level of the occupants. This study suggests that an allowable visibility for occupants unfamiliar with their surroundings is 13 m (42 ft); therefore, the visibility design criteria for this project will be 42 ft (13 m).

Radiant Flux: The CIBSE Guide E – Fire Engineering (CIBSE Guide E, 1997) indicates that a 2.5 kW/m² incident radiant flux upon the skin of an occupant would result in severe damages with a short exposure and recommends using a lower flux. Another reference, the SFPE Engineering Guide, "Predicting 1st and 2nd Degree Skin Burns from Thermal Radiation" indicates that an incident radiant flux greater than 1.7 kW/m² would cause pain on the exposed skin of an occupant with a prolonged exposure. Based upon these two references, a thermal flux of 2.0 kW/m² was chosen as the design criteria. If smoke temperatures are maintained below (350ºF) 180ºC, the thermal radiation from the hot upper layer to the occupants below will not exceed the tenability criteria.

Carbon Monoxide: Toxic gases impair an individual's ability to self-evacuate by decreasing the amount of oxygen available, causing disorientation and possibly unconsciousness. In building fires, the most common toxic gas is carbon monoxide (CO) and, to a lesser extent, hydrogen cyanide (CHN) which is more toxic. NFPA 101-2006 specifies a CO tenability limit as an integrated dose, 30,000 ppm/min, (1,000 ppm for 30 minutes).

Table 33 summarizes the tenability criteria used in this project to evaluate each fire scenario at a height 6 feet above the finished floor levels.

Table 33- Tenability criteria

Design Criteria	Tenability Limit	Ref.
Temperature	140 °F (60°C)	NFPA 130, Standard for Fixed Guideway and Passenger Rail Systems
Visibility	42 feet (13 meters)	Jin, SFPE Handbook, Table 2-4.2. Assume building occupants are unfamiliar with surroundings
Radiant Flux [Smoke Upper Later Temperature]	1.7 kW/m² [350 °F (180°C)]	SFPE Engineering Guide, Predicting 1st and 2nd Degree Skin Burns from Thermal Radiation
Carbon Monoxide	30,000 ppm/min (1,000 ppm for 30 minutes)	NFPA 101, Life Safety Code

The life safety strategy in this case is intended to provide tenable conditions for a duration that enables safe evacuation of building occupants.

5.4.2 Design Fires Scenarios

As explained in 5.1.4, the ASET analysis for this project considers four fire scenarios included in a Smoke Management Study (ARUP, 2009). In this study each fire scenario was simulated using the following assumptions:

- Qualitative Hazard Analysis. The peak fire growth rate or maximum heat release rate and duration of a fire within a given space is dependent upon the type, quantity and configuration of the materials within the space, as well as the effect of sprinklers. A qualitative hazard analysis was performed to determine the expected range of fire scenarios. Potential fuel sources and potential ignition sources were reviewed based upon representative materials and equipment within various areas where a performance-based approach was used. Fuel sources were chosen based upon the potential for a developing fire to cause conditions where occupants or the structure may be threatened.

- Heat Release Rate (HRR): The fire scenarios were quantified by assuming a fast t^2 fire. This assumption is based upon the types of hazards that are likely in the building. The maximum heat release rate was estimated by determining the expected time for sprinkler activation and by estimating the maximum fire size of a given fuel package.

- Determination of Smoke Production. Soot yields corresponding to polyurethane foam with some cellulosic material were used (effective yield of 5%). This generally results in conservative predictions of visibility.

Figure 31 shows the relation of t-squared fires to some fire tests. The value of α for the fast t^2 fire curve (highlighted in red color in this figure) is 0.0469 kW/s^2, according to NFPA 72- 2007, Table B.2.3.2.3.6.

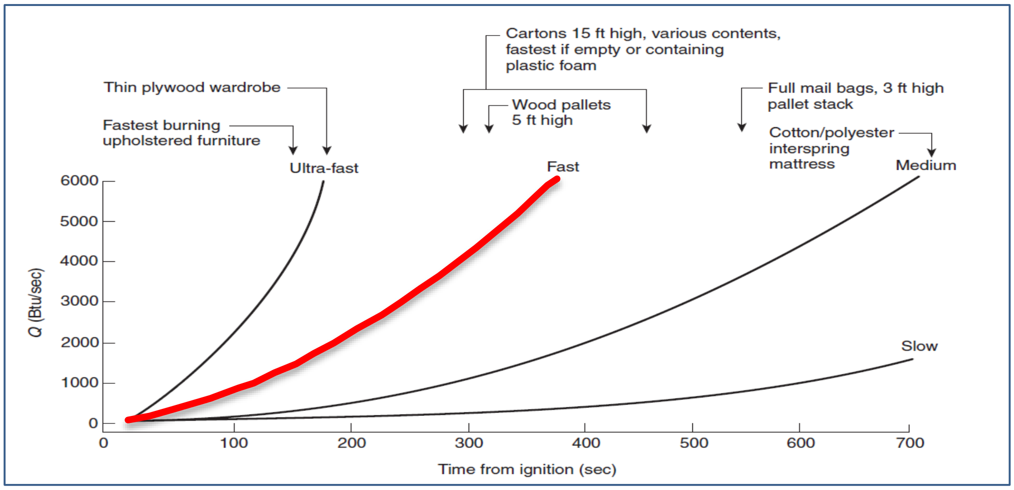

Figure 31 – Relation of t-squared fires to some fire tests

Ref. NFPA 92B-2009, Figure C.2(c)

Design Fire Scenarios:

Design Fire Scenario # 1 (DF#1) – Center of Atrium, Level 2

DF#1 evaluates the potential for a sizable fire to develop within the atrium below the balcony located within the center of the space. The fire is assumed to be a sprinkler controlled fire. The maximum HRR of approximately 1,411 kW[29] is governed by the ceiling height and the fuel loads are assumed to be a mixture of cellulosic and hydrocarbon materials of a generally non-hazardous and non-toxic nature. The fire grows in accordance with a fast-growth t^2 fire, similar to the second curve (highlighted in red) in Figure 31, until it reaches its maximum (sprinkler activation), at which point the heat release rate remains constant at the maximum value as a result of sprinkler control. For the simulations performed with FDS, the maximum HRR in this scenario was approximated to 1,500 kW.

Design Fire Scenario # 2 (DF#2) – High-bay space, Level 2

DF #2 considers a potential hazard associated with a fire originating on Level 2 in the high-bay space on either side of the balcony. The high-bay space is open to Levels 3-6 above by means of two atrium spaces. The ceiling is approximately 80 feet above the fire, which would result in a fire that would not likely be controlled by automatic fire suppression

[29] The maximum HRR of 1,411 kW obtained in the Smoke Management Study (ARUP, 2009) was calculated using a DETACT algorithm and considering a ceiling height of 16 feet, but the ceiling (and therefore the sprinklers) in Level 2 is installed to 3.8 m (12.46 feet) as shown in Figure 40. The maximum HRR obtained with the DETACT algorithm provided in Class FPE-522 for the ceiling of 3.8 m is 1,355 kW (see Appendix 9.14), nonetheless, the maximum HRR defined in the Smoke Management was considered in this project, in order to maintain a conservative approach.

systems. A fuel-controlled fire of approximately 2,500 kW is considered to result from the light to moderate fuel load located in these spaces. Such a fire would be representative of boxes, several full trash bags, miscellaneous light furniture, or cleaning materials and similar items. This fire size correlates well with peak and sustained heat releases for the majority of furnishings indicated in B.5.3(d) of NFPA 92B, 2005 edition, with the exception of two items:

- Traditional loveseat with a wood frame and fire resistant polyurethane padding (2890 kW).
- Traditional sofa with wood frame and fire resistant polyurethane padding (3120 kW).

As the spaces in second level are predominantly used for circulation, the assumption of the maximum HRR being less than 2,500 kW was considered reasonable and conservative in the Smoke Management Study.

The design fire grows in accordance with a fast-growth t^2 fire until it reaches its maximum HRR of 2,500 kW, at which point the HRR remains constant.

Design Fire Scenario # 3 (DF#3) – Student Work Space, Level 4

Level 4 contains two student work spaces and is open to Levels 2 & 3 below, and Levels 5 & 6 above by means of the two atrium spaces. DF#3 evaluates the potential for a high and uncontrolled combustible fuel load (a mixture of cellulosic and hydrocarbon materials) within the Student Work Space.

The heat release rate grows at a fast fire growth rate until the upper layer gas temperature reaches sprinkler activation temperature, at which time the fire is assumed to be controlled by the sprinkler system and the heat release rate remains constant at a maximum HRR of 1,250 kW[30]. For the simulations performed with FDS, the maximum HRR in this scenario was approximated to 1,300 kW.

Design Fire Scenario # 4 (DF#4) – Center of Atrium, Level 5

Level 5 is open to Levels 2-4 and Level 6 by means of two atrium spaces. This fire (a mixture of cellulosic and hydrocarbon materials) is located in the center of the atrium on Level 5.

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30 The maximum HRR of 1,250 kW obtained in the Smoke Management Study (ARUP, 2009) was calculated using a DETACT algorithm and considering a ceiling height of 14 feet, but the ceiling (and therefore the sprinklers) in Level 4 is installed to 3.8 m (12.46 feet) as shown in Figure 40. The maximum HRR obtained with the DETACT algorithm provided in Class FPE-522 for the ceiling of 3.8 m is 1,355 kW (see Appendix 9.14), which is very close to the maximum HRR of 1,300 kW defined in the Smoke Management for simulating the design fire with FDS in this case.

The heat release rate grows at a fast fire growth rate until the upper layer gas temperature reaches sprinkler activation temperature, at which time the fire is assumed to be controlled by the sprinkler system and the heat release rate remains constant at 1,411 kW[31]. Smoke and heat generated as a result of this fire would spread along the balcony of the Level 5 and spill through the two openings. For the simulations performed with FDS, the maximum HRR in this scenario was approximated to 1,500 kW.

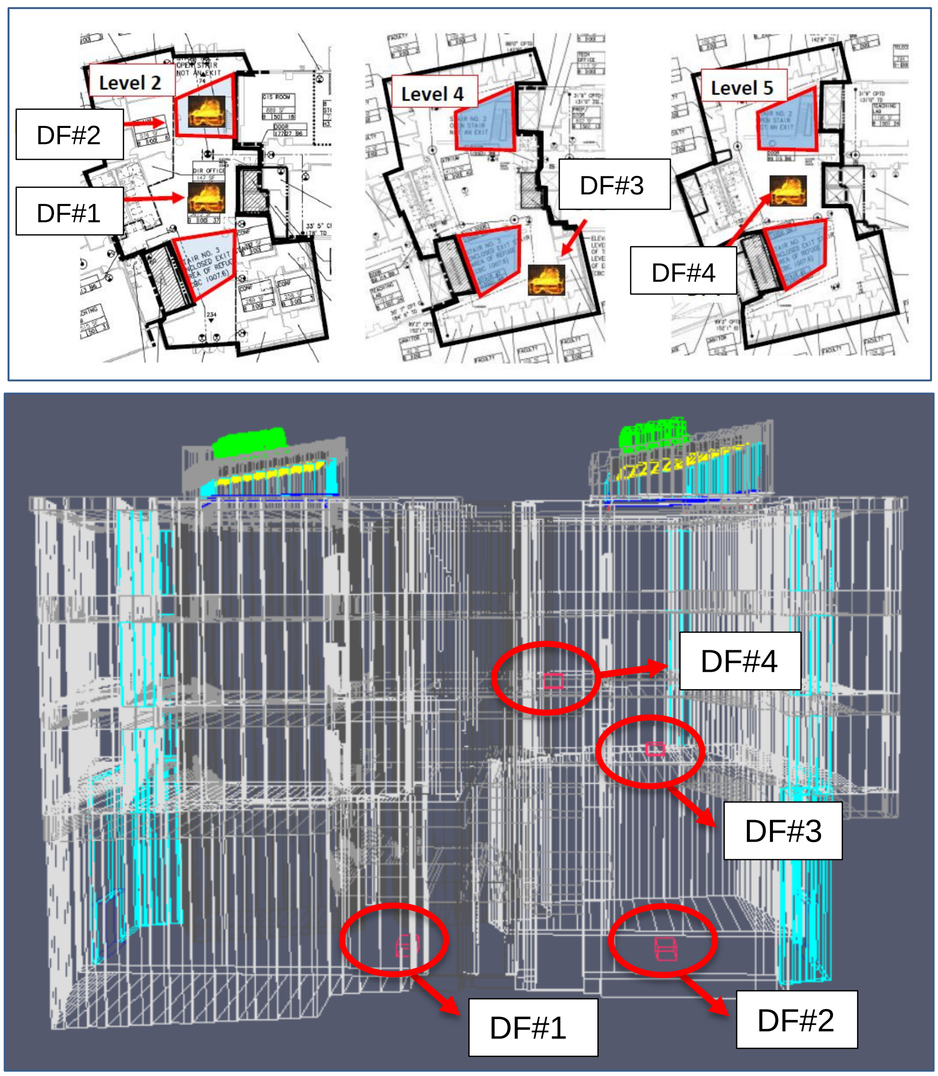

Figure 32 – Locations of design fires in the atrium

Smoke Management Study, 2009

31 The maximum HRR of 1,411 kW obtained in the Smoke Management Study (ARUP, 2009) was calculated using a DETACT algorithm and considering a ceiling height of 16 feet, but the ceiling (and therefore the sprinklers) in Level 5 is installed to 3.8 m (12.46 feet) as shown in Figure 40. The maximum HRR obtained with the DETACT algorithm provided in Class FPE-522 for the ceiling of 3.8 m is 1,355 kW (see Appendix 9.14), nonetheless, the maximum HRR defined in the Smoke Management was considered in this project, in order to maintain a conservative approach.

Figure 32 summarizes the design fire details.

Table 34- Design Fires scenarios			
Design Fire	**Location**	**Calculated Fire Size***	**FDS Fire Size****
DF#1	Center of Atrium, Level 2	1,411	1,500
DF#2	High-bay space, Level 2	2,500	2,500
DF#3	Student Work Space, Level 4	1,250	1,300
DF#4	Center of Atrium, Level 5	1,411	1,500
*HRR values based on calculation developed in the Smoke Management Study using the DETACT algorithm. **HRR values used for FDS modeling in the Smoke Management Study.			

5.4.3 Available Safe Egress Time (ASET)- Results

The four design fires described in 5.4.2 were simulated with FDS in order to predict the effects on the interior environment of the CSM.

Ventilation conditions were identical for all design fire scenarios and consistent with the geometry of the building for all simulations. The communication between the interior environment with the exterior air include two sets of double-doors at the North and South ends of the atrium (representing the two 144 inch double doors shown in Figure 30), and two roof vents located at the highest level of the atrium (see Figure 33). The areas of these ventilation openings are as follows:

- North Double-Doors area = 133.5 ft^2
- South Double-Doors area = 133.5 ft^2
- North roof vent area = 100 ft^2
- South roof vent area = 100 ft^2

Figure 33 provides an overview of the FDS model geometry used in the Smoke Management Study (ARUP, 2009).

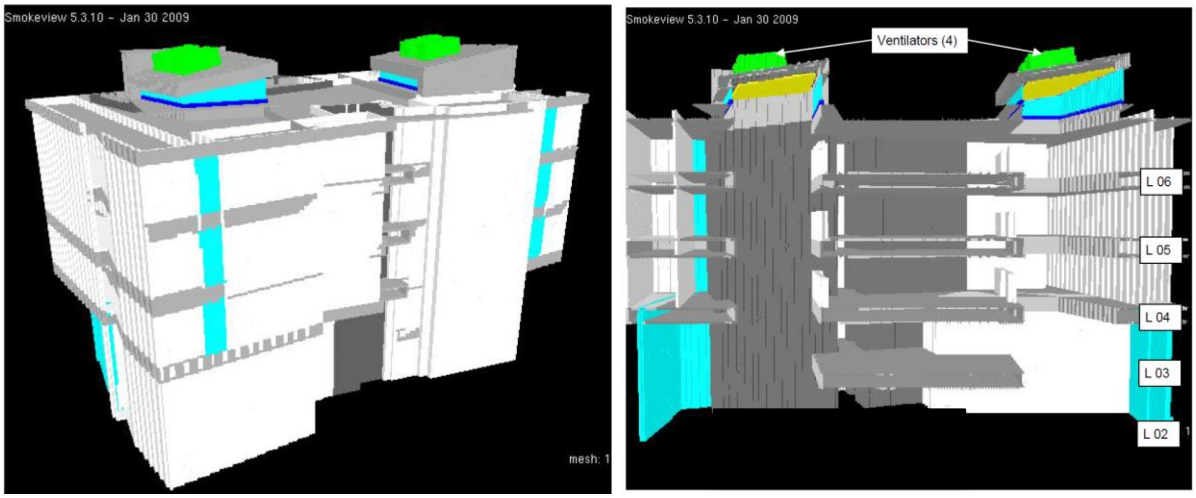

Figure 33 – FDS model used in the Smoke Management Study

Ref. Smoke Management Study, 2009

When analyzing the visibility conditions in the atrium, it is very important to define a proper value of the non-dimensional constant C used to calculate the visibility (S), according to the relation stated in the FDS User's Manual: S = C/K.

Where K is the light extinct coefficient that varies with the density of smoke particulate and a mass specific extinction coefficient. However, C is specified according to the object being viewed through the smoke. For example, C = 8 for a light-emitting sign and C = 3 for a light-reflecting sign. For the Smoke Management Study, C was specified as 8 since the exit signs in the building would be the light-emitting type.

Other important parameter for defining the smoke production during the simulations is the Soot Yield of the fuel. In this case Soot Yields corresponding to polyurethane foam with some cellulosic material were used (effective yield of 5%), which generally results in conservative predictions of visibility. There is no reference in the Smoke Management Study about the Carbon Monoxide Yield used for FDS simulations.

Simulations were conducted in FDS for a maximum period of time of 20 minutes (1200 seconds). This time was defined based upon the results obtained in the RSET analysis (section 5.3 of this report) and the requirement of CBC-2007, Section 909.4.6[32]

Table 35 summarizes the ASET for each design fire scenario.

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[32] CBC-2007, Section 904.4.6 Duration of Operation. All portion of active or passive smoke control systems shall be capable of continued operation after detection of the fire event for a period of not less than either 20 minutes or 1.5 times the calculated egress time, whichever is less.

Table 35- ASET - results
(Seconds)

Design Fire Scenario	Atrium Level	Tenability Criteria	
		Temperature 140 °F (60 °C)	**Visibility 42 feet (13 meters)**
DF#1	2	1,200	1,200
	3	1,200	***240***
	4	1,200	720
	5	1,200	720
	6	1,200	720
DF#2	2	1,200	1,200
	3	1,200	1,200
	4	1,200	***400***
	5	1,200	360
	6	1,200	260
DF#3	2	1,200	1,200
	3	1,200	1,200
	4	1,200*	1,200*
	5	1,200	***320***
	6	1,200	400
DF#4	2	1,200	1,200
	3	1,200	1,200
	4	1,200	1,200
	5	1,200*	1,200*
	6	***240***	***180 (240)***

Ref. Ref. Smoke Management Study, 2009; Radle, L., 2013

*Outside the fire plume

Note: According to the Smoke Management Study, in DF #4 the visibility on Level 6 becomes reduced below 13m after approximately 180s at the eastern exit from the atrium. However, the visibility in other areas of the atrium at this level is maintained for a duration of 240s. While the temperatures above Level 6 become elevated above 60ºC at a time of 240s in one isolated located zone at the eastern exit from the atrium, the average temperature on the remainder of the level is approximately 48ºC, which is within the tenable limits.

As shown in **bold** in Table 35, the ASET for each level of the atrium is as follows:

- Level 2 has an ASET of 1200 seconds in all design fire scenarios.
- Level 3 has an ASET of 240 seconds, limited by DF#1.
- Level 4 has an ASET of 400 seconds, limited by DF#2.
- Level 5 has an ASET of 320 seconds, limited by DF#3.
- Level 6 has an ASET of 180 (240) seconds, limited by DF#4.

5.5 RSET vs ASET Analysis

The RSET and ASET obtained in 5.3 and 5.4 are compared as illustrated in Table 36 and Table 37.

Table 36- RSET vs ASET according to Smoke Management Study

Level	RSET (Seconds)	ASET (Seconds)	Results: Tenability Criteria
2	212	1200	OK
3	236	240	OK
4	231	400	OK
5	240	320	OK
6	239	180(240)	FAIL (OK)

Ref. Ref. Smoke Management Study, 2009

Note: The RSET calculations were performed with the software STEPS and assuming a pre-movement time of 60 seconds (W1). See also the note in Table 35, regarding the results for Level 6.

Table 37- RSET vs ASET according Pathfinder results

Level	RSET (Seconds)	ASET (Seconds)	Results: Tenability Criteria
2	216-396	1200	OK-OK
3	336-516	240	FAIL - FAIL
3*	221-401	240	OK - FAIL
4	284-464	400	OK - FAIL
5	257-437	320	OK - FAIL
6	254-434	180(240)	FAIL - FAIL

Ref. Ref. Smoke Management Study, 2009

** Level 3 in this case excludes the student work spaces from evacuating because a 1- hour fire rated wall separates the atrium space from all other areas on this Level.*

Note: The RSET calculations were performed with the software PATHFINDER considering pre-movement times of 60 and 180 seconds (W1 and W2). See also the note in Table 35, regarding the results for Level 6.

Table 36 and Table 37 show that when conducting a performance-based approach analysis in the atrium of the CSM, different results may be obtained, depending of the assumption made in each case.

According to the Smoke Management Study results, when the RSET calculations were performed with the software STEPS and the pre-movement time was assumed of 60 seconds (W1), the ASET time is greater than the RSET time for all levels[33] and passes the tenability criteria described in Section 5.3 of this report.

33 See also the note in Table 35, regarding the results for Level 6.

However, when the RSET calculations are performed with the software PATHFINDER, different results may be obtained depending on the pre-movement time assumed. Table 37 shows that Level 2 is the only one that passes the tenability criteria, regardless the pre-movement time considered.

Level 3 pass the tenability criteria when a pre-movement time is assumed of 60 seconds and when Level 3 considers the case that excludes the student work spaces from evacuating because a 1- hour fire rated wall separates the atrium space from all other areas on this Level. If the 1- hour fire rated wall is not considered, tenability criteria in Level 3 fails, regardless the pre-movement time considered.

Levels 4 and 5 may pass or not the tenability criteria depending on the pre-movement time assumed. As explained in 5.3.2, in the Smoke Management Study the pre-movement time of 60 seconds was assumed on the basis that all of the design fires are in relatively close proximity to occupied spaces where occupants would clearly be able to see smoke and flames, and so W1 condition for pre-movement time was considered.

Nonetheless, as also indicated in 5.3.2, the validity of this assumption may be challenged because there are administrative offices and work spaces that subdivide the atrium space on Levels 2-6 in which it may not be reasonable to assume that all occupants would be able to clearly see smoke and flames in case of a fire. In addition, the characteristics of EVAC installed and operated in the building are representative of a system performing as the one described for scenario W2, with nondirective voice messages (pre-recorded) and for which the pre-movement time suggested by SFPE Handbook is 180 seconds, instead of the 60 seconds considered by ARUP.

5.5.1 Assessment of Assumptions Stated in the Smoke Management Study

HRR Curves.

An important issue to be evaluated in this analysis is the one related to the assumptions considered in the Smoke Management Study regarding the HRR for the design fire scenarios.

DF#1, DF#3 and DF#4 are considered conservative because the maximum HRR simulated is approximately equal or greater than the one obtained by the DETACT model in all cases.

DF#2, consider a fuel-controlled fire of approximately 2,500 kW, that would be representative of boxes, several full trash bags, miscellaneous light furniture, or cleaning materials and similar items. This fire size was assumed based upon the data from NFPA

92B, 2005 edition, Section B.5.3(d), where heat releases for the majority of furnishings are below 2,500 kW. The Smoke Management Study considered this design fire as conservative based on the above description and the fact that the spaces are predominantly used for circulation.

However 92B, 2005 edition, Section B.5.3(d), also shows some exceptions of furniture exceeding the HRR of 2,500 kW, for instance, a traditional loveseat with a wood frame and fire resistant polyurethane padding (2,890 kW) and a traditional sofa, also with wood frame and fire resistant polyurethane padding (3,120 kW).

Figure 34 shows a curve of a sofa (F32) similar to the one described in 92B, 2005 edition, Section B.5.3(d) with the maximum HRR of approximately 3,120 kW.

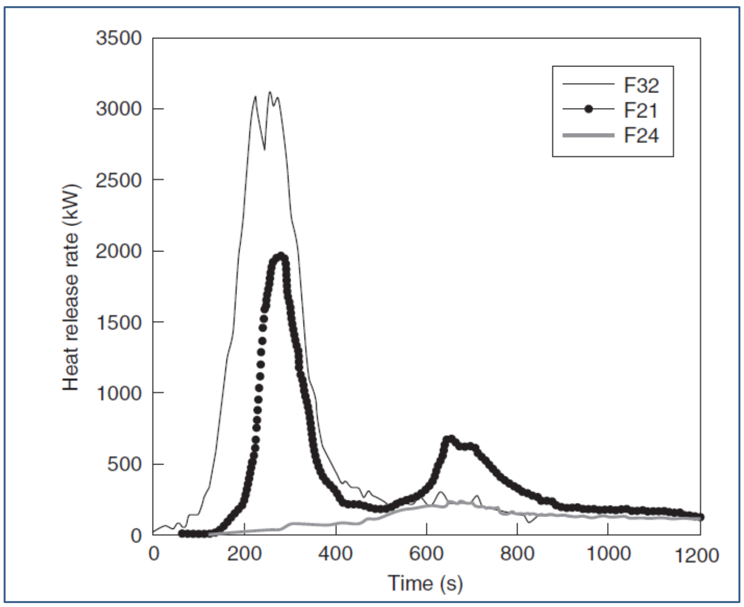


Figure 34 – HRR curves of upholstered furniture items tested by NIST

Ref. SFPE Handbook, 2002, Figure 3.1.52

Some sofas and loveseats are currently located at different levels of the building as shown in Figure 35. These pictures were taken during several visits to the building in 2014 and 2015.

Figure 35 –Sofas and loveseats currently located in several levels of the CSM

Ref. Pictures taken during 2014 -2015. The picture below was taken at the south high bay zone on level 2

In order to evaluate the effects of a fire like the one described in Figure 34 over the RSET-ASET analysis developed in the Smoke Management Study (FD#2), an FDS simulation was performed in this project, maintaining the same construction configuration of the atrium[34].

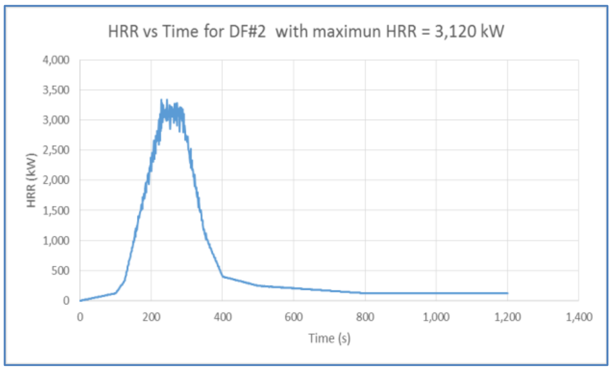
The main parameters stated for this FDS simulation are summarized below:

- HRR curve: similar to the one described in Figure 34 (see Figure 36).
- Design Fire Location: Same as the DF#2 in Smoke Management Study (see Figure 36).
- Ventilation Conditions: Same as the DF#2 in Smoke Management Study (Section 5.4.3)

[34] The construction configuration was the same used in the Smoke Management Study (provided by ARUP North America Ltd.).

- Soot yield: Same as the DF#2 in Smoke Management Study: effective yield of 5%.
- Carbon Monoxide Yield: 0.031(J. Hou, 2011, based on polyurethane foams)
- Visibility Factor: Same as the DF#2 in Smoke Management Study (C =8.0).

Figure 36 shows the FDS model and the HRR curve generated for this simulations.



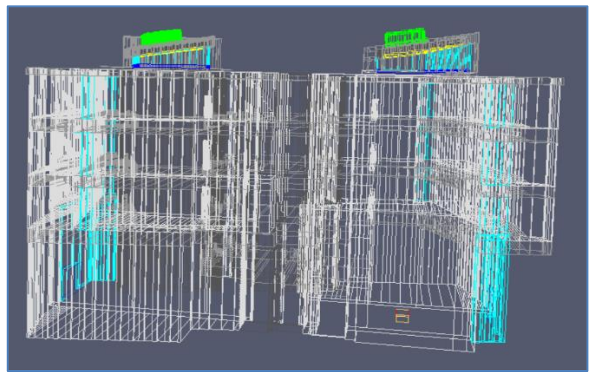


Figure 36 – HRR curve for DF#2 with maximum HRR = 3,120 kW

Ref. SFPE Handbook, 2002, Figure 3.1.52

Appendix 9.15 shows the results of the above simulation and Table 38 summarizes the ASET values for visibility, temperature and Carbon Monoxide obtained.

Table 38- ASET results for DF#2 with maximum HRR = 3,120 kW
(Seconds)

Design Fire Scenario	Atrium Level	Tenability Criteria		
		Temperature 140 °F (60 °C)	Visibility 42 feet (13 meters)	Carbon Monoxide (30,000 ppm/min)
DF#2 HRR = 3,120 kW	2	1,200	1,200	1,200
	3	1,200	1,200	1,200
	4	1,200	285	1,200
	5	1,200	230	1,200
	6	1,200	215	1,200

As shown in Table 38, when using the HRR curve tested by NIST for a sofa similar to those existing nowadays in several levels of the CSM, DF#2 fails the tenability criteria of visibility even earlier than the design fire used for the Smoke Management Study. This is a logical result since the HRR for the sofa of this scenario is always greater than the fast t-squared fire during the first 300 seconds of simulation.

Visibility Factor:

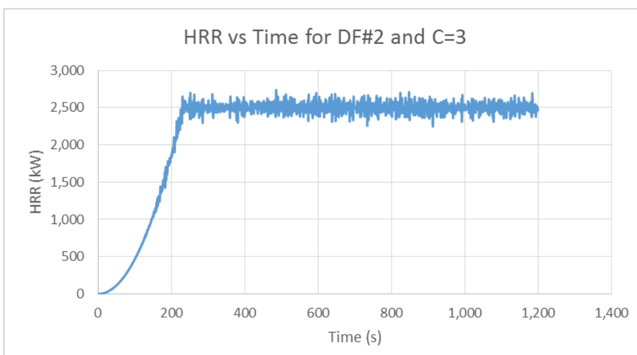
The Smoke Management Study considered a visibility factor C = 8, which is a reasonable value since the exit signs in the building are of the light-emitting type.

In this project a new simulation was conducted for analyzing the effects of using a visibility factor C = 3[35] over the generals results obtained in the Smoke management Study, taking into account that: visibility was the tenability criteria failed in all scenarios analyzed; visibility factor (C = 8 and C = 3) are average values[36]; and in real situations it could be possible to have the exit signs (light-emitting type) non-operative for different reasons.

The main parameters stated for this FDS simulation are summarized below:

- HRR curve: Same as the DF#2 in Smoke Management Study (see Figure 37).
- Design Fire Location: Same as the DF#2 in Smoke Management Study.
- Ventilation Conditions: Same as the DF#2 in Smoke Management Study.
- Soot yield: Same as the DF#2 in Smoke Management Study: effective yield of 5%.
- Carbon Monoxide Yield: 0.031 (J. Hou, 2011, based on polyurethane foams).
- Visibility Factor: C = 3.0.

Figure 37 shows the HRR curve and two general views (at 300, left and 1200 seconds, right) of the smoke generated in this simulation.



35 Visibility Factor C = 3 in is more conservative, since it represents a light-reflecting sign.

36 For light-emitting signs C ranges from 5 to 10 and for reflecting signs C ranges from 2 to 4.

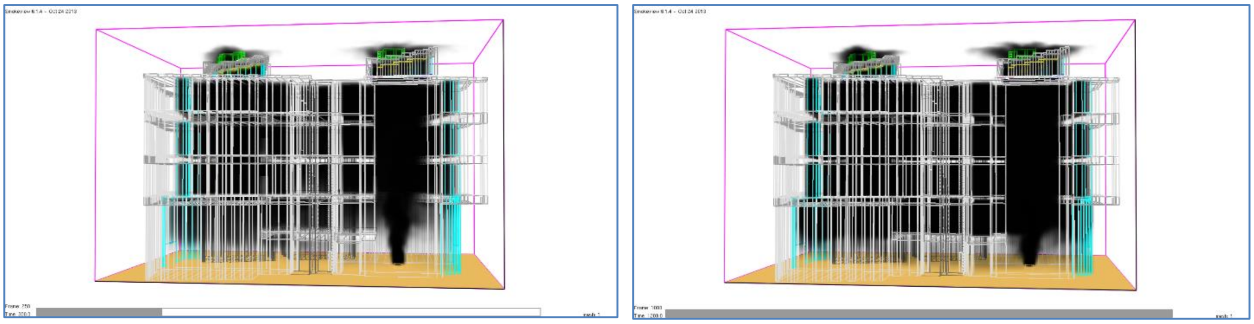
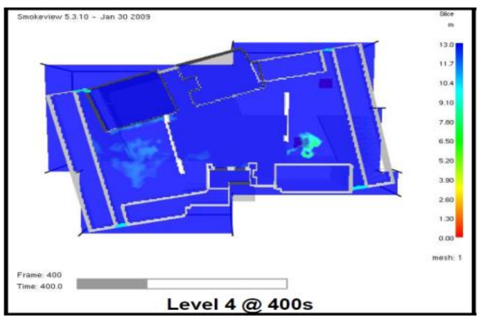


Figure 37 – HRR curve and smoke view pictures for DF#2 with C = 3

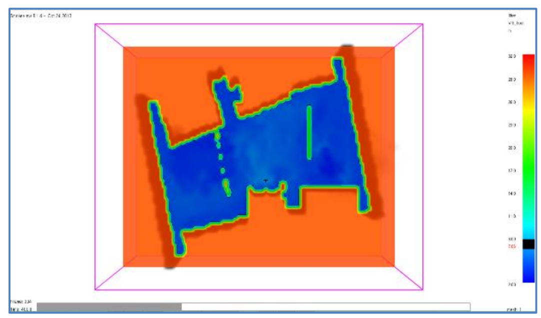
Figure 38 compares the visibility at different periods of times at Levels 4-6.

Smoke Management Study

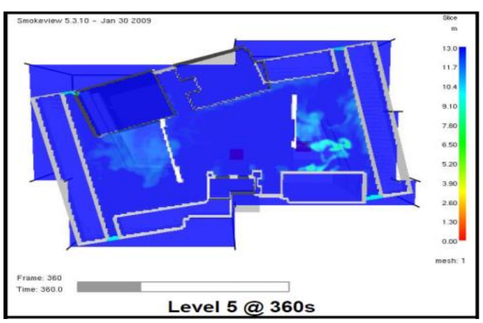
C = 8 | C = 3



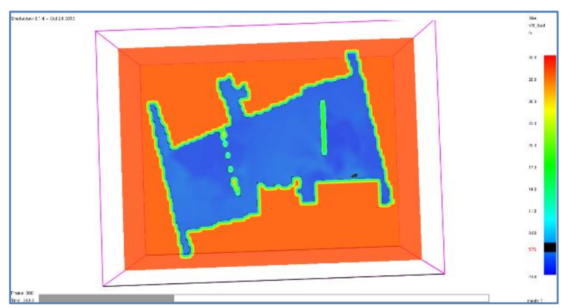
13 m of visibility at 400 seconds – Level 4



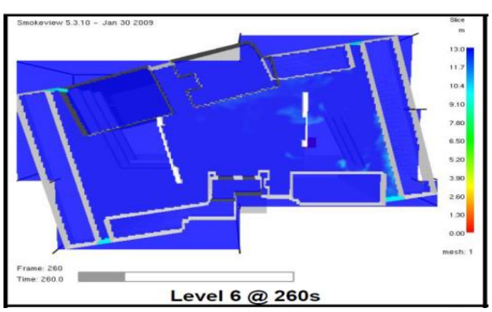
≈ 5-7 m of visibility at 400 seconds – Level 4



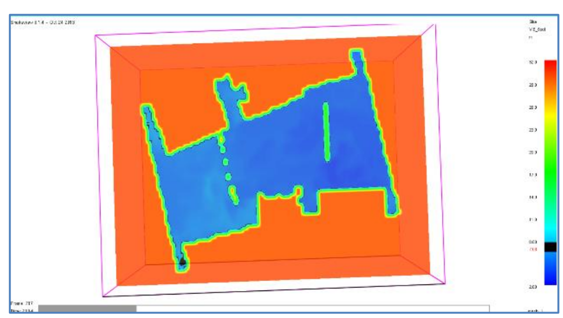
13 m of visibility at 360 seconds – Level 5



≈ 5-7 m of visibility at 360 seconds – Level 5



13 m of visibility at 260 seconds – Level 6



≈ 5-7 m of visibility at 260 seconds – Level 6

Figure 38 – Visibility at Levels 4-6 for DF#2 using two visibly factors

The results obtained with this simulation show that when using the visibly factor C = 3, the visibility is reduced approximately half the value obtained with C = 8. This is a logical result since the visibility is directly proportional to C factor (S=C/K).

Figure 39 shows that with a visibility factor C = 3, the visibility is reduced to 13 m on Levels 3-6 at 350 seconds, and only Level 2 passes the visibility criteria until 1200 seconds.

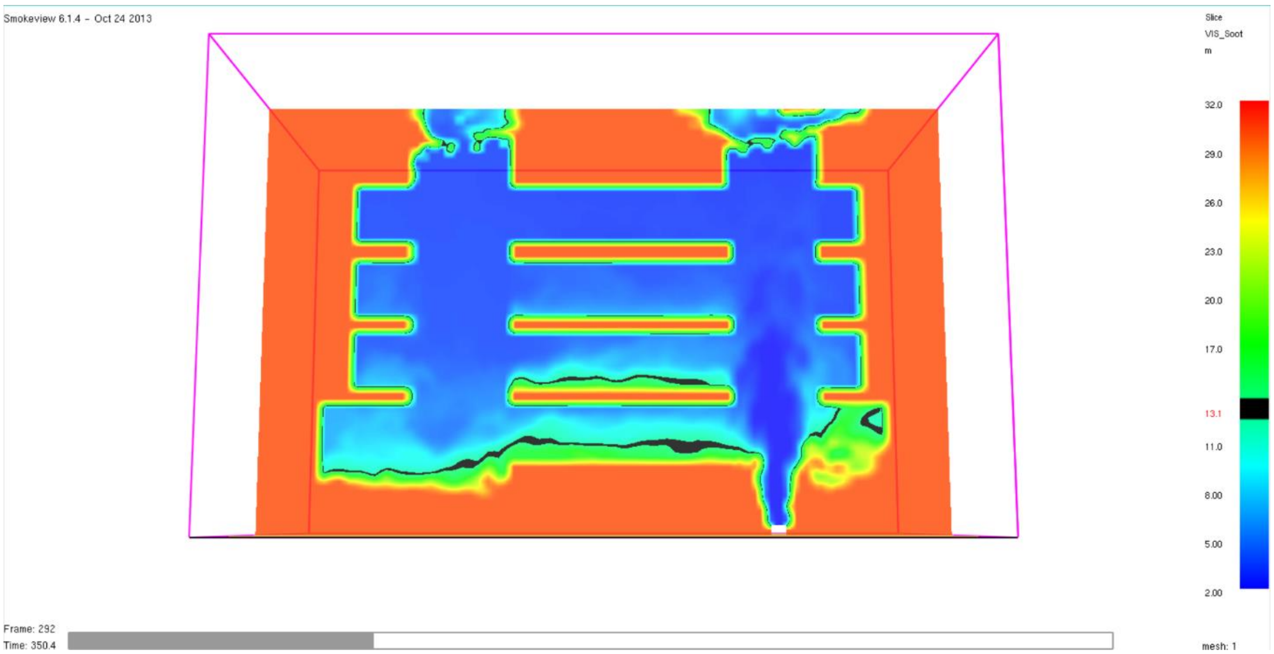


Figure 39 – Visibility at Levels 2-6 for DF#2 with C = 3

5.6 Analysis of the Performance of an Exhaust System in the CSM.

The smoke control system currently installed in the CSM is a natural ventilation smoke management system. Based upon the results obtained in 5.5, in this section are analyzed the requirements and design parameters for a smoke control system in the atrium space within the CSM, intended to maintain a tenable environment for building occupants for a period of at least 1.5 times the calculated egress time, using the exhaust method.

Smoke control systems are designed to keep building occupants safe from the effects of smoke in the event of a fire. Buildings that contain large volume spaces, like atriums often require smoke control systems that rely on the exhaust method to maintain tenable requirements for building occupants (Radle, L., 2013).

An exhaust method removes smoke from the building at a rate that is greater than or equal to the rate at which smoke is being generated from the fire, or at a rate that maintains a tenable environment for occupants during building evacuation

The code requirements for this kind of system are summarized in Appendix 9.16.

5.6.1 Design Parameters for the Smoke Control System.

CBC-2007, Section 909.8 requires smoke control systems using the Exhaust Method to be designed in accordance with NFPA 92B.

NFPA 92B provides a primary set of equations for determining the required exhaust rate of axisymmetric plumes (NFPA 92B-2005, Section 6.2.1).

The basic design parameters for smoke control systems in atriums are determined in this section, following the methodology described in NFPA 92B for the Exhaust Method.

Design Fire Development and tenability criteria.

Section 909.9 of the CBC requires a rational analysis for selected fuel and heat release rates of the design fire.

Of the design fires analyzed in the Smoke Management Study, DF#2 produces the most smoke because it develops the greatest HRR and is located in the inferior level (highest *z*). In addition, as analyzed in 5.5.1, if the exceptions for the HRR curves described in NFPA 92B-2005, are considered , the mechanical exhaust system must be designed for a fast fire growth rate with peak HRR of 3,120 kW, and for maintaining the tenability criteria described in 5.4.1.

Required Exhaust Rate

NFPA 92B - 2005, equations 6.2.1.1a(1) and 6.2.1.1b(1) can be used to calculate the rate at which smoke is produced from the fire plume. Once the rate of smoke production is known, the required exhaust rate needs to be equal to or greater than the rate at which smoke is produced by the fire in order to maintain tenable conditions 1.83 meters (6 feet) above the highest walking surface.

The highest walking surface is Level 6, approximately 19.6 meters (64 feet) above the floor of the atrium. The smoke layer must be kept 6 feet (1.83 m) above the Level 6 walking surface (21.43 m above the atrium's first floor).

With the geometrics characteristics described in Figure 40, the main design parameters for the smoke control system are calculated according to the methodology detailed in NFPA 92B – 2005, as follow.

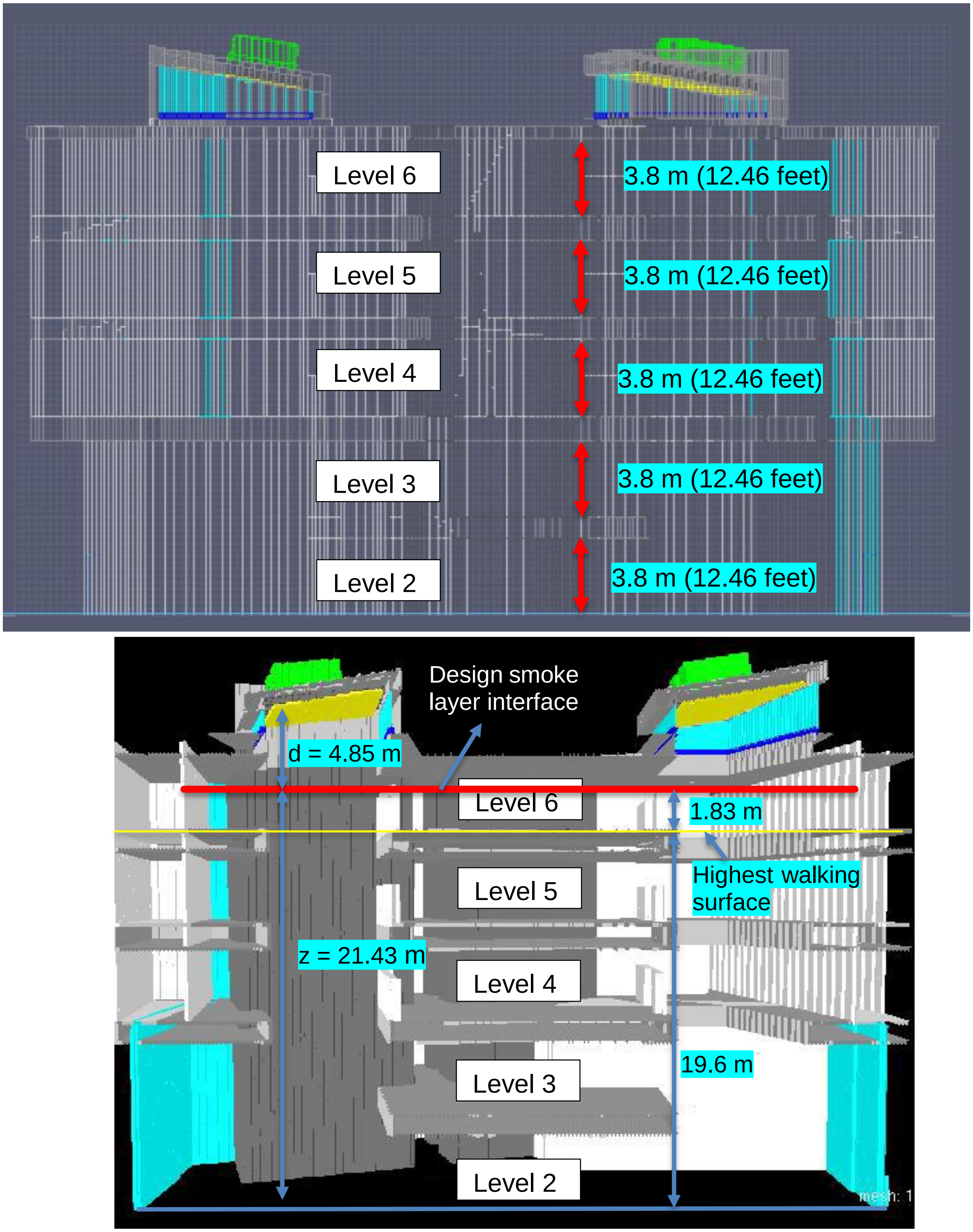


Figure 40 – Atrium geometric details

Ref. ARUP, 2009; ZGF, 2009)

The equation numbers indicated in this section corresponds to the number specified in in NFPA 92B – 2005.

Smoke Rate Production (Eq. 6.2.1.1b (1))

m = 156.22 kg/s

Maximum volumetric flow rate for exhaust vent to prevent plug-holing ((Eq. 6.3.3.b)

V_{max} = 16.6 m^3/s.

In this case, the depth of smoke layer below the lowest point of the exhaust inlet, *d*, is considered 4.85 m, because the exhaust inlets are supposed to be located on the top of the light monitors covering the atrium bays, as shown in Figure 42.

The exhaust location factor, γ, is considered 0.5, for exhaust inlets centered less than twice the diameter from the nearest wall. This is conditioned by the dimensions of light monitors covering the atrium bays, where the exhaust vents are supposed to be located in this design.

Required volumetric flow rate of smoke exhaust (Eq. 6.4b)

V = 132.8 m^3/s

Number of exhaust vents = V/V_{max}

N_{Vents} = 7.98 ≈ 8 exhaust vents

Minimum separation distance between exhaust vents (Eq. 6.3.9b)

S_{min} = 3.67 m.

Diameter of the exhaust vents (D_i)

For rectangular vents of 1m x 1.5 m , D_i = 2ab/(a+b) = 1.2 < d/2 → OK, according to NFPA 92B, 2005, Section 6.3.7.

Makeup Air Requirements

According to NFPA 92B- 2005, Section 4.6, makeup air requirements include determining the area of supply vents required so that the supply air velocity does not exceed 1.02 m/s.

The smoke exhaust system is designed for a smoke flow rate of 156.22 kg/s. Therefore, a makeup air system designed at 90%[37] of the exhaust system requires 140.6 kg/s of makeup air. For ambient temperature of 20 °C with a density of 1.2 kg/m^3, the volumetric flow rate of makeup air supply required is then 117.2 m^3/s.

In this case, the area of supply vents required for maintaining the supply air velocity (average) under 1.02 m/s, must be of at least 114.8 m^2.

5.6.2 FDS Simulations Considering a Mechanical Smoke Control System

Based upon the results obtained in previous section, an FDS model was implemented, for evaluating the effect of an mechanical smoke control system over the tenability conditions on the atrium.

Tenability design criteria are different for analyses using Computational Fluid Dynamics (CFD) models than for systems designed using parametric equations such as those found in either the IBC Section 909 or NFPA 92B. Nonetheless, in this case the idea is to check if with the implementation of the design parameters obtained according to NFPA 92B in 5.6.1, the conditions within the atrium pass the tenability criteria.

The FDS model considered the following items/conditions:

- Eight exhaust vents (four in each light monitor roof) of 1.5mx1m were implemented on the atrium roof, each one with a volumetric flow rate of 16.6 m^3/s, which is the maximum calculated for preventing plug-holing.
- The exhaust vents are located at 4.5 m above the design smoke layer interface defined in in 5.6.1, close to the roof of the light monitors above the atrium bays (see Figure 40).
- The vents were located as shown in Figure 41 and Figure 42, trying to maintain the maximum possible distance between them[38].

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[37] Makeup air must be less than the mass flow rate of the mechanical smoke exhaust system and is recommended to be designed at 85% to 95% of the exhaust system. This is based upon the theory that the remaining air (5%-15%) will enter the atrium space through leakage paths preventing positive pressurization of the atrium, (NFPA 92B - 2005, Section A.4.6.2).

[38] In this case, as the design consider an exhaust location factor of 0.5 for exhaust inlets centered less than twice the diameter from the nearest wall, there is no an specific restriction for the separation between the vents and the walls (the light monitors lateral walls). Given the current dimensions on the light monitors, there are some cases where the minimum separation distance required between exhaust vents (as calculated in in 5.6.1) are not complied, but the breaches are minimum.

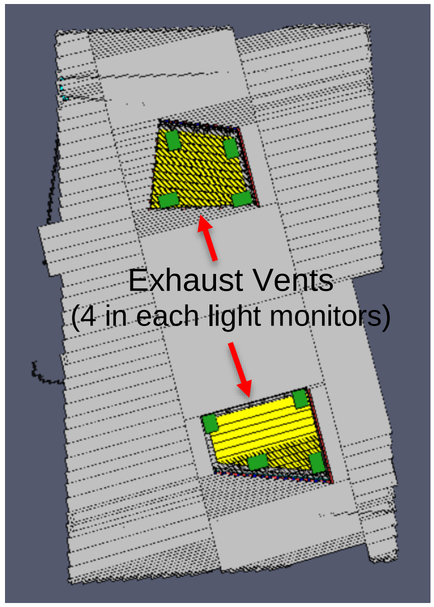

Figure 41 – View of the exhaust vents located on roof (from Level 6)

- The total area of supply vents implemented was of 126.3 m^2, which on average maintains the supply air velocity around 0.93 m/s (< 1.02 m/s required).
- The supply vents are located as shown in Figure 42. The area of the supply vents are as follows:
  - South and North Double Exit doors (2 doors) : 10.95 m^2 each one, according the arquitecture plans (Ref. ZGF 2009).
  - South and North opening (2 openings) above the double exit doors: 45 m^2 each one, according to the space available on the South and North glass walls located at levels 2 and 3.
  - East and West opening (4 openings) on Level 4: 3.6 m^2 each one, according to the space available on the East and West glass walls located at levels 4.
- The openings for the supply vents were located on the outer glass walls in the building, since these are the most convenient locations for communicating the interior environment with the exterior air.
- The natural ventilation roof vents[39] used in the Smoke Management Study were not considered in this case, namely, they were assumed as closed.
- Soot yield: Same of the DF#2 in Smoke Management Study: effective yield of 5%.
- Carbon Monoxide Yield: 0.031 (J. Hou, 2011, based on polyurethane foams).
- Visibility Factor: Same as the DF#2 in Smoke Management Study (C =8.0).

39 Represented as the green boxes on the light monitor roof in Figure 42.

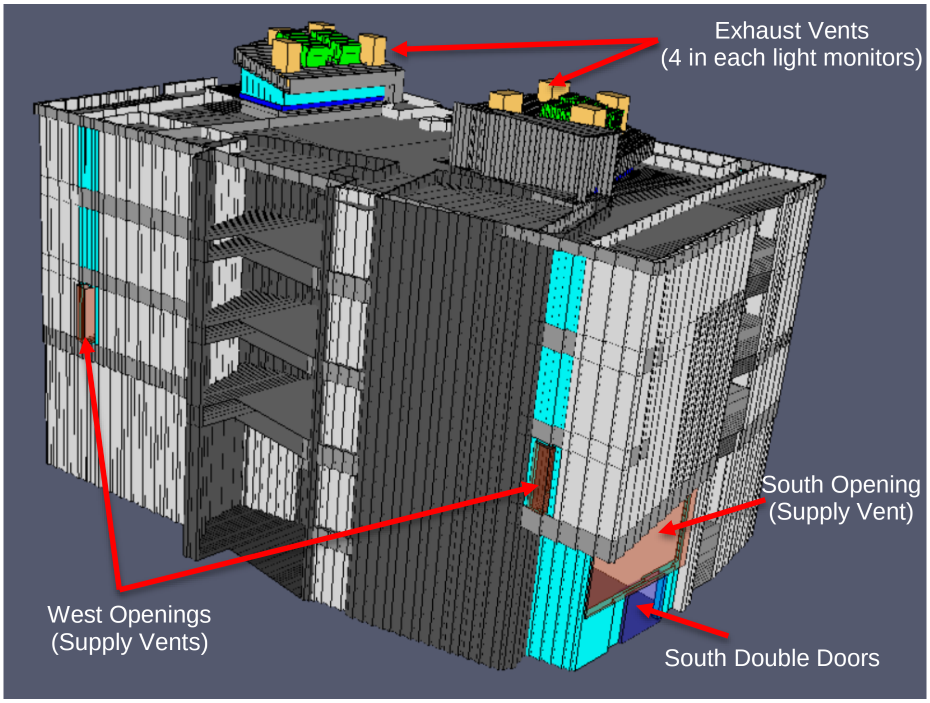

Figure 42 – FDS model for the atrium with the Smoke Control System
Ref. ARUP, 2009; ZGF, 2009)

Based upon the above considerations, different design fire scenarios were analyzed with the FDS model. The idea was to check the results of the design fires with the most severe effects in the atrium, according to the results obtained in the Smoke Management Study. DF#2 was evaluated because it produces the most smoke and requires the highest exhaust rate. DF#4 was assessed because it makes fail the tenability criteria on Level 6 at 180 seconds, which is the worst ASET obtained in the study.

<u>Design fires evaluated considering a Mechanical Smoke Control System</u>

Design Fire Exhaust System A (DFES-A): Considers the same fire location and HRR curve of DF#2 in the Smoke Management Study. The design fire will grow in accordance with a fast-growth t^2 fire until it reaches its maximum HRR of 2,500 kW, at which point the HRR remains constant.

Design Fire Exhaust System B (DFES-B): Considers the same fire location of DF#2 in the Smoke Management Study, and a HRR curve similar to Figure 34, representing a sofa fire with a maximum HRR of 3,120 kW.

Design Fire Exhaust System D (DFES-C): Considers the same fire location and HRR curve of DF#4 in the Smoke Management Study. The heat release rate grows at a fast fire growth rate until the upper layer gas temperature reaches sprinkler activation temperature, at which time the fire is assumed to be controlled by the sprinkler system and the heat release rate remains constant at 1,500 kW.

5.6.3 FDS Simulations Results - Mechanical Smoke Control System

DFES-A: Appendix 9.17 shows the FDS results for this design fire scenario and Table 39 summarizes the ASET values for visibility, temperature and Carbon Monoxide obtained at Levels 2-6.

Table 39- ASET results DFES-A (Seconds)

Design Fire Scenario	Atrium Level	Tenability Criteria		
		Temperature 140 °F (60 °C)	Visibility 42 feet (13 meters)	Carbon Monoxide (1,000 ppm)
DFES-A HRR = 2,500 kW	2	1,200	1,200	1,200
	3			
	4			
	5			
	6			

DFES-B: Appendix 9.18 shows the FDS results for this design fire scenario and Table 40 summarizes the ASET values for visibility, temperature and Carbon Monoxide obtained at Levels 2-6.

Table 40- ASET results DFES-B (Seconds)

Design Fire Scenario	Atrium Level	Tenability Criteria		
		Temperature 140 °F (60 °C)	Visibility 42 feet (13 meters)	Carbon Monoxide (1,000 ppm)
DFES-B HRR = 3,120 kW	2	1,200	1,200	1,200
	3			
	4			
	5			
	6			

DFES-C: Appendix 9.19 shows the FDS results for this design fire scenario and Table 41 summarizes the ASET values for visibility, temperature and Carbon Monoxide obtained at Levels 2-6.

Table 41- ASET results DFES-C (Seconds)				
Design Fire Scenario	**Atrium Level**	**Tenability Criteria**		
		Temperature 140 °F (60 °C)	**Visibility 42 feet (13 meters)**	**Carbon Monoxide ((1,000 ppm)**
DFES-C HRR = 1,500 kW	2	1,200	1,200	1,200
	3			
	4			
	5			
	6			

5.7 RSET vs ASET Analysis - Mechanical Smoke Control System

Table 42 shows the results of the RSET-ASET analysis, based upon the simulations performed in 5.6.3, considering the operation of a Mechanical Smoke Control System as the one designed in 5.6.1.

Table 42- RSET vs ASET considering a Mechanical Smoke Control System			
Level	**RSET (Seconds)**	**ASET (Seconds)**	**Results: Tenability Criteria**
2	216-396	1200	OK
3	336-516	1200	OK
3*	221-401	1200	OK
4	284-464	1200	OK
5	257-437	1200	OK
6	254-434	1200	OK

** Level 3 in this case excludes the student work spaces from evacuating because a 1- hour fire rated wall separates the atrium space from all other areas on this Level.*

Note: The RSET calculations were performed with the software PATHFINDER considering pre-movement times of 60 and 180 seconds (W1 and W2).

According to above results, all levels in the atriums passes the tenability criteria evaluated, regardless the pre-movement time considered.

6. Conclusions

The conclusions that can be drawn from this project are listed next.

- Relevant fire safety codes, standards and regulations related to the construction and operation of the building were identified and analyzed in depth.
- The fire protection prescriptive requirements were evaluated taking into account the building's characteristics.
- The fire safety performance objectives and criteria related to the building were determined and evaluated using available state-of-the-art computer-based models.

According to the analysis performed, the CSM complies with the prescriptive requirements stated on the applicable codes for this kind of buildings. The performance-based analysis, however, showed that different results might be obtained depending on the assumptions made for the evaluations.

The results obtained in a previous Smoke Management Study developed by ARUP indicated that when the RSET calculations were based on simulations performed with the software STEPS, and the pre-movement time is assumed to be 60 seconds, the ASET is greater than the RSET for all levels, and therefore the building's atrium passes the tenability criteria defined in this report.

However, when the RSET calculations were performed with the software PATHFINDER, different results were obtained depending on the pre-movement time assumed, and only Level 2 passed the tenability criteria regardless the pre-movement time considered.

Based on the above cited results, it is worth noting that in the Smoke Management Study developed by ARUP, the pre-movement time of 60 seconds was assumed on the basis that all of the design fires simulated are in relatively close proximity to the occupied spaces, where the occupants would clearly be able to observe smoke and flames.

Nonetheless, the validity of this assumption may be challenged since there are administrative offices and work spaces that subdivide the atrium space on Levels 2-6, in which it may not be reasonable to assume that all occupants would be able to clearly see smoke and flames in the event a fire. In addition, the EVAC system installed in the building operates through nondirective (pre-recorded) voice messages. For this kind of system, the pre-movement time suggested by the SFPE Handbook is 180 seconds, instead of the 60 seconds indicated in the previous Smoke Management Study developed by ARUP.

Based upon the analysis in this report, the requirements and design parameters for a Mechanical Smoke Control System in the atrium space within the CSM were defined. These requirements were intended to maintain a tenable environment for building occupants, using the exhaust method. The design parameters were then used to simulate the most severe design fires scenarios in the atrium with FDS.

The simulation of the atrium, considering the operation of the Mechanical Smoke Control Systems, showed that all levels in the atriums successfully pass the tenability criteria evaluated, regardless the pre-movement time considered.

7. Recommendations

The following recommendations emanate from the results obtained in this report:

- Prepare and implement a Fire Safety Management Plan for the building, in conformity with the requirements stated on the International Fire Code, Chapter 4 (see Appendix 9.20). The plan must clearly specify the location of furniture to be allowed in the atrium at its different levels. The plan also must include the procedures and requirements for a "staged evacuation" in the building, which allow occupants within close proximity of the fire to evacuate the building first.

- Conduct a detailed study in the current conditions of the building, in order to ascertain more accurately the validity of the assumptions made in the Smoke Management Study regarding that: "as all the design fires simulated are in relatively close proximity to occupied spaces, the occupants would clearly be able to see smoke and flames in case of a fire."

- Make the decision of redesign or change the EVAC system currently operating through nondirective (pre-recorded) voice messages, for a W1 system[40].

- Conduct a detailed cost-benefit analysis for determining the feasibility of:

  - Installing a Mechanical Smoke Control System in the atrium, like the one defined in Section 5.6 of this report or;

  - Improving/changing the current natural smoke controls systems, in order to rely on a system able to provide at least 1.5 times the required RSET evacuation time for the safe occupant evacuation. The latter should revolve on conservative assumptions for the required evacuation times.

[40] W1 system: Live directives using a voice communication system from a control room with closed-circuit television facility, or live directives in conjunction with well-trained, uniformed staff that can be seen and heard by all occupants in the space"

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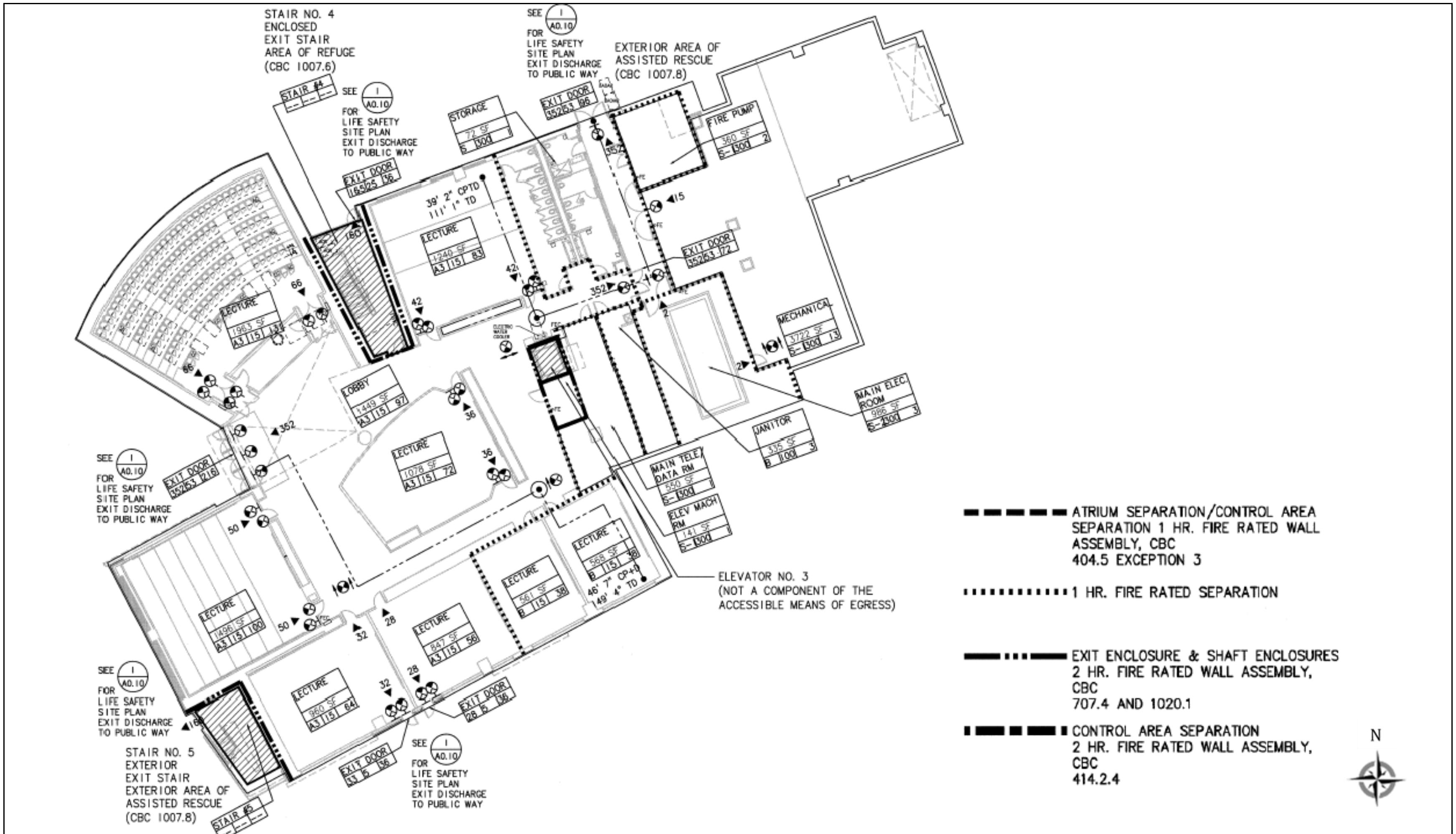
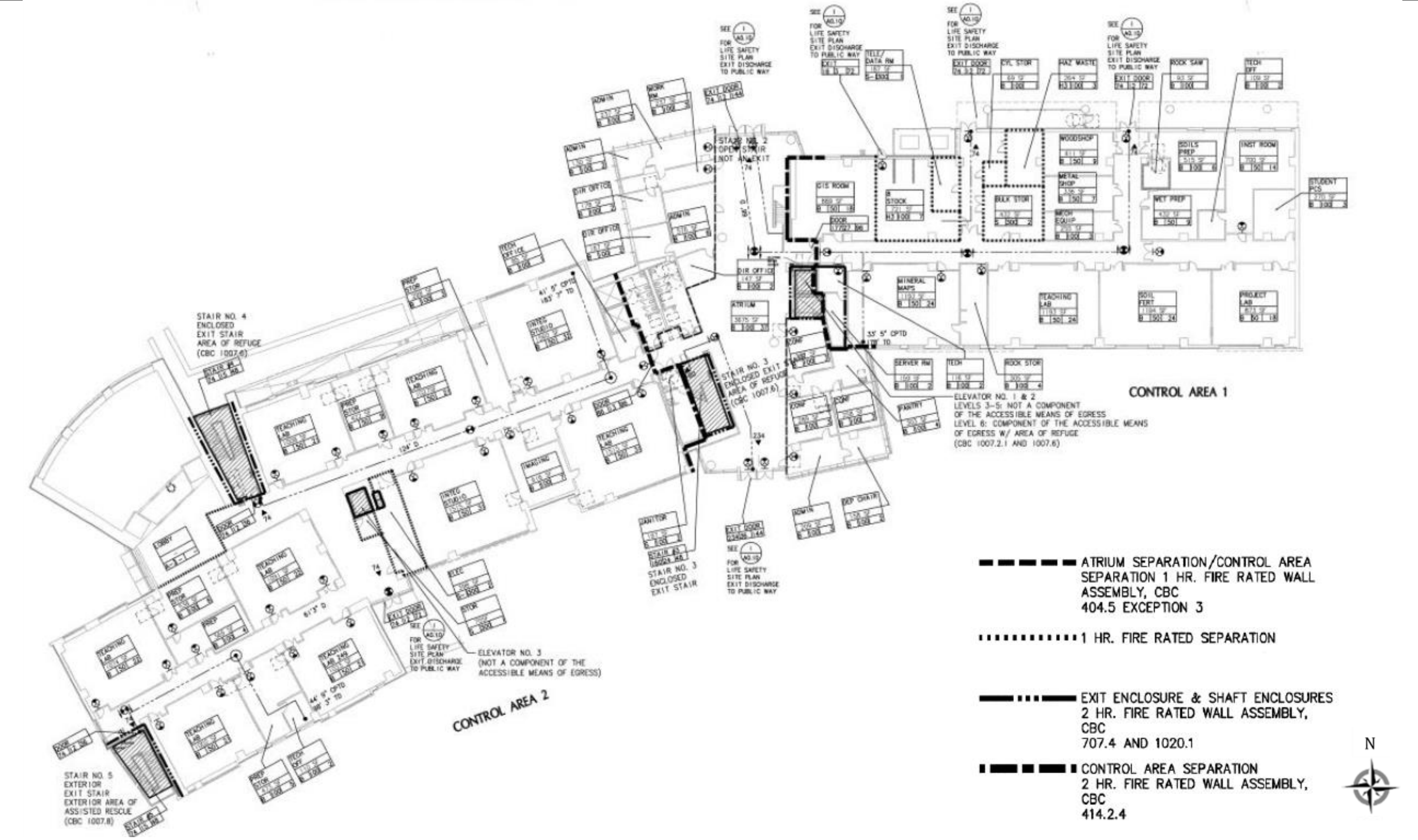
9. Appendices

9.1 Floor Plans and Fire-resistance Ratings between Occupancy Boundaries[41]

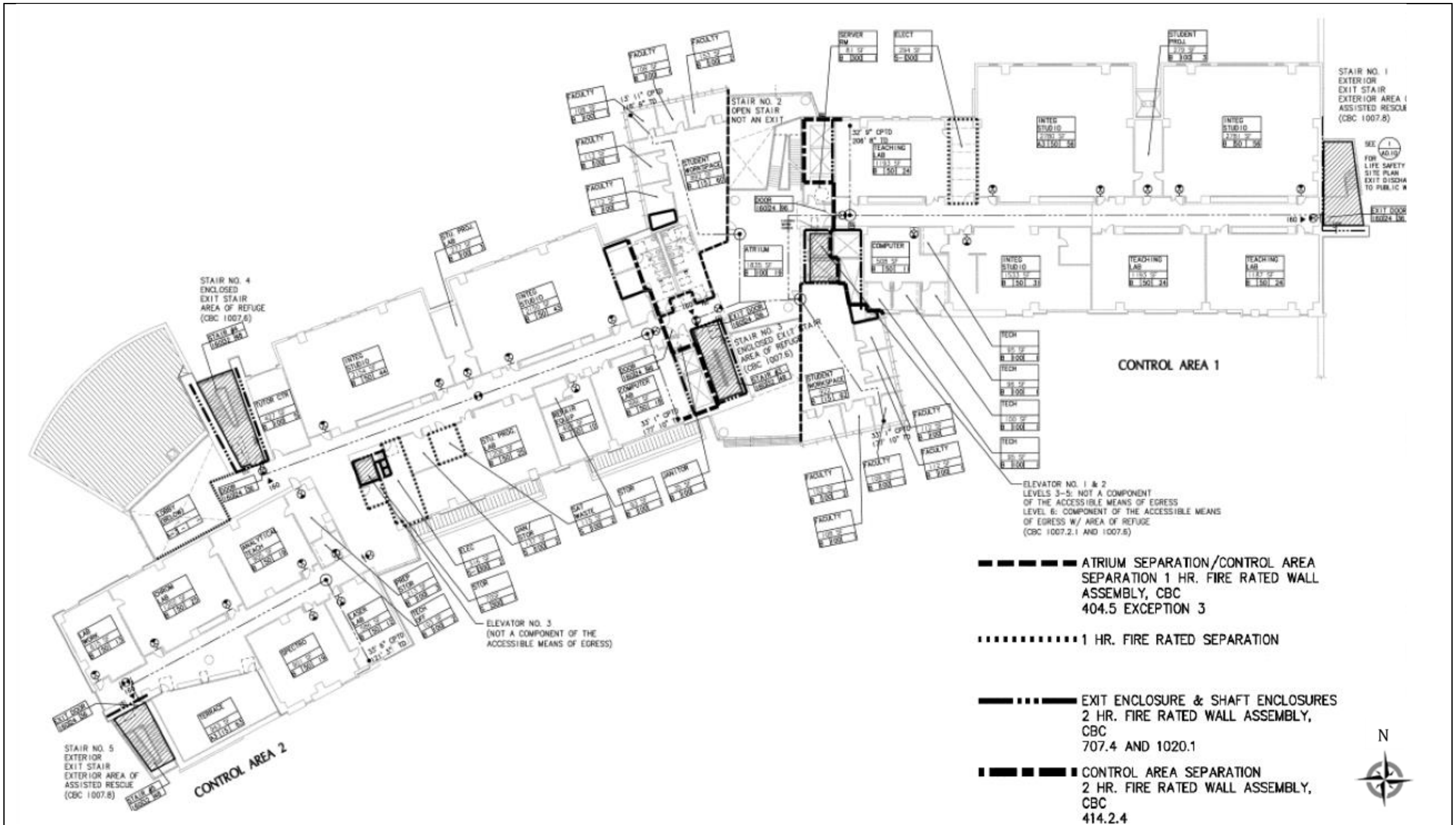


Level 1- Fire-Resistance Ratings

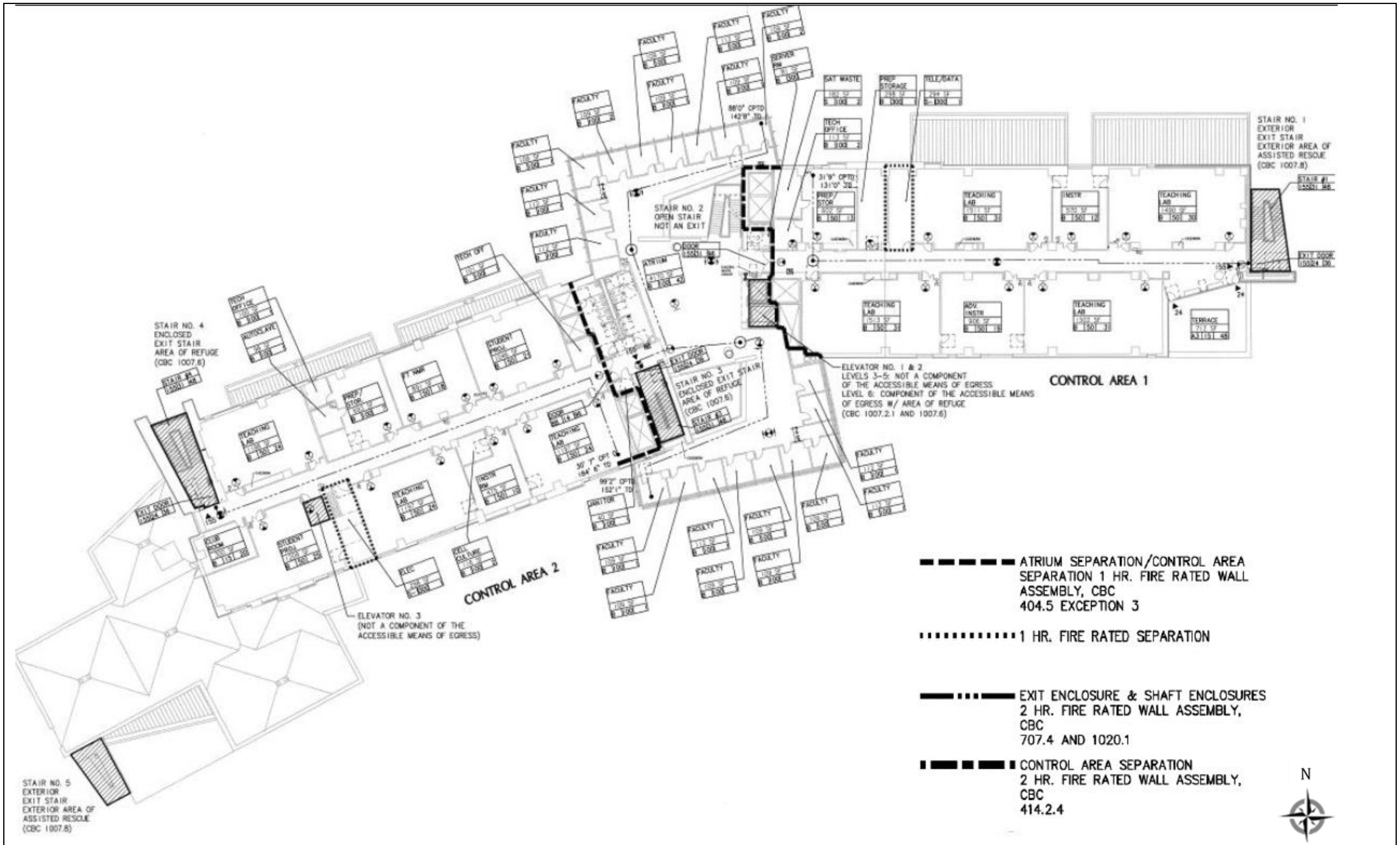
41 Ref. ZGF, 2009



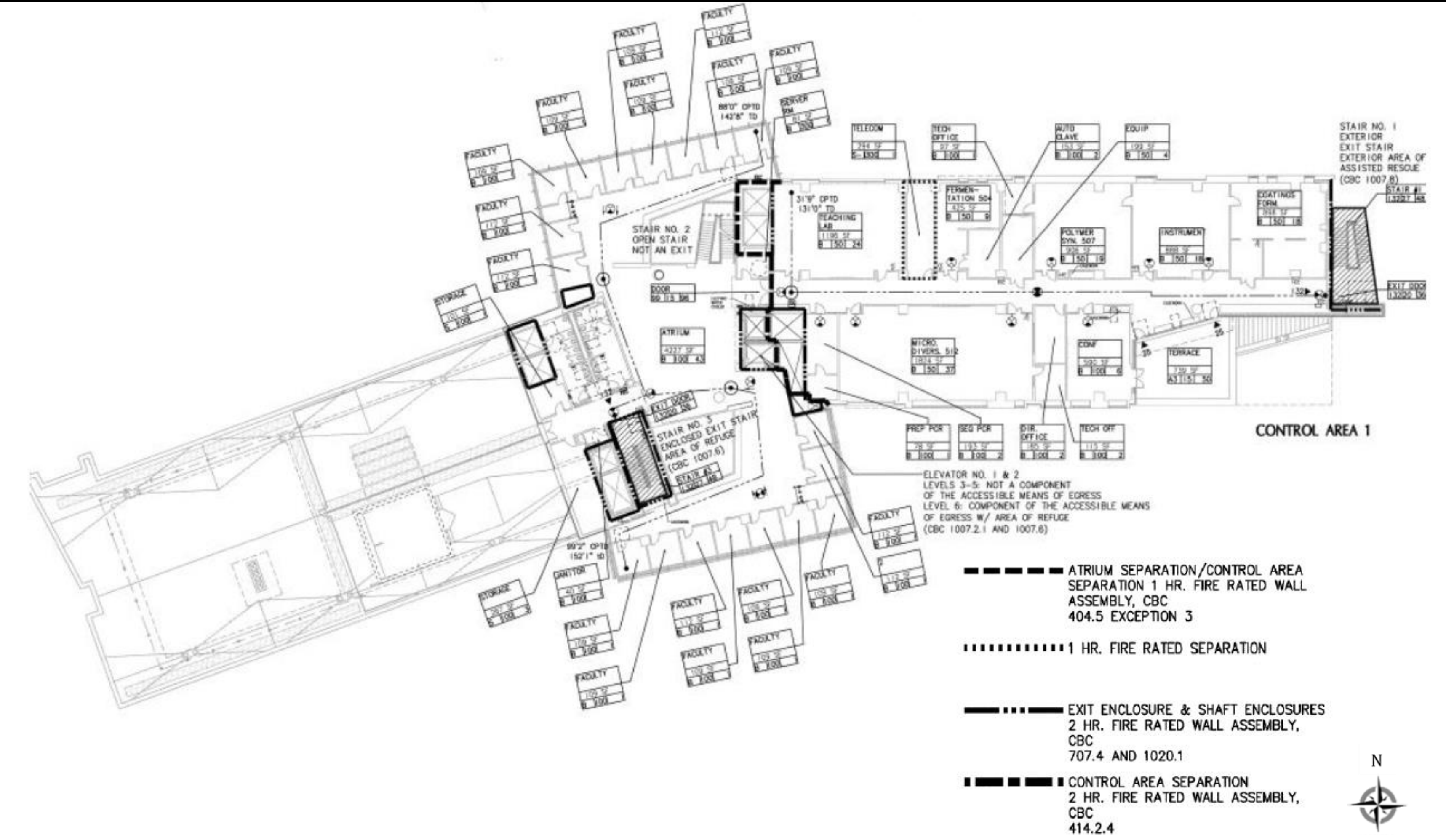
Level 2 - Fire-Resistance Ratings



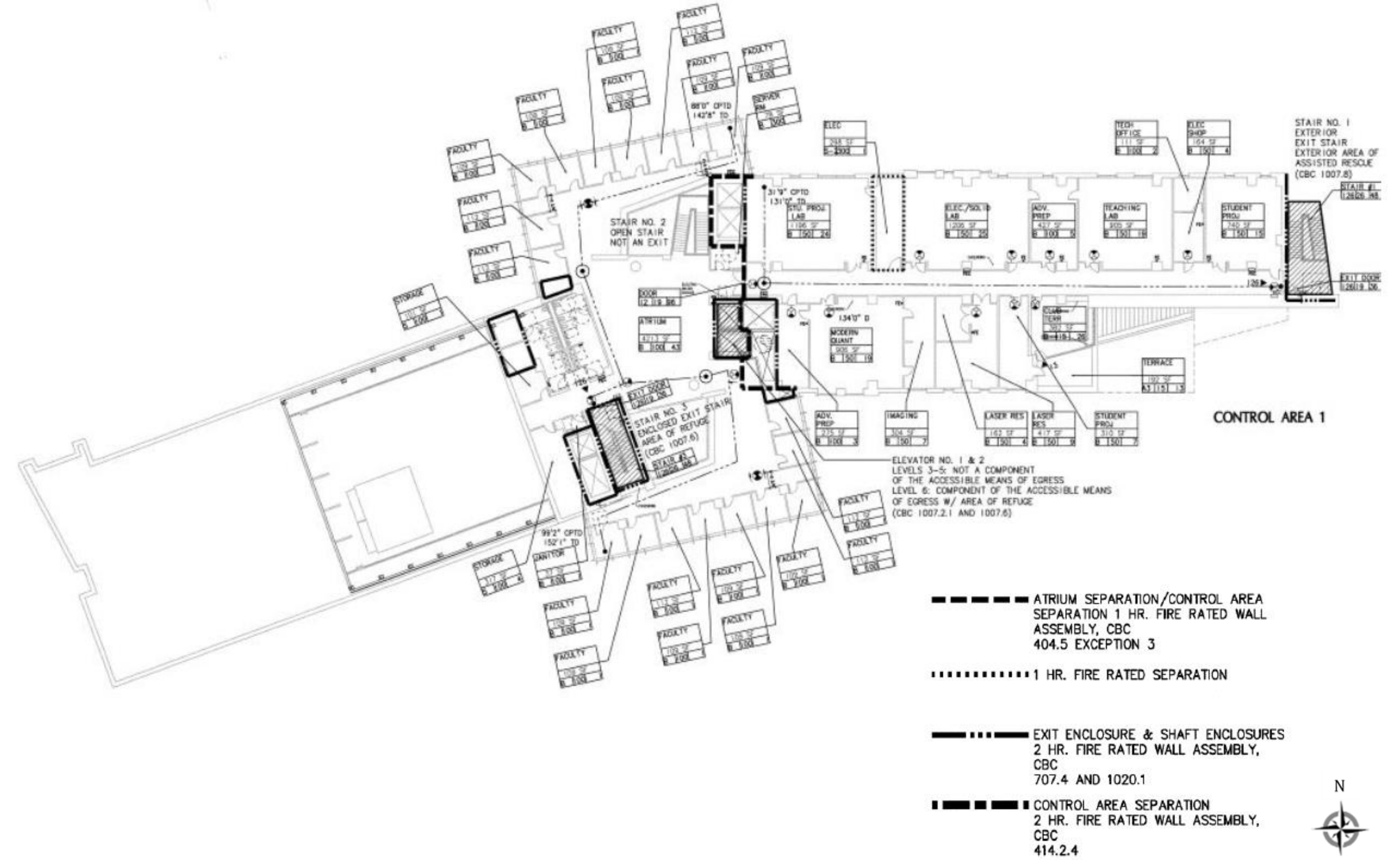
Level 3 - Fire-Resistance Ratings



Level 4 - Fire-Resistance Ratings

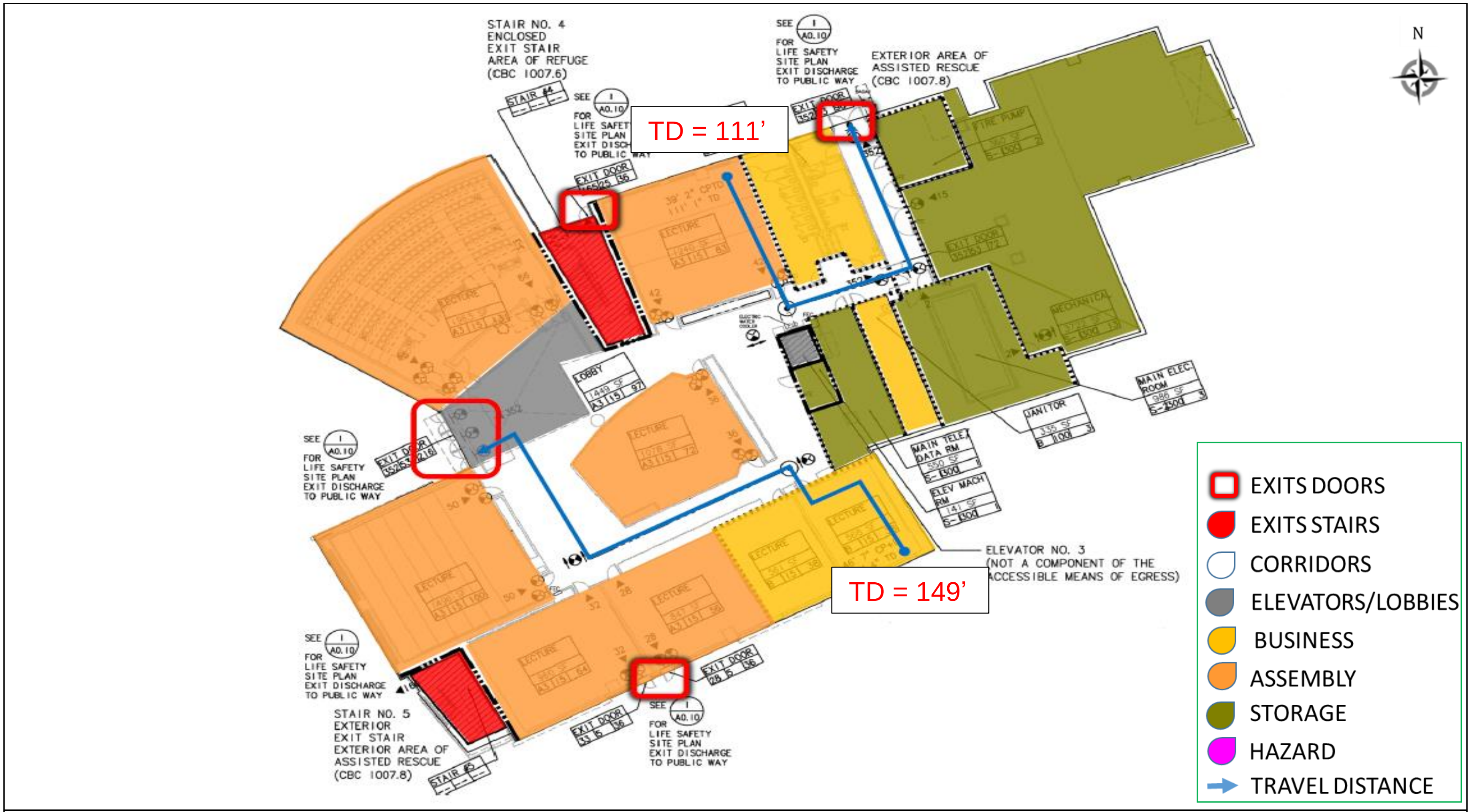


Level 5 - Fire-Resistance Ratings



Level 6 - Fire-Resistance Ratings

9.2 Occupancy Classifications and Maximum Travel Distance (TD)[42]



Level 1 - Occupancy Classifications and Travel Distances

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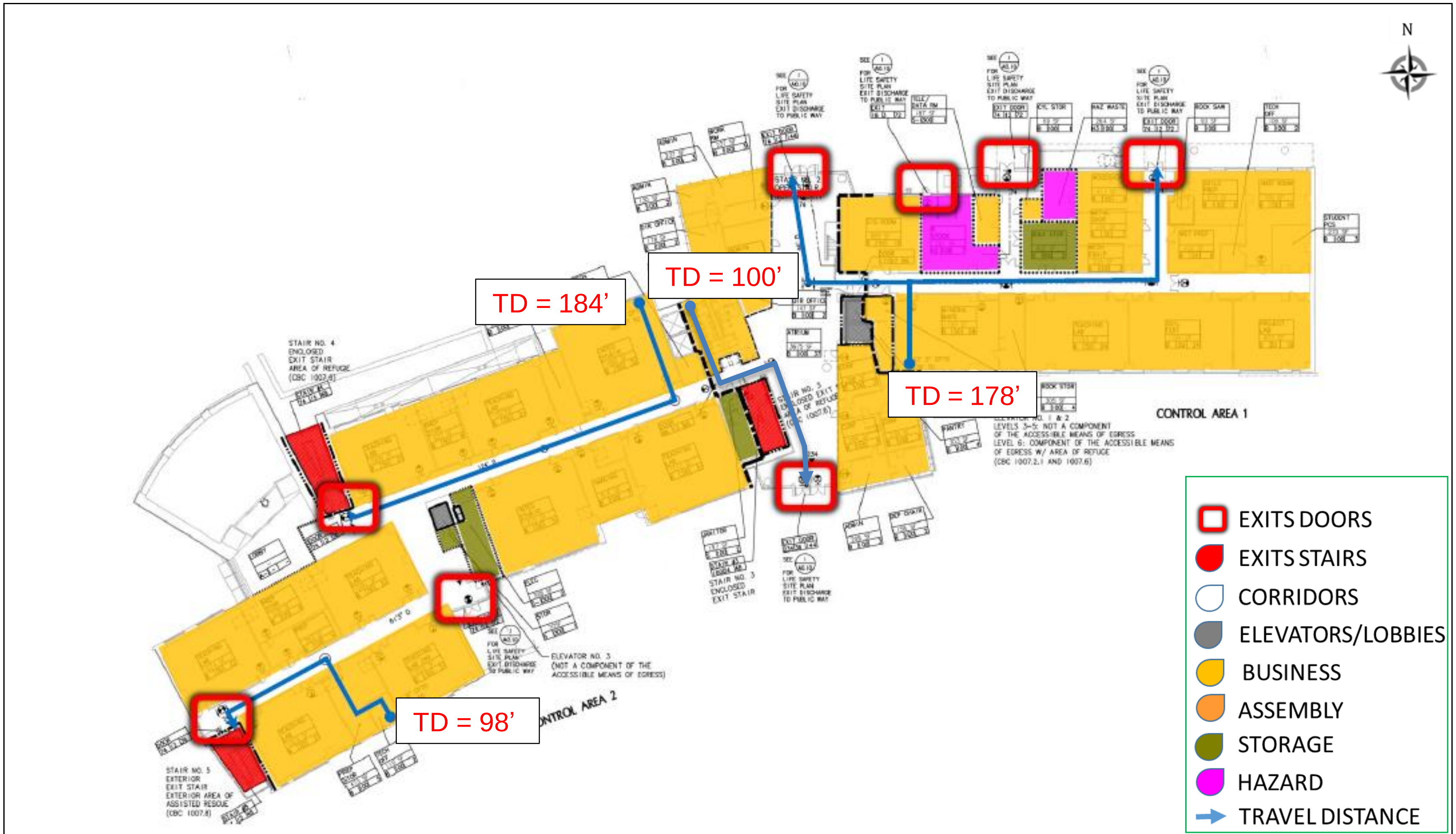
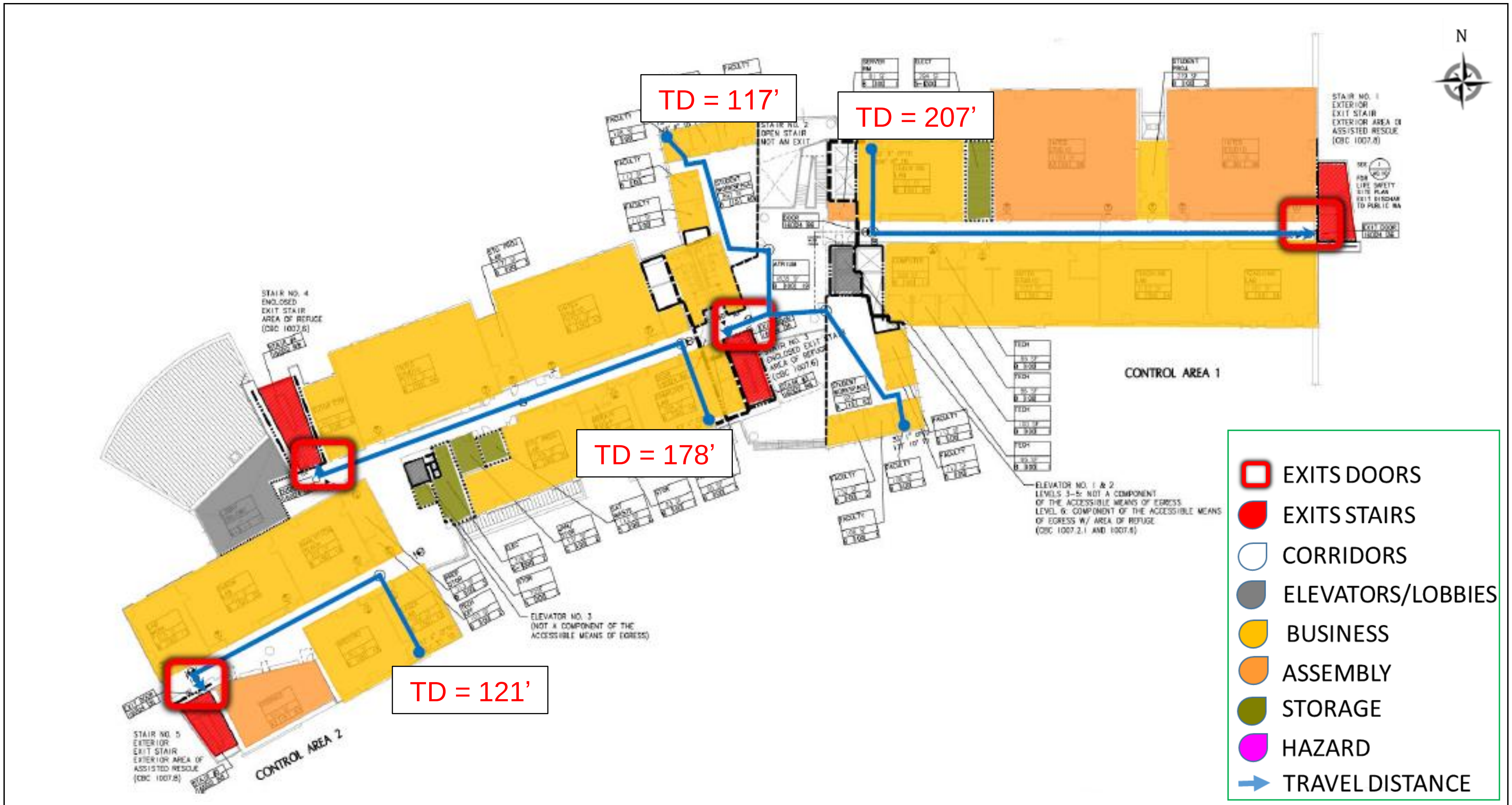
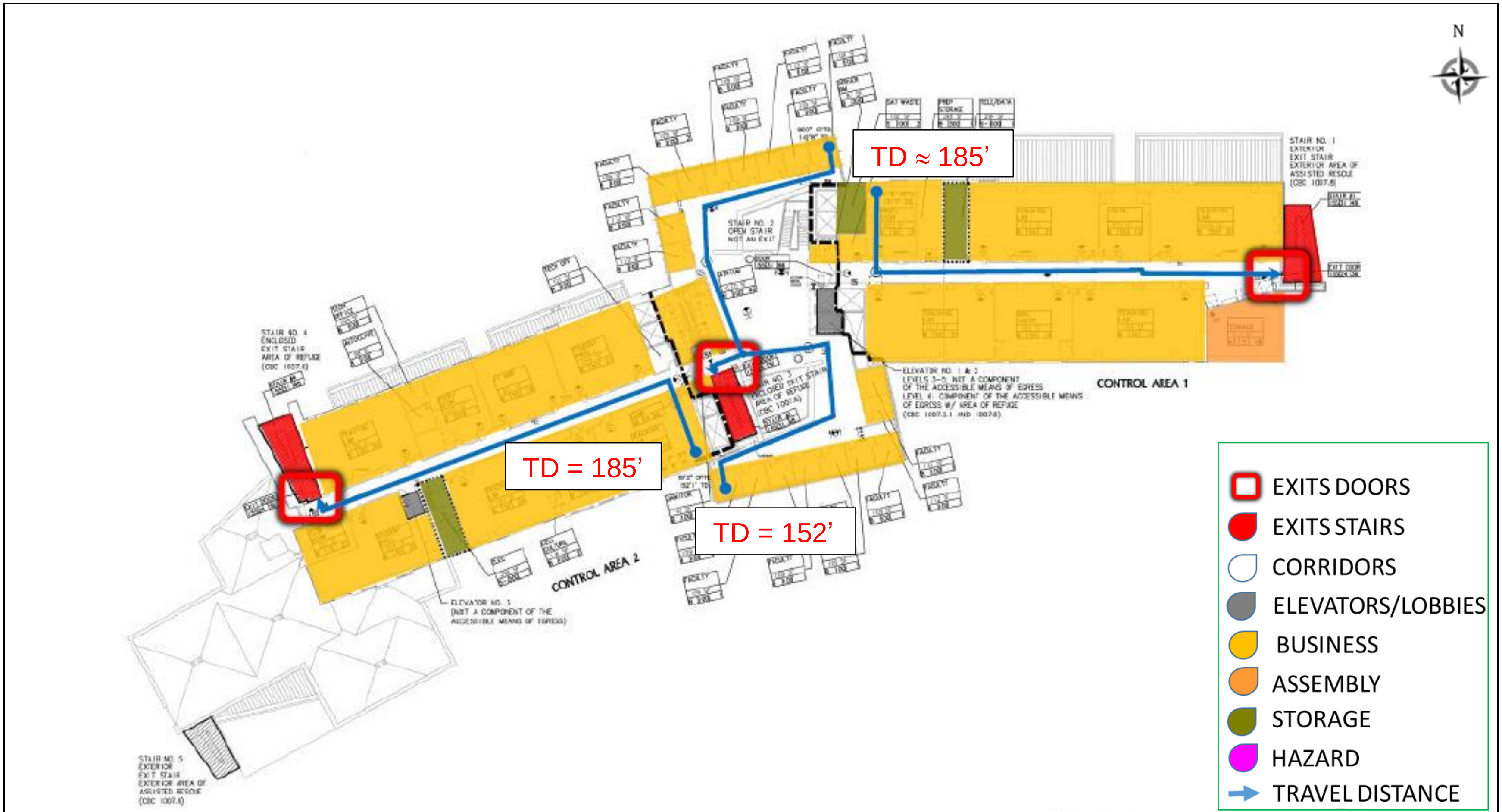
42 Ref. ZGF, 2009



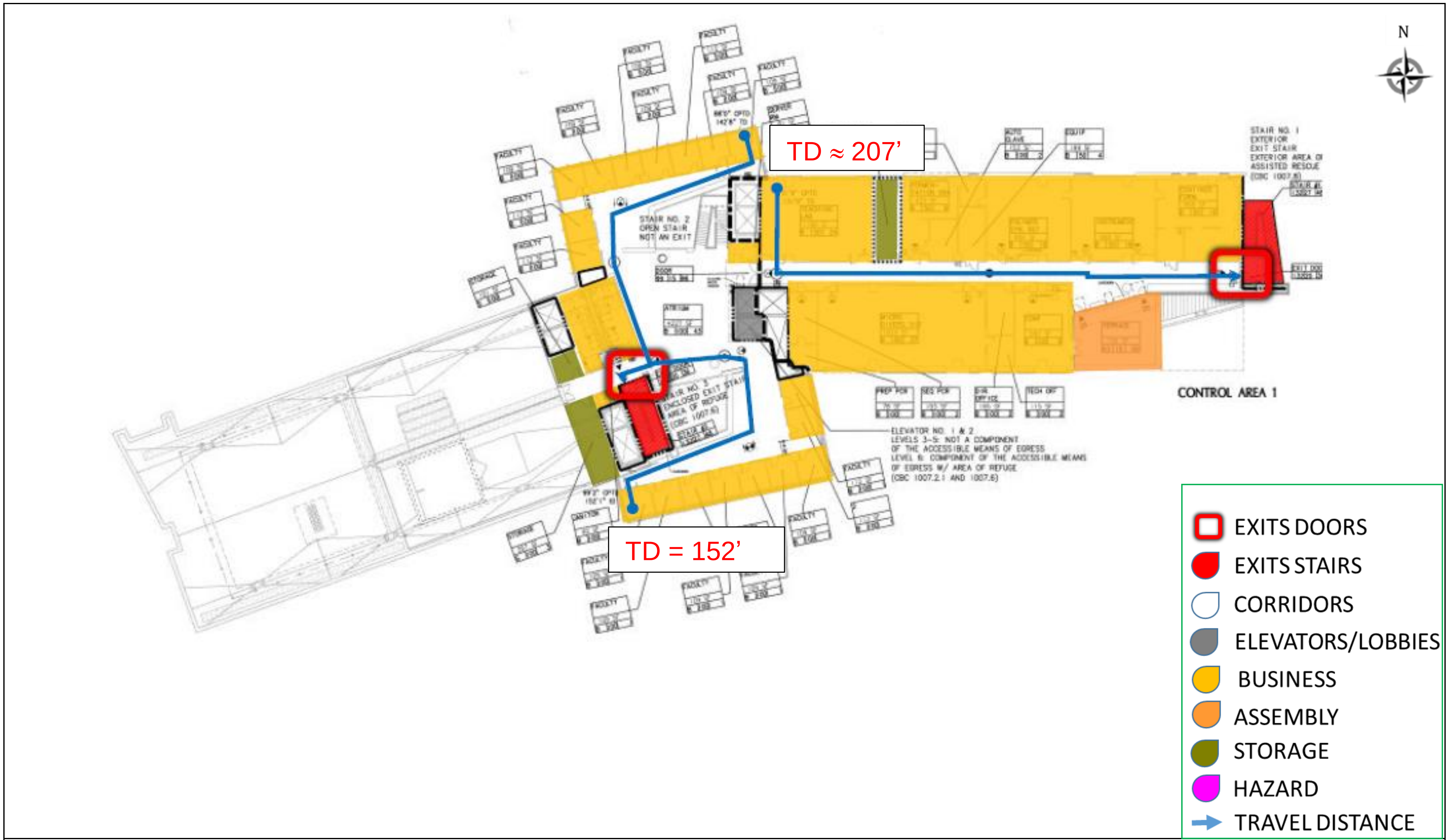
Level 2 - Occupancy Classifications and Travel Distances



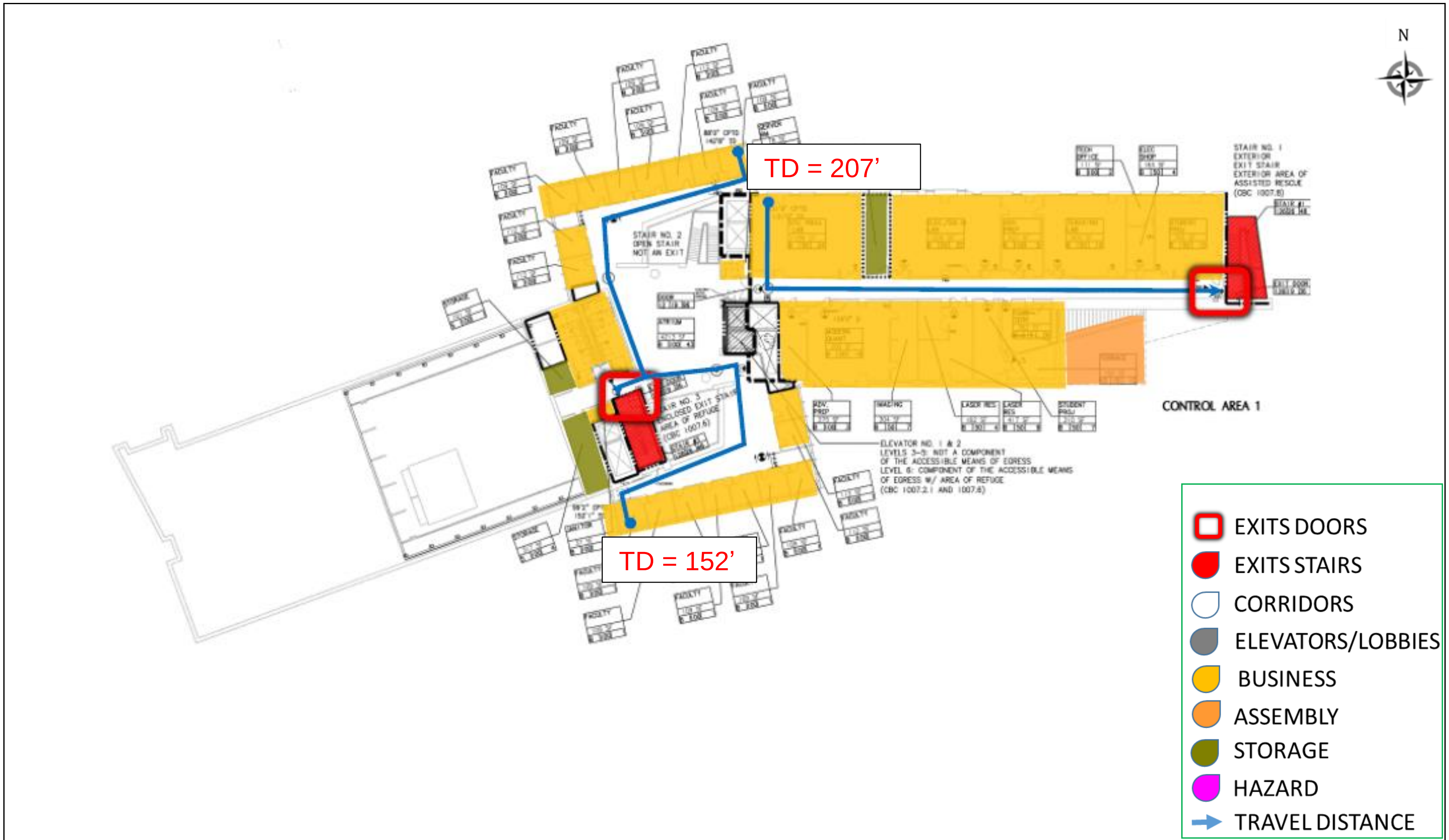
Level 3 - Occupancy Classifications and Travel Distances



Level 4 - Occupancy Classifications and Travel Distances



Level 5 - Occupancy Classifications and Travel Distances



Level 6 - Occupancy Classifications and Travel Distances

9.3 Main Requirements for the Fire Alarms and Detection System

CBC-2007

SECTION 907 – Fire Alarm and Detection Systems

907.2 Where required, an approved manual, automatic or manual and automatic fire alarm system installed in accordance with the provisions of this code and NFPA 72 shall be provided in new buildings and structures in accordance with Sections 907.2.1 through 907.2.23 and provide occupant notification in accordance with Section 907.9, unless other requirements are provided by another section of this code.

Where automatic sprinkler protection installed in accordance with Section 903.3.1.1 or 903.3.1.2 is provided and connected to the building fire alarm system, automatic heat detection required by this section shall not be required. The automatic fire detectors shall be smoke detectors.

907.2.2 Group B. A manual fire alarm system shall be installed in Group B occupancies having an occupant load of 500 or more persons or more than 100 persons above or below the lowest level of exit discharge. Exception: Manual fire alarm boxes are not required where the building is equipped throughout with an automatic sprinkler system and the alarm notification appliances will activate upon sprinkler water flow.

907.2.12.2 Emergency voice/alarm communication system.
The operation of any automatic fire detector, sprinkler water-flow device or manual fire alarm box shall automatically sound an alert tone followed by voice instructions giving approved information and directions for a general or staged evacuation on a minimum of the alarming floor, the floor above and the floor below in accordance with the building's fire safety and evacuation plans required by Section 404 of the California Fire Code.

907.2.12.3 Fire department communication system.
An approved two-way, fire department communication system designed and installed in accordance with NFPA 72 shall be provided for fire department use. It shall operate between a fire command center complying with Section 911 and elevators, elevator lobbies, emergency and standby power rooms, fire pump rooms, areas of refuge and inside enclosed exit stairways. The fire department communication device shall be provided at each floor level within the enclosed stairway.

907.2.13 Atriums connecting more than two stories.
A fire alarm system shall be installed in occupancies with an atrium that connects more than two stories. Such occupancies in Group A, E or M shall be provided with an emergency voice/alarm communication system complying with the requirements of Section 907.2.12.2

SECTION 909 - SMOKE CONTROL SYSTEMS

Openings in smoke barriers shall be protected by self-closing devices or automatic-closing devices actuated by the required controls for the mechanical smoke control.
909.16 A fire-fighter's smoke control panel for fire department emergency response purposes only shall be provided and shall include manual control or override of automatic control for mechanical smoke control systems.

NFPA 72 -2007

Protection of Fire Alarm System (4.4.5*). In areas that are not continuously occupied, automatic smoke detection shall be provided at the location of each fire alarm control unit(s), notification appliance circuit power extenders, and supervising station transmitting equipment to provide notification of fire at that location. Exception No. 2: Fully sprinklered buildings shall not require protection in accordance with 4.4.5

Elevator Shutdown (Section 6.16.4). Heat detectors used to shut down elevator power prior to sprinkler operation must be located within 3 ft. of each sprinkler head and have both a lower temperature rating and a higher sensitivity.

5.4.6 Initiating devices shall be installed in all areas, compartments, or locations where required by other NFPA codes and standards or as required by the authority having jurisdiction.

5.5.2.2* Partial or Selective Coverage. Where codes, standards, laws, or authorities having jurisdiction require the protection of selected areas only, the specified areas shall be protected in accordance with this Code.

Elevator Recall for Fire Fighters' Service
6.16.3.5* A lobby smoke detector shall be located on the ceiling within 6.4 m (21 ft) of the centerline of each elevator door within the elevator bank under control of the detector Door Releasing Service

Door Releasing Service
5.16.6.5.1.1 If the depth of wall section above the door is 610 mm (24 in.) or less, one ceiling-mounted smoke detector shall be required on one side of the doorway only, or two wall-mounted detectors shall be required, one on each side of the doorway.

CMC -2007

609.0 Automatic Shutoffs
Air-Moving systems supplying air in excess of 2,000 cubic feet per minute (944 L/s) to enclosed spaces within building shall be equipped with an automatic shutoff. Automatic shutoff shall be accomplished by interrupting the power source of the air-moving equipment upon detection of smoke in the main supply-air duct served by such equipment… Where fire-detectors or alarm systems are provided for the building, the smoke detectors required for this section shall be supervised by such systems and installed in accordance with NFPA 72 and the CBC and CFC.

9.4 Requirements for EVACS and Two-way Emergency communication System

CBC-2007

Emergency voice/alarm communication system (EVACS), CBC-2007, Section 907.2.12.2

- The operation of any automatic fire detector, sprinkler water-flow device or manual fire alarm box shall automatically sound an alert tone followed by voice instructions giving approved information and directions for a general or staged evacuation on a minimum of the alarming floor, the floor above and the floor below in accordance with the building's fire safety and evacuation plans required by Section 404 of the California Fire Code.
- Speakers shall be provided throughout the building by paging zones. As a minimum, paging zones shall be provided as follows:
  - Elevator groups.
  - Exit stairways.
  - Each floor.
  - Areas of refuge
- A manual override for emergency voice communication shall be provided on a selective and all-call basis for all paging zones.
- The emergency voice/alarm communication system shall also have the capability to broadcast live voice messages through paging zones on a selective and all-call basis.
- The emergency voice/alarm communication system shall be designed and installed in accordance with NFPA 72.

Two-way Emergency communication System respectively: CBC-2007, Section 907.2.12.3

- An approved two-way, fire department communication system designed and installed in accordance with NFPA 72 shall be provided for fire department use.
- It shall operate between a fire command center complying with Section 911 and elevators, elevator lobbies, emergency and standby power rooms, fire pump rooms, areas of refuge and inside enclosed exit stairways.
- The fire department communication device shall be provided at each floor level within the enclosed stairway.

NFPA 72-2007

*Emergency Voice/Alarm Communications (*NFPA 72-2007, Section 6.9*).*

- Speakers and their enclosures shall be installed in accordance with Chapter 7.
- Fire alarm systems used for partial evacuation and relocation shall be designed and installed such that attack by fire within an evacuation signaling zone shall not impair control and operation of the notification appliances outside the evacuation signaling zone.
- All circuits necessary for the operation of the notification appliances shall be protected until they enter the evacuation signaling zone that they serve. Any of the following methods shall be considered acceptable as meeting the requirements of this subsection:
  - A 2-hour fire rated circuit integrity (CI) cable
  - A 2-hour fire rated cable system (electrical circuit protective system)
  - A 2-hour fire rated enclosure
  - Performance alternatives approved by the authority having jurisdiction
  - Buildings fully protected by an automatic sprinkler system installed in accordance with NFPA 13, and with the interconnecting wiring or cables used for the operation of notification appliances installed in metal raceways and in accordance with Article 760 of NFPA 70

*Two-Way Communication Service (*NFPA 72-2007, Section 6.10*).*

- Two-way telephone communications equipment shall be listed for two-way telephone communications service and installed in accordance with Section 6.10.1.
- Two-way telephone communications service, if provided, shall be for use by the fire service and collocated with the emergency voice alarm communications equipment.
- In buildings equipped with a fire pump(s), a telephone station or jack shall be provided in each fire pump room.
- If telephone jacks are provided, two or more portable handsets, as determined by the authority having jurisdiction, shall be stored at each control center for use by emergency responders.
- All circuits necessary for the operation of two-way telephone communication systems shall be installed using one of the following methods:
  - A 2-hour fire rated circuit integrity (CI) cable
  - A 2-hour fire rated cable system (electrical circuit protective system)
  - A 2-hour fire rated enclosure
  - Performance alternatives approved by the authority having jurisdiction
  - Buildings fully protected by an automatic sprinkler system installed in accordance with NFPA 13, with the wiring or cables installed in metal raceways and in accordance with Article 760 of NFPA 70.

9.5 Main Devices Used in the Fire Alarm of the CSM[43]

Devices	Specifications	Picture
System Devices		
Fire Alarm Control Panel (FACP)	Notifier / Honeywell CAB-4 Series Cabinets: ONYX Series Backboxed with Locking Doors. Fabricated from 16-gauge steel, the cabinet assembly consists of two basic parts: a backbox and a locking door. Complies with seismic requirements of CBC 2007. Located on Level 1 in the Main Electrical Room. UL Listed: S635, FM Approved	
Manual Fire Alarm Boxes		
Manual Fire Alarm Boxes (Manual Pull station)	NBG-12LX Addressable Manual Pull Station by Notifier /Honeywell.	
Automatic smoke detectors		
Duct Smoke Detector	Intelligent Non-relay Photoelectric Duct Smoke Detector. Photoelectric, integrated low-flow technology, air velocity rating from 300 ft/min to 4000 ft/min, operating temperature (-4 to 158) and humidity (0% to 95% non-condensing).	
Beam Detector	Open-area Smoke Imaging Detection (OSID) by Xtralis.	
Smoke Detector	Notifier FAPT-851(A): intelligent, addressable, multi-sensing, low-profile detector. Uses a combination of photoelectric and thermal sensing technologies to increase immunity to false alarms.	
Addressable monitoring modules and water alarm devices details		
Addressable Module	The FCM-1(A) addressable control module provides Notifier intelligent fire alarm control panels a circuit for Notification Appliances (strobes, speakers, etc.). Addressability allows the FCM-1(A) to be activated, either manually or through panel programming, on a select (zone or area of coverage) basis.	
Water flow switch	By others. Image shown is a water flow switch installed in the CSM.	

43 Ref. Deep Blue Integration. 2013; Radle,L., 2013

Devices	Specifications	Picture
Supervisory signal initiating devices		
Valve Tamper Switch	By others. Image shown is a valve tamper switch installed in the CSM.	
Fire pump	By others. Image shown is a supervisory signal initiating device installed in the CSM.	
Smoke Fire Damper position indicator	By others. Image shown is a smoke damper position indicator installed in the CSM. .	
Firefighter smoke control panel	By others. Image shown is the firefighter smoke control panel installed in the CSM.	
	Notification Devices	
Bell	By others. Image shown is a typical fire alarm bell.	
Strobe	SpectrAlert Advance- Indoor Selectable Output Speaker Strobes by Notifier / Honeywell. Designed to reduce ground faults. UL Listed: S4048, FM Approved	
Speaker	SpectrAlert Advance- Indoor Selectable Output Dual Voltage Evacuation Speakers by Notifier / Honeywell. Designed to reduce ground faults. The low total harmonic distortion of the SP speaker offers high fidelity sound output while the SPV speaker offers high volume sound output for use in high ambient noise applications. UL Listed: S4048 FM Approved	
Remote Annunciator	FTM-1(A) Firephone Control Module FlashScan Mode Only. The FTM-1(A) gives the FACP the capability to monitor and control a circuit of up to two firefighter phones. The FTM-1(A) has the ability to differentiate between normal, off-hook, and trouble conditions. This module is used to connect a remote firefighter telephone to a centralized telephone console. UL Listed: S635, FM Approved	

9.6 Configuration options and field of view for OSID

Table 43 shows the configuration options, available field of view and detection ranges for OSID.

Table 43- OSID Available Fields of View and Detection Ranges

Imager Lens Type	Usable Field of View		Detection Range				Max. Number of Emitters
	Horizontal	Vertical	Standard Power		High Power		
			Min	Max	Min	Max	
10°	7°	4°	30 m (98 ft)	150 m (492 ft)	- -	- -	1
45°	38°	19°	15 m (49 ft)	60 m (197 ft)	30 m (98 ft)	120 m (393 ft)	7
90°	80°	48°	6 m (20 ft)	34 m (111 ft) (see note 4)	12 m (39 ft)	68 m (223 ft) (see note 4)	7

Ref. Xtralis,2011

Figure 43, Figure 44 and Figure 45 show the alignment guidelines for a 90 Imager with multiple Emitters. This configuration is similar to the expected use in atrium space, Level 3 of the CSM building.

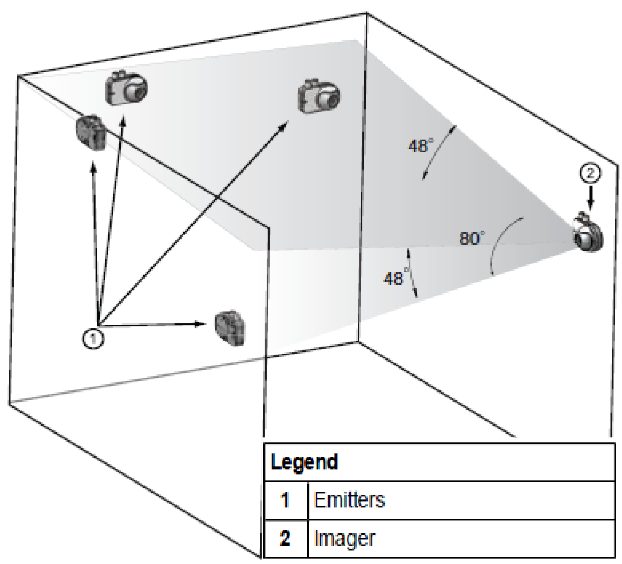


Figure 43 – Alignment guidelines for the 90° Imager to Emitter

Ref. Xtralis,2011

Imager	Maximum Angular Offset from center Field of View	Maximum Range
90°	5°	34 m (111 ft.)
	10°	33 m (108 ft.)
	20°	32 m (105 ft.)
	30°	30 m (98 ft.)
	40°	27 m (89 ft.)

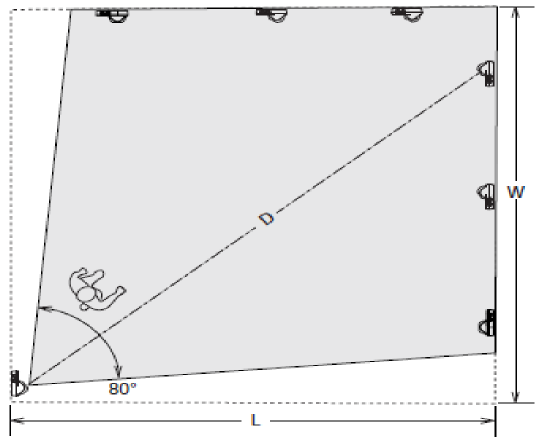


Figure 44 – Alignment guidelines for the 90° Imager to Emitter[44] - Horizontal Plane[45]

Ref. Xtralis,2011

Distance between Imager and Emitter (D) (m)	FOV height (W) (m)
Standard Power Emitter	
10 m (32.8 ft)	8.9 m (29.4 ft)
20 m (65.6 ft)	17.8 m (58.4 ft)
30 m (98.4 ft)	26.7 m (87.5 ft)
34 m (111.5 ft)	30.2 m (99.0 ft)
High Power Emitter	
40 m (131.1 ft)	35.6 m (116.7 ft)
50 m (163.9 ft)	44.5 m (145.9 ft)
60 m (196.7 ft)	53.4 m (175.1 ft)

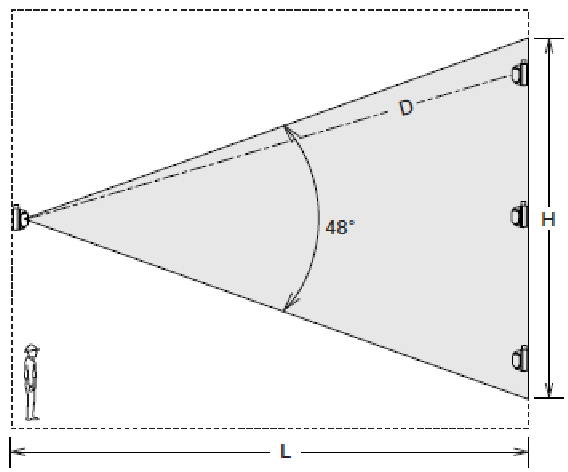


Figure 45 – Alignment guidelines for the 90° Imager to Emitter[46] - Vertical Plane[47]

Ref. Xtralis,2011

44 Field of View (FOV) : 80°

45 Horizontal Plane Measurements: The 90 Imager will suit all rectangular room configurations as long as the maximum distance specified between the emitter and imager (D) is not exceeded. Path lengths (D) which are greater than the ranges in the table below require High Powered Emitters.

46 Field of View (FOV) : 80°

47 Vertical Plane Measurements: The FOV heights listed on the table below are calculated using the following equation: H = D x 0.890

9.7 Commissioning and ITM of Alarm Systems

To ensure operational integrity, the fire alarm system must have an inspection, testing, and maintenance (ITM) program. Inspection, testing, and maintenance programs must satisfy the requirements of the Code, must conform to the equipment manufacturer's published instructions, and must verify correct operation of the fire alarm system (NFPA 72-2007, Section 10.2.1.1).

In this Appendix are summarized the most important aspect related to the Commissioning and Inspection, Testing and Maintenance (ITM) of alarm systems according to NFPA 72-2007, Section 10.2.

General

- The building owner is responsible for inspection, testing, and maintenance of the system and for alterations or additions to the system. If a defect or malfunction is not corrected at the conclusion of system inspection, testing, or maintenance, the system owner must be informed of the impairment in writing within 24 hours.
- Before proceeding with any testing, and at the conclusion of testing, all persons and facilities receiving alarm, supervisory, or trouble signals and all building occupants must be notified of the testing to prevent unnecessary response.

Personnel:

- Service personnel must be qualified and experienced in the inspection, testing, and maintenance of fire alarm systems. Qualified personnel include but are not limited to one or more of the following:
- Personnel who are factory trained and certified for fire alarm system service of the specific type and brand of system.
- Personnel who are certified by a nationally recognized fire alarm certification organization acceptable to the AHJ.
- Personnel who are registered, licensed, or certified by a state or local authority
- Personnel who are employed and qualified by an organization listed by a nationally recognized testing laboratory for the servicing of fire alarm systems

Test Methods:

Fire alarm and voice communication system components must be visually inspected on a semiannual basis and tested on an annual basis to comply with NFPA 72. The FACP and RNPS can be visually inspected on an annual basis. Test methods for each component are summarized below:

- Control Equipment (FACP and RNPS): At a minimum, control equipment must be tested to verify correct receipt of alarm, supervisory, and trouble signals (inputs), operation of evacuation signals and auxiliary functions (outputs), circuit supervision including detection of open circuits and ground faults, and power supply supervision for detection of loss of AC power and disconnection of secondary batteries.
- Manual Pull Station: Manual pull stations (fire alarm boxes) must be tested per the manufacturer’s published instructions.
- Remote Annunciators: Verify the correct operation and identification of annunciators.
- Electromechanical Releasing Device: Verify correct operation by removing the fusible link and associated operating device. Lubricate any moving parts as necessary.
- Smoke Detectors: Test the detector in place to ensure smoke entry into the sensing chamber initiates an alarm response. Testing with smoke or listed aerosol approved by the manufacturer is permitted as acceptable test methods. At least one of the following tests must be performed to ensure that each smoke detector is within its listed and marked sensitivity range:
  - Calibrated test method.
  - Manufacturer’s calibrated sensitivity test instrument.
  - Smoke detector/control unit arrangement whereby the detector causes a signal at the control unit when its sensitivity is outside its listed sensitivity range.
  - Other calibrated sensitivity test method approved by the AHJ.
- Duct Smoke Detectors: Test air duct detectors to ensure that the device will sample the airstream. Test in accordance with the manufacturer’s published instructions.
- Audible Alarm Notification Appliances : Measure sound pressure level with a sound level meter meeting ANSI S1.4a, Specifications for Sound Level Meters, Type 2 requirements. Measure and record levels throughout the protected area. Set the sound level meter in accordance with ANSI S3.41, American National Standard Audible Evacuation Signal, using the time-weighted characteristic F (FAST). Record
- Visual Alarm Notification Appliances: Test strobes in accordance with the manufacturer’s published instructions. Verify appliance locations per approved layout and confirm that no floor plan changes affect the approved layout. Verify the candela rating marking agrees with the approved drawing. Confirm that each strobe flashes.
- Digital Alarm Communicator Transmitter: Ensure the UDACT is connected to two separate means of transmission. Test UDACT for line seizure capability by initiating a signal while using the primary line for a telephone call. Verify receipt of the correct signal at the supervising station. Verify completion of the transmission attempt within 90 seconds from going off-hook to on-hook. Disconnect the primary line from the UDACT and verify that a trouble signal occurs at the premises as well as transmission to the supervising station within 4 minutes of detection of the fault. Disconnect the secondary line from the UDACT and verify that a trouble signal occurs at the premises as well as

transmission to the supervising station within 4 minutes of detection of the fault. Verify that the UDACT transmits a signal to the digital alarm communicator receiver (DACR).

- Emergency Communications Equipment: Visually inspect phone jack and initiate communication path through jack.
- Interface Equipment: Test interface equipment by operating or simulating the equipment being supervised. Verify the required signal is transmitted at the control unit. Interface equipment shall be tested at the same frequency required by the equipment being supervised.
- Beam Smoke Detector: Test beam type smoke detector by introducing smoke, other aerosol, or an optical filter into the beam path. Note: There are currently no beam smoke detectors in the design of the fire alarm and voice evacuation system. Beam smoke detector testing method has been included in the event that the fire alarm system design changes to incorporate beam type smoke detection.

Maintenance:

- Fire alarm system equipment must be maintained in accordance with the manufacturer's published instructions. Maintenance frequency depends on the type of equipment and the local ambient conditions.

Records:

- Upon successful completion of acceptance tests approved by the AHJ a set of reproducible as-built installation drawings, operation and maintenance manuals, and a written sequence of operation must be provided to the building owner (CPSU) or the owner's designated representative. The owner is responsible for maintaining these records for the life of the system for examination by any AHJ.
- Maintenance, Inspection, and Testing Records must be retained until the next test and for 1 year thereafter. The records must be on a medium that will survive the retention period, (paper or electronic copy).
- Records pertaining to signals received at the supervising station that results from maintenance, inspection, and testing must be maintained for at least 12 months. Upon request, a hard copy record must be provided to the AHJ, (paper or electronic version).

9.8 Sprinkler System Installation Details

As explained in 4.4.3, the automatic sprinkler system of the building is supplied with water from a Public Water Main, which according to the flow test, can provide a static pressure of 54 psi and a flow of 914 GPM at a residual pressure of 49 psi.

The pressure available from the Public Water Main was not enough to satisfy the requirements of the sprinkler and standpipe system of the building, therefore a pump has to be installed for supplementing the existing pressure deficit. This pump was installed in a Fire Pump Room inside the building (Figure 46).

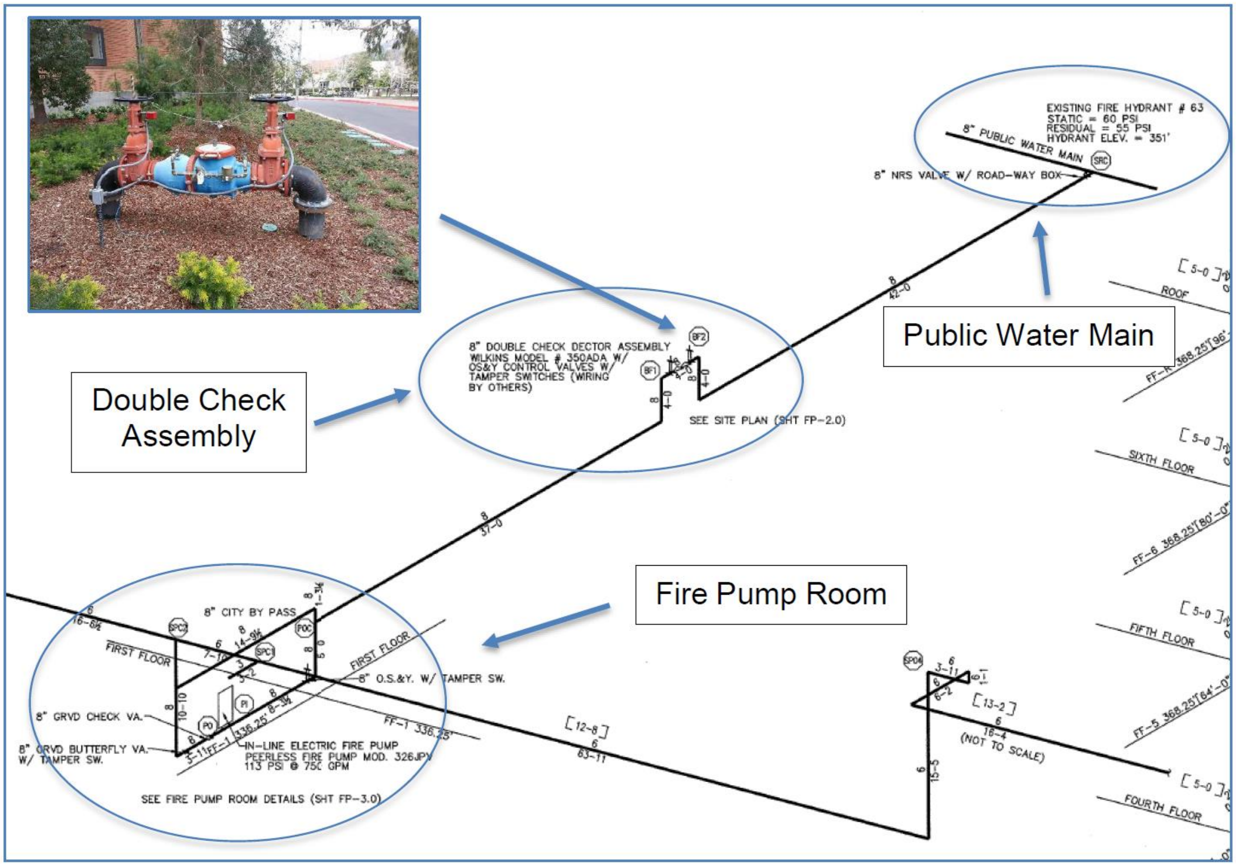


Figure 46 – Isometric view of the fire pump connection from the Public Main

As shown in Figure 46, between the Public Water Main and the Fire Pump Room there is a Double Check Assembly, which constitutes a Cross-Connection between the Public and Private supply. This is intended to protect the public water supply from potential contamination.

The setup of the Fire Pump is detailed in Figure 47, where it is shown the Point of Connection (POC), the Vertical Inline Fire Pump, the Jockey Pump, the City Bypass connection, and the Test Header. It is also indicated the size and elevation of pipes and equipment and the Fire Pump settings.

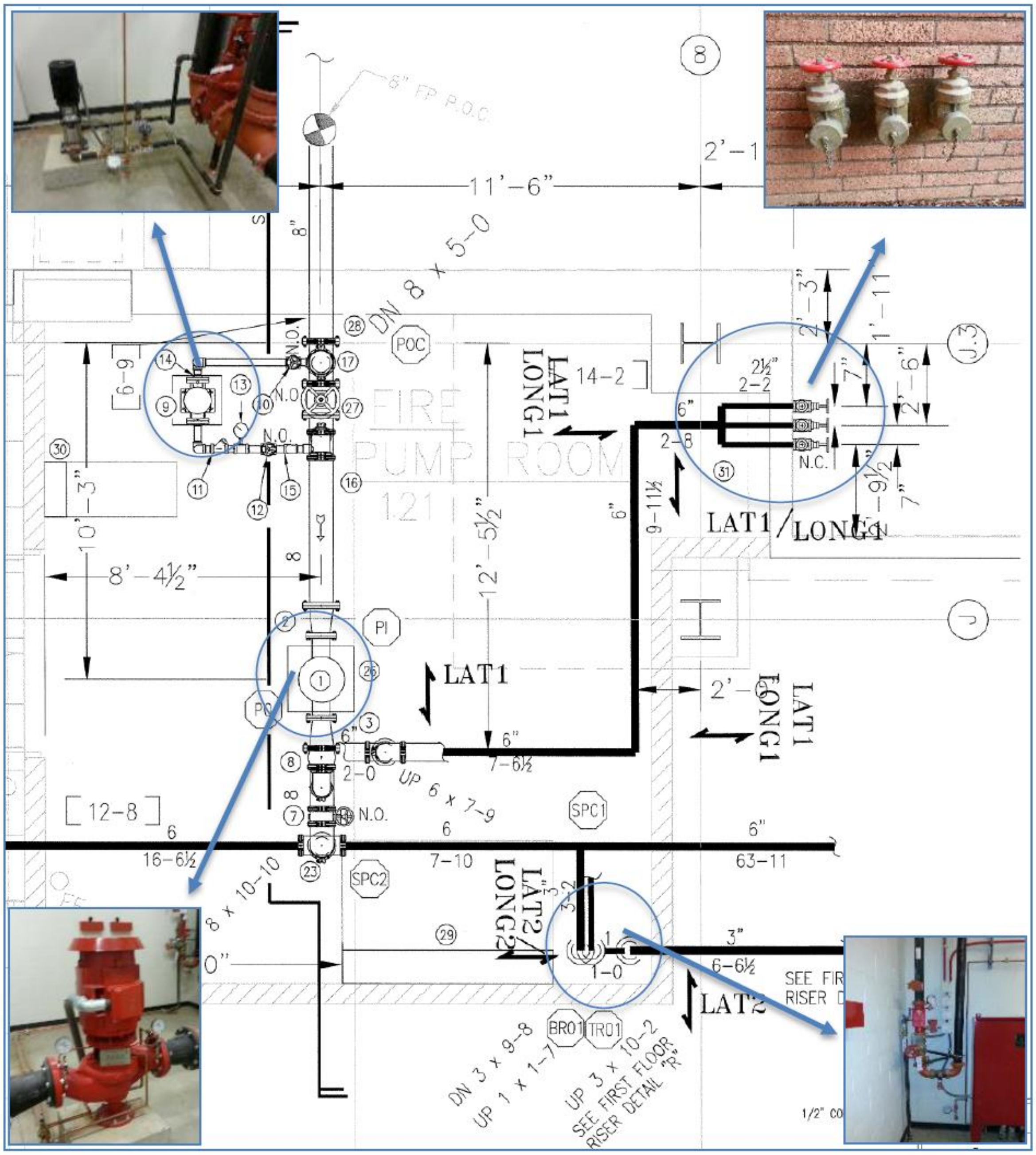


Figure 47 – Schematic Top View of the equipment in the Fire Pump Room

Figure 48 show some views of equipment in Fire Pump Room

Figure 48 – Equipment in the Fire Pump Room

From the Fire Pump Room the water is fed to the standpipes and the risers for the sprinkler systems. The riser for the sprinkler system in the first floor is located just inside Fire Pump Room (Figure 49) and the risers for sprinklers protecting from second to sixth floor come from the Standpipe situated at Stair 3 (Figure 50).

The cross-mains are 2 ½” to 3” Schedule 10 pipe and the branch lines are 1” to 1 ¼” Schedule 10 pipes, varying depending on area of protection and distance from cross-main.

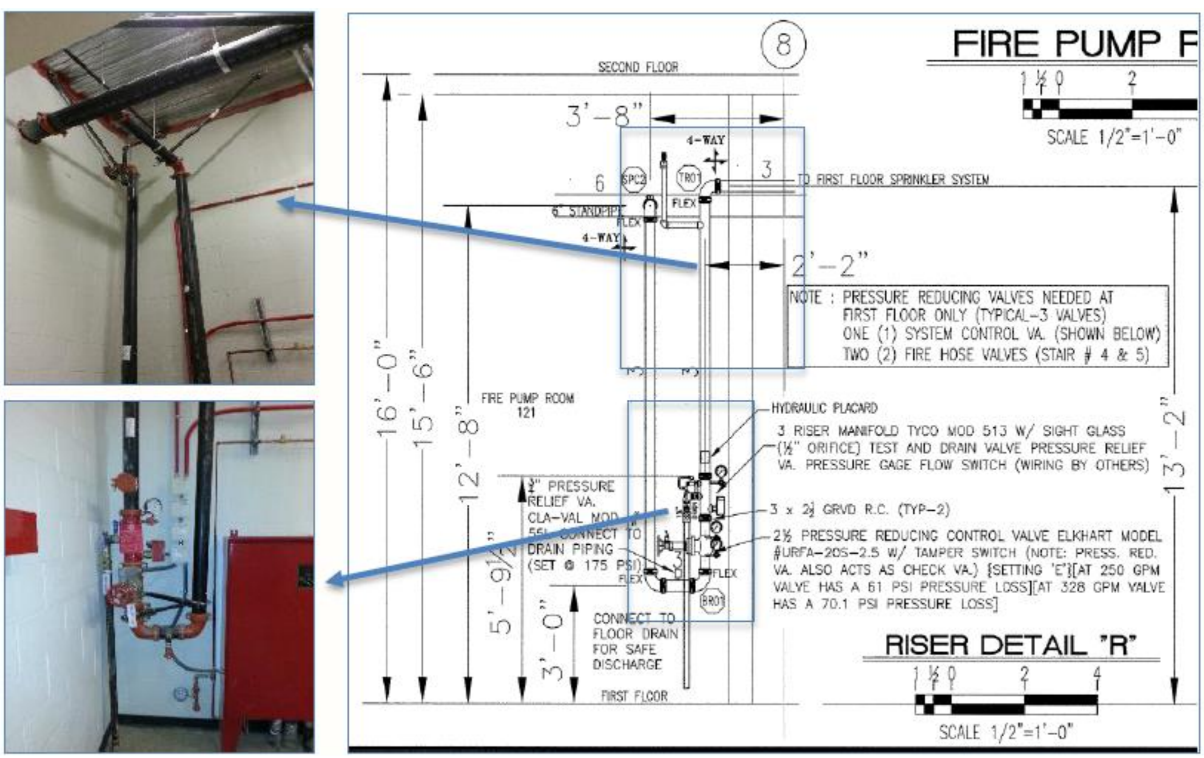


Figure 49 – Schematic Side View of the sprinkler riser in Pump Room

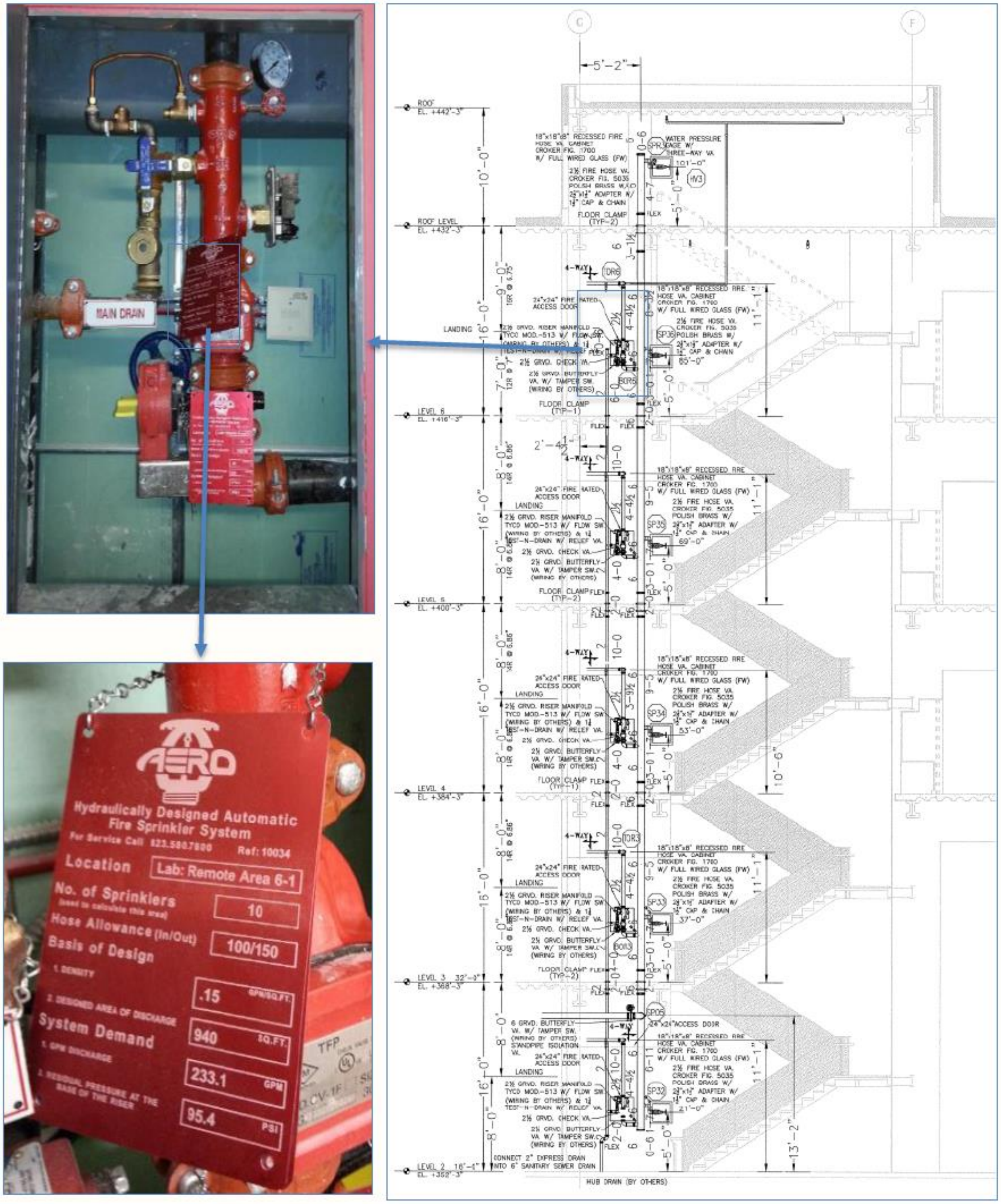


Figure 50 – Schematic side view of the risers from second to sixth floor

System Installation General Notes[48]

- All system piping must be hydrostatically tested at 200 psi or at 50 psi above the operational static pressure of the system, whichever is greater for two hours.
- Each valve must have a permanently affixed sign indicating its function and all sprinkler system control valve handles must be located 7'-0" max A.F.F.
- A stock of spare sprinklers of each style and temperature rating, with a sprinkler wrench, must be located near the riser.
- Sprinklers must be quick response with chrome-recessed escutcheons U.O.N and must be in alignment and parallel to ceiling grids.
- Sprinklers in unfinished areas must be TYCO Model TY-FRB quick response brass upright.
- Main piping for this system must be schedule 10 pipe with grooved ends with applicable fittings.
- Branch line connections to the main must be pre-drilled with shop-welded outlets.
- Threaded piping 1" to 2" must be black steel BMT schedule 40 with black cast iron or ductile iron fittings.
- 1-1/4" and larger branch line and main piping must be schedule 10 pipe with grooved ends and grooved fittings.
- All materials used in the installation of these systems must be new and of current issue and approved by UL and/or FM.
- All materials must be in conformance with NFPA 13, 2007 as well as the AHJ.
- System piping will be supported with hangers in accordance with NFPA 13, 2007.
- Spacing of the support and bracings of fire sprinkler piping must comply with NFPA 13, 2007.

48 Ref. NFPA 13-2007, Radle L. 2013.

9.9 Wet Pipe Fire Sprinkler System – Calculation Design Summary[49]

CALCULATION DESIGN INFORMATION

AREA: "1–1"
OCCUPANCY: LECTURE
HAZARD: LIGHT HAZARD
DENSITY: 0.10 GPM / SQ.FT.
AREA OF OPERATION: 1520 SQ. FT.
AREA PER HEAD: 168 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE:

SYSTEM DEMAND

PSI REQ. AT BASE OF RISER:	126.6
GPM REQ. AT BASE OF RISER:	250.6
PSI REQ. AT SOURCE:	7.27
GPM REQ. AT SOURCE:	350.6
PSI AVAILABLE AT SOURCE:	53.15
TOTAL PSI SAFETY FACTOR:	45.88

CALCULATION DESIGN INFORMATION

AREA: "1–2"
OCCUPANCY: LECTURE
HAZARD: LIGHT HAZARD
DENSITY: 0.10 GPM / SQ.FT.
AREA OF OPERATION: 1575 SQ. FT.
AREA PER HEAD: 163 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE:

SYSTEM DEMAND

PSI REQ. AT BASE OF RISER:	162.2
GPM REQ. AT BASE OF RISER:	328.4
PSI REQ. AT SOURCE:	45.59
GPM REQ. AT SOURCE:	428.4
PSI AVAILABLE AT SOURCE:	52.76
TOTAL PSI SAFETY FACTOR:	7.17

Calculation Design Information Level 1: Areas 1 and 2 (Sprinkler System).

CALCULATION DESIGN INFORMATION

AREA: "3–1"
OCCUPANCY: LAB
HAZARD: ORDINARY HAZARD GR. 1
DENSITY: 0.15 GPM / SQ.FT.
AREA OF OPERATION: 967 SQ.FT.
AREA PER HEAD: 130 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE: 150

SYSTEM DEMAND

PSI REQ. AT BASE OF RISER:	102.61
GPM REQ. AT BASE OF RISER:	252.75
PSI REQ. AT SOURCE:	−0.88
GPM REQ. AT SOURCE:	502.75
PSI AVAILABLE AT SOURCE:	52.35
TOTAL PSI SAFETY FACTOR:	53.23

EMOTE AREA REDUCED BY 39.25% (CH=10'-6
[912 SQ.FT. MIN.]

CALCULATION DESIGN INFORMATION

AREA: "3–2"
OCCUPANCY: LAB
HAZARD: ORDINARY HAZARD GR. 1
DENSITY: 0.15 GPM / SQ.FT.
AREA OF OPERATION: 1135 SQ.FT.
AREA PER HEAD: 130 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE: 150

SYSTEM DEMAND

PSI REQ. AT BASE OF RISER:	107.33
GPM REQ. AT BASE OF RISER:	233.54
PSI REQ. AT SOURCE:	3.22
GPM REQ. AT SOURCE:	483.54
PSI AVAILABLE AT SOURCE:	52.45
TOTAL PSI SAFETY FACTOR:	49.23

EMOTE AREA REDUCED BY 39.25% (CH=10'-6
[912 SQ.FT. MIN.]

Calculation Design Information Level 3: Areas 1 and 2 (Sprinkler System)

49 Ref. Aero Automatic Sprinkler Co. 2011-SD

CALCULATION DESIGN INFORMATION

AREA:	"6–2"
OCCUPANCY:	CORRIDOR
HAZARD:	LIGHT HAZARD
DENSITY:	0.10 GPM / SQ.FT.
AREA OF OPERATION:	5 HEADS CORR.
AREA PER HEAD:	225 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE: INSIDE:	100
OUTSIDE:	

SYSTEM DEMAND

PSI REQ. AT BASE OF RISER:	34.5
GPM REQ. AT BASE OF RISER:	113.1
PSI REQ. AT SOURCE:	–51.52
GPM REQ. AT SOURCE:	213.09
PSI AVAILABLE AT SOURCE:	53.58
TOTAL PSI SAFETY FACTOR:	105.1

CALCULATION DESIGN INFORMATION

AREA:	"6–4"
OCCUPANCY:	OFFICE / LOBBY
HAZARD:	LIGHT HAZARD
DENSITY:	0.10 GPM / SQ.FT.
AREA OF OPERATION:	1567 SQ. FT.
AREA PER HEAD:	210 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE: INSIDE:	100
OUTSIDE:	

SYSTEM DEMAND

PSI REQ. AT BASE OF RISER:	116.86
GPM REQ. AT BASE OF RISER:	347.3
PSI REQ. AT SOURCE:	39.09
GPM REQ. AT SOURCE:	447.3
PSI AVAILABLE AT SOURCE:	52.66
TOTAL PSI SAFETY FACTOR:	13.57

CALCULATION DESIGN INFORMATION

AREA:	"6–1"
OCCUPANCY:	LAB
HAZARD:	ORDINARY HAZARD GR. 1
DENSITY:	0.15 GPM / SQ.FT.
AREA OF OPERATION:	940 SQ.FT.
AREA PER HEAD:	130 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE: INSIDE:	100
OUTSIDE:	150

SYSTEM DEMAND

PSI REQ. AT BASE OF RISER:	95.47
GPM REQ. AT BASE OF RISER:	233.15
PSI REQ. AT SOURCE:	12.35
GPM REQ. AT SOURCE:	483.15
PSI AVAILABLE AT SOURCE:	53.35
TOTAL PSI SAFETY FACTOR:	40.1

REMOTE AREA REDUCED BY 39.25% (CH=10'-6")
[912 SQ.FT. MIN.]

CALCULATION DESIGN INFORMATION

AREA:	"6–3"
OCCUPANCY:	LAB
HAZARD:	ORDINARY HAZARD GR. 1
DENSITY:	0.15 GPM / SQ.FT.
AREA OF OPERATION:	920 SQ.FT.
AREA PER HEAD:	130 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE: INSIDE:	100
OUTSIDE:	150

SYSTEM DEMAND

PSI REQ. AT BASE OF RISER:	108.4
GPM REQ. AT BASE OF RISER:	273.4
PSI REQ. AT SOURCE:	26.71
GPM REQ. AT SOURCE:	523.4
PSI AVAILABLE AT SOURCE:	52.11
TOTAL PSI SAFETY FACTOR:	25.4

REMOTE AREA REDUCED BY 39.25% (CH=10'-6")
–7½" 11'–8" 9'–10"
[912 SQ.FT. MIN.]

Calculation Design Information Level 6: Areas 1- 4 (Sprinkler System)

CALCULATION DESIGN INFORMATION

STANDPIPE NO.: S/P # 1
OCCUPANCY: LIGHT / ORD. HAZ. DR. 1
FLOW @ TOP MOST OUTLET: 500 GPM
PRESS. @ TOP MOST OUTLET: 100 PSI
FLOW FOR ADDITIONAL S/P: 250 GPM
TOTAL STANDPIPE FLOW: 750 GPM
HOSE STREAM ALLOWANCE:
INSIDE: N/A OUTSIDE: N/A

SYSTEM DEMAND

PSI REQ. AT PUMP DISCHARGE: 156.36
GPM REQ. AT PUMP DISCHARGE: 1000
PSI REQ. AT SOURCE: 44.73
GPM REQ. AT SOURCE: 750
PSI AVAILABLE AT SOURCE: 50.52
TOTAL PSI SAFETY FACTOR: 5.79

CALCULATION DESIGN INFORMATION

STANDPIPE NO.: S/P # 1
OCCUPANCY: LIGHT / ORD. HAZ. DR. 1
FLOW @ TOP MOST OUTLET: 500 GPM
PRESS. @ TOP MOST OUTLET: 100 PSI
FLOW FOR ADDITIONAL S/P: 500 GPM
TOTAL STANDPIPE FLOW: 1000 GPM
HOSE STREAM ALLOWANCE:
INSIDE: N/A OUTSIDE: N/A

SYSTEM DEMAND

PSI REQ. AT PUMP DISCHARGE: 144.08
GPM REQ. AT PUMP DISCHARGE: 1000
PSI REQ. AT SOURCE: 47.18
GPM REQ. AT SOURCE: 1000
PSI AVAILABLE AT SOURCE: 48.09
TOTAL PSI SAFETY FACTOR: 0.91

CALCULATION DESIGN INFORMATION

STANDPIPE NO.: S/P # 5
OCCUPANCY: LIGHT / ORD. HAZ. DR. 1
FLOW @ TOP MOST OUTLET: 500 GPM
PRESS. @ TOP MOST OUTLET: 100 PSI
FLOW FOR ADDITIONAL S/P: 500 GPM
TOTAL STANDPIPE FLOW: 1000 GPM
HOSE STREAM ALLOWANCE:
INSIDE: N/A OUTSIDE: N/A

SYSTEM DEMAND

PSI REQ. AT PUMP DISCHARGE: 143.7
GPM REQ. AT PUMP DISCHARGE: 1000
PSI REQ. AT SOURCE: 46.80
GPM REQ. AT SOURCE: 1000
PSI AVAILABLE AT SOURCE: 48.08
TOTAL PSI SAFETY FACTOR: 1.28

CALCULATION DESIGN INFORMATION

STANDPIPE NO.: S/P # 4
OCCUPANCY: LIGHT / ORD. HAZ. DR. 1
FLOW @ TOP MOST OUTLET: 500 GPM
PRESS. @ TOP MOST OUTLET: 100 PSI
FLOW FOR ADDITIONAL S/P: 500 GPM
TOTAL STANDPIPE FLOW: 1000 GPM
HOSE STREAM ALLOWANCE:
INSIDE: N/A OUTSIDE: N/A

SYSTEM DEMAND

PSI REQ. AT PUMP DISCHARGE: 144.08
GPM REQ. AT PUMP DISCHARGE: 1000
PSI REQ. AT SOURCE: 45.85
GPM REQ. AT SOURCE: 1000
PSI AVAILABLE AT SOURCE: 48.09
TOTAL PSI SAFETY FACTOR: 2.24

Calculation Design Information Standpipe 1- 4 (Sprinkler System)

9.10 Sprinkler Hand Calculations for Remote Area 1-1

The Remote Area, Branch Lines , Cross Mains , Feed Mains and some of the nodes used for hydraulic calculations evaluation are detailed from Figure 51 and Figure 52.

Figure 51 – Remote Area evaluated through hand calculations

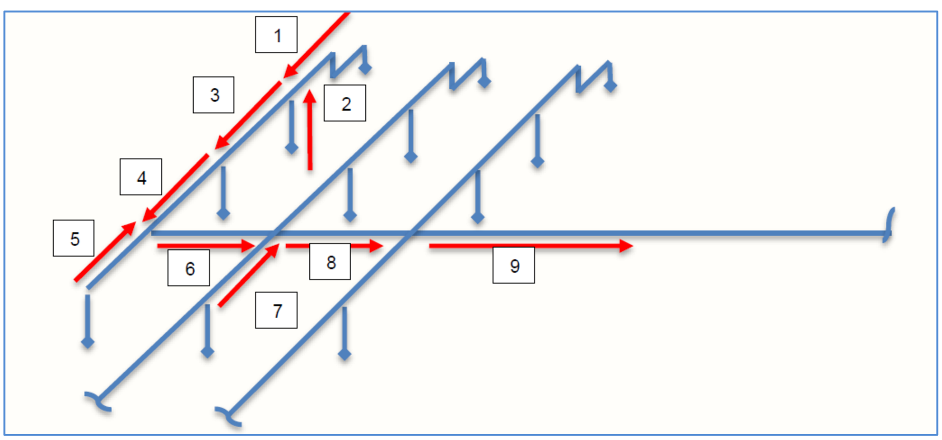


Figure 52 –Steps for hand calculations

Table 44-Hand Calculation Results

Step No.	Nozzle Ident and Location		Flow in gpm	Pipe size	Pipe Fittings and Devices		Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary (psi)		Normal Pressure	D (gpm/ft² Fig. 11.2.3.1.1) =	0.1
Project name: Building 180 Level 1: Area 1:			Light Hazard								Date:3/20/2014			A =	168
		q		1" (Sched 40)=		L	14.41	C=	120	Pt	9.0	Pt		K=	5.6
1	**BL-1 - Sp1**			**1.049**	**3 Elbow (3*2)**	F	**6**			Pe	**-1.1556**	Pv		Pt (psi) = (Q/K)² =	9.0
		Q	16.8			T	20.41	pf	0.094	Pf	1.9	Pn		Q(gpm)=D*A =	16.8
											9.77				
		q		1" (Sched 40)=		L =	2.66	C=	120	Pt	9.0	Pt		K=	5.6
2	**BL-1 - Sp2**			**1.049**	**1 Tee (5*1)**	F	**5**			Pe	**-1.1556**	Pv		Pt (psi) = (Q/K)² =	9.0
		Q	16.800			T	7.66	pf	0.094	Pf	0.7	Pn		Q(gpm)=D*A =	16.8
											8.6			K= q/(Pt)0.5=	5.7
	BL-1 - Sp2 Balanced		17.940	17.81											
	BL-1 - (Sp1 and Sp2) Balanced		34.7	33.61											
		q		1" (Sched 40)=		L =	12	C=	120	Pt	9.8	Pt			
3	**BL-1 - Step3**			**1.049**		F	0			Pe	0	Pv			
		Q	34.7			T	12	pf	0.361	Pf	4.3	Pn			
											14.11				
		q	21.6	1" (Sched 40)=		L =	8.54	C=	120	Pt	14.1	Pt			
4	**BL-1 - North Step4**			**1.049**	**1 Tee (5*1)**	F	**5**			Pe	0	Pv			
		Q	56.3			T	13.54	pf	0.883	Pf	12.0	Pn			
			54.66								26.1			K (BL-1 North) = q/(Pt)^0.5=	11.03
		q		1" (Sched 40)=		L	6.11	C=	120	Pt	9.0	Pt		K=	5.6
5	**BL-1 - South Step5**			**1.049**	**1 Elbow (1*2) , 1 Tee (1*5)**	F	**7**			Pe	**-1.1556**	Pv		Pt (psi) = (Q/K)² =	9.0
		Q	16.8			T	13.11	pf	0.094	Pf	1.2	Pn		Q(gpm)=D*A =	16.8
											9.1			K (BL-1 South)= q/(Pt)0.5=	5.58
	BL-1 - South Step5 Balanced		28.460	27.03											
	BL-1 - (Step4 North and Step5 South) Balanced		84.8	82.69										K (BL-1) = q/(Pt)^0.5=	16.6
		q		2 1/2" (Sched 10)=		L	14	C=	120	Pt	26.1	Pt			
6	**CM to BL-2**			**2.635**		F	0			Pe	0	Pv			
		Q	84.8			T	14	pf	0.021	Pf	0.3	Pn			
											26.4				
		q		1" (Sched 40)=		L	6.11	C=	120	Pt	9.0	Pt		K=	5.6
7	**BL-2 - South Step7**			**1.049**	**2 Tee (2*5)**	F	**10**			Pe	**-1.1556**	Pv		Pt (psi) = (Q/K)² =	9.0
		Q	16.8			T	16.11	pf	0.094	Pf	1.5	Pn		Q(gpm)=D*A =	16.8
											9.4			K (BL-2 South)= q/(Pt)0.5=	5.49
	BL-2 - South Step7 Balanced		28.187	27.18											
	BL-2 - North Step7 Balanced		56.6	55.97											
		q	84.8	2 1/2" (Sched 10)=		L	14	C=	120	Pt	26.4	Pt			
8	**CM to BL-3**			**2.635**		F	0			Pe	0	Pv			
		Q	169.6			T	14	pf	0.077	Pf	1.1	Pn			
											27.4				
	M103 to M104	q	87.0	2 1/2" (Sched 10)=		L	74.245	C=	120	Pt	27.4	Pt			
9				**2.635**	**Tee (1*12)**	F	**12**			Pe	0.00	Pv			
		Q	256.5			T	86.245	pf	0.165	Pf	14.2	Pn			
			250.6						41.43		41.6				
	M104 to M105	q	0.0	2 1/2" (Sched 10)=		L	43.875	C=	120	Pt	41.6	Pt			
10				**2.635**	**2 Elbow (2*6) , 1 Tee (1*12)**	F	**24.00**			Pe	0	Pv			
		Q	256.5			T	67.9	pf	0.165	Pf	11.2	Pn			
									51.61		52.8				
	M105 to Top Riser (TR01)	q	0.0	3 " (Sched 10) =		L	107.45	C=	120	Pt	52.8	Pt			
11				**3.26**	**4 Elbow (4*7) , 1 Tee (1*15)**	F	**43.00**			Pe	0	Pv			
		Q	256.5			T	150.5	pf	0.058	Pf	8.8	Pn			
									60.32		61.6				
		q	0.0	3 " (Sched 10) =		L	10.16	C=	120	Pt	61.6	Pt			
12	**TR01 to Base Riser (BR01)**			**3.26**	**[illegible] 1 Press. Red Valve (1*61/0.433) , 1 Alarma Valve (1*15)**	F	**22.00**			Pe	4.402328	Pv			
		Q	256.5			T	32.2	pf	0.058	Pf	1.9	Pn		* Fixed loss = 60.9 psi ≈ 61psi	
									126.7		128.7				
		q	0.0	3 " (Sched 10) =		L	13.82	C=	120	Pt	128.7	Pt			
13	**BR01 to Standpipe Conection (SPC1)**			**3.26**	**2 Elbow (2*7), 1 Tee (1*15)**	F	**29.00**			Pe	-4.40233	Pv			
		Q	256.5			T	42.8	pf	0.058	Pf	2.5	Pn			
									125.168		126.8				
		q	100.0	6 " (Sched 40) =		L	7.83	C=	120	Pt	126.8	Pt			
14	**SPC1 to SPC2**			**6.065**	**1 Tee (1*30)**	F	**30.00**			Pe	0	Pv			
		Q	356.5			T	37.8	pf	0.005	Pf	0.2	Pn			
			350.6						125.36		127.0				
		q	0.0	8 " (Sched 40) =		L	14.69	C=	120	Pt	127.0	Pt			
15	**SPC2 to PO**			**7.981**	**1 Elbow (1*18), 1 Butterfly Valve (1*12) , 1 Check Valve (1*15)**	F	**75.00**			Pe	4.688306	Pv			
		Q	356.5			T	89.7	pf	0.001	Pf	0.1	Pn			
					System Demand Pressure				130.164		131.9				

Source: Fire Protection Handbook -2008

9.11 System Demand Curves for Riser and Standpipe System of the Building

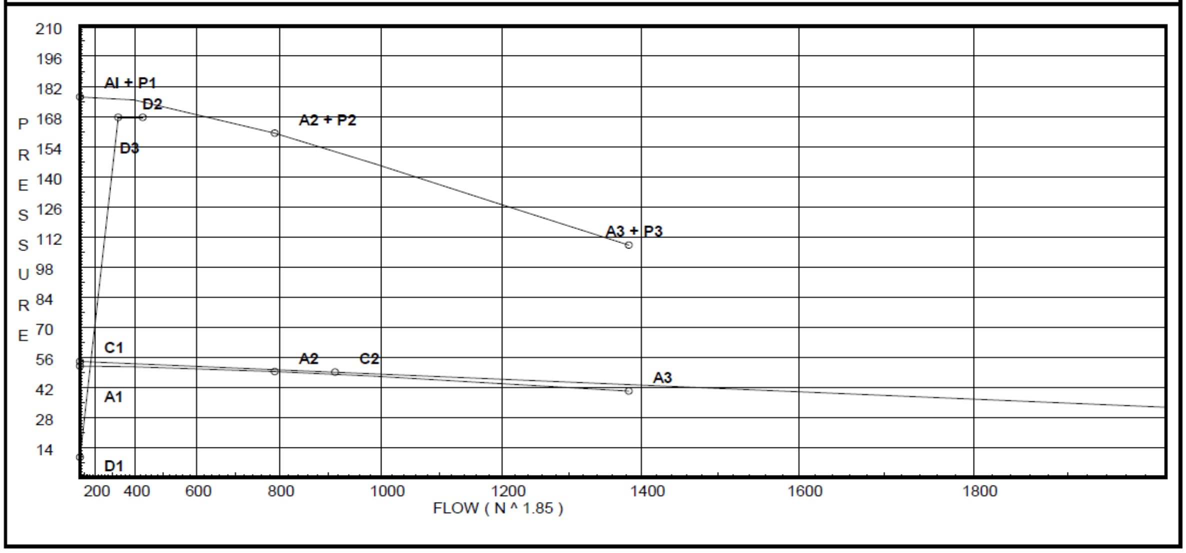
Aero Automatic Sprinkler Co. Page 2
Cal Poly Center for Science LVL 1 [R/A=2] Date 9-25-11

City Water Supply:
C1 - Static Pressure : 54
C2 - Residual Pressure: 49
C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet
for Pf - Elev - Hose Flow
A1 - Adjusted Static: 51.872
A2 - Adj Resid : 49.314 @ 790.2
A3 - Adj Resid : 40.224 @ 1382.9

Pump Data:
P1 - Pump Churn Pressure : 125.2
P2 - Pump Rated Pressure : 110.9
P2 - Pump Rated Flow : 790.2
P3 - Pump Pressure @ Max Flow : 67.9
P3 - Pump Max Flow : 1382.9
City Residual Flow @ 0 = 3307.91
City Residual Flow @ 20 = 2576.03
City Water @ 150% of Pump = 43.24

Demand:
D1 - Elevation : 9.420
D2 - System Flow : 328.401
D2 - System Pressure : 167.582
Hose (Adj City) : ______
Hose (Demand) : 100
D3 - System Demand : 428.401
Safety Margin : 7.179



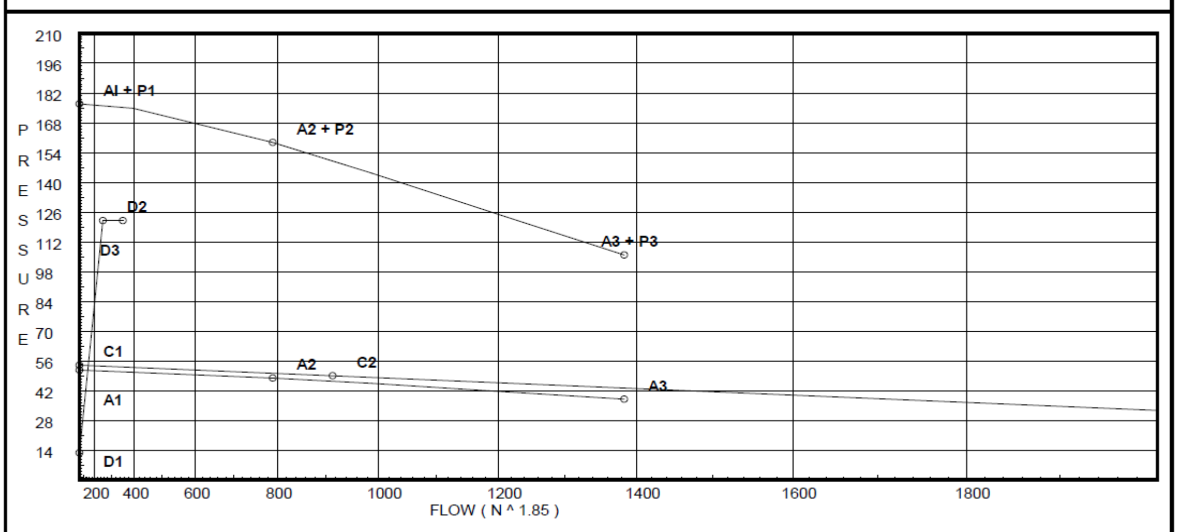
Aero Automatic Sprinkler Co. Page 2
Cal Poly Center for Science LVL 3 [R/A=1] Date 9-25-11

City Water Supply:
C1 - Static Pressure : 54
C2 - Residual Pressure: 49
C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet
for Pf - Elev - Hose Flow
A1 - Adjusted Static: 51.696
A2 - Adj Resid : 47.866 @ 790.2
A3 - Adj Resid : 37.967 @ 1382.9

Pump Data:
P1 - Pump Churn Pressure : 125.2
P2 - Pump Rated Pressure : 110.9
P2 - Pump Rated Flow : 790.2
P3 - Pump Pressure @ Max Flow : 67.9
P3 - Pump Max Flow : 1382.9
City Residual Flow @ 0 = 3307.91
City Residual Flow @ 20 = 2576.03
City Water @ 150% of Pump = 43.24

Demand:
D1 - Elevation : 12.776
D2 - System Flow : 252.757
D2 - System Pressure : 121.999
Hose (Adj City) : 150
Hose (Demand) : 100
D3 - System Demand : 352.757
Safety Margin : 53.231



Aero Automatic Sprinkler Co.
Cal Poly Center for Science LVL 3 [R/A=2]

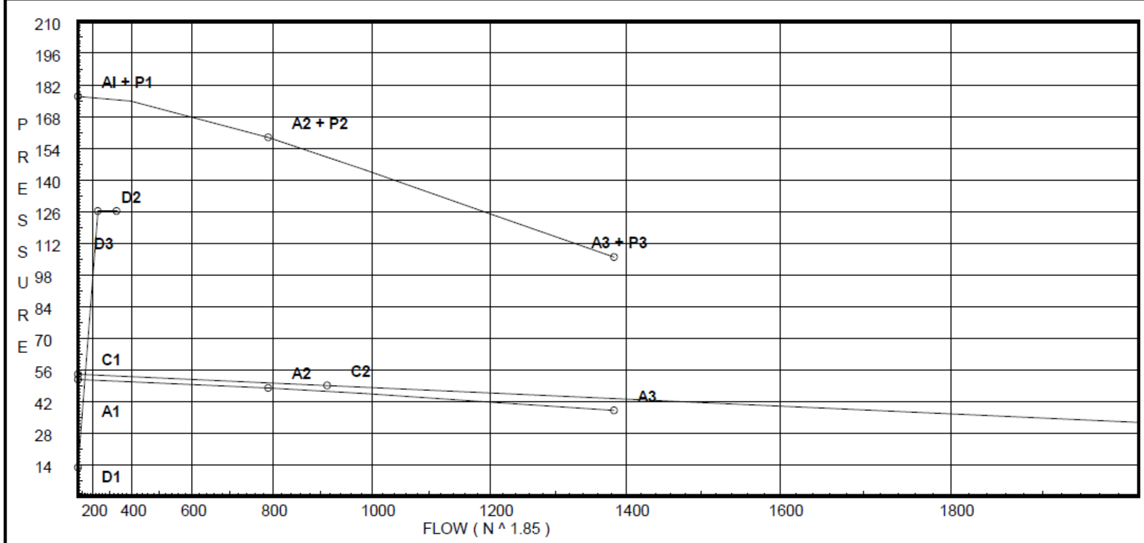
Page 2
Date 9-25-11

City Water Supply:
- C1 - Static Pressure : 54
- C2 - Residual Pressure: 49
- C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet for Pf - Elev - Hose Flow
- A1 - Adjusted Static: 51.696
- A2 - Adj Resid : 47.866 @ 790.2
- A3 - Adj Resid : 37.967 @ 1382.9

Pump Data:
- P1 - Pump Churn Pressure : 125.2
- P2 - Pump Rated Pressure : 110.9
- P2 - Pump Rated Flow : 790.2
- P3 - Pump Pressure @ Max Flow : 67.9
- P3 - Pump Max Flow : 1382.9
  - City Residual Flow @ 0 = 3307.91
  - City Residual Flow @ 20 = 2576.03
  - City Water @ 150% of Pump = 43.24

Demand:
- D1 - Elevation : 12.776
- D2 - System Flow : 233.543
- D2 - System Pressure : 126.159
- Hose (Adj City) : 150
- Hose (Demand) : 100
- D3 - System Demand : 333.543
- Safety Margin : 49.232



Aero Automatic Sprinkler Co.
Cal Poly Center for Science LVL 6 [R/A=1]

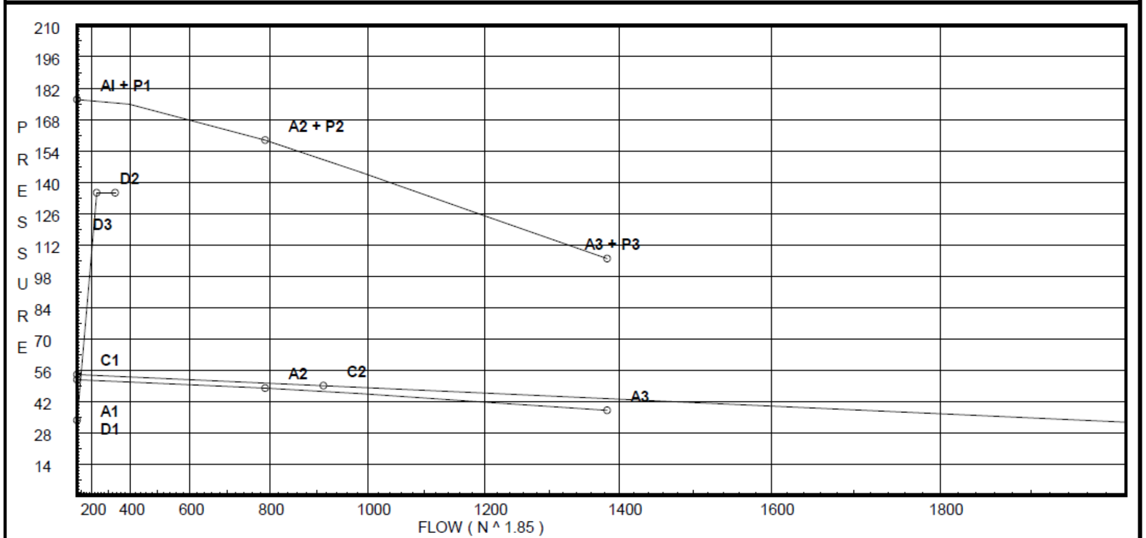
Page 2
Date 9-25-11

City Water Supply:
- C1 - Static Pressure : 54
- C2 - Residual Pressure: 49
- C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet for Pf - Elev - Hose Flow
- A1 - Adjusted Static: 51.696
- A2 - Adj Resid : 47.866 @ 790.2
- A3 - Adj Resid : 37.967 @ 1382.9

Pump Data:
- P1 - Pump Churn Pressure : 125.2
- P2 - Pump Rated Pressure : 110.9
- P2 - Pump Rated Flow : 790.2
- P3 - Pump Pressure @ Max Flow : 67.9
- P3 - Pump Max Flow : 1382.9
  - City Residual Flow @ 0 = 3307.91
  - City Residual Flow @ 20 = 2576.03
  - City Water @ 150% of Pump = 43.24

Demand:
- D1 - Elevation : 33.565
- D2 - System Flow : 233.159
- D2 - System Pressure : 135.285
- Hose (Adj City) : 150
- Hose (Demand) : 100
- D3 - System Demand : 333.159
- Safety Margin : 40.106



Aero Automatic Sprinkler Co.
Cal Poly Center for Science LVL 6 [R/A=2]

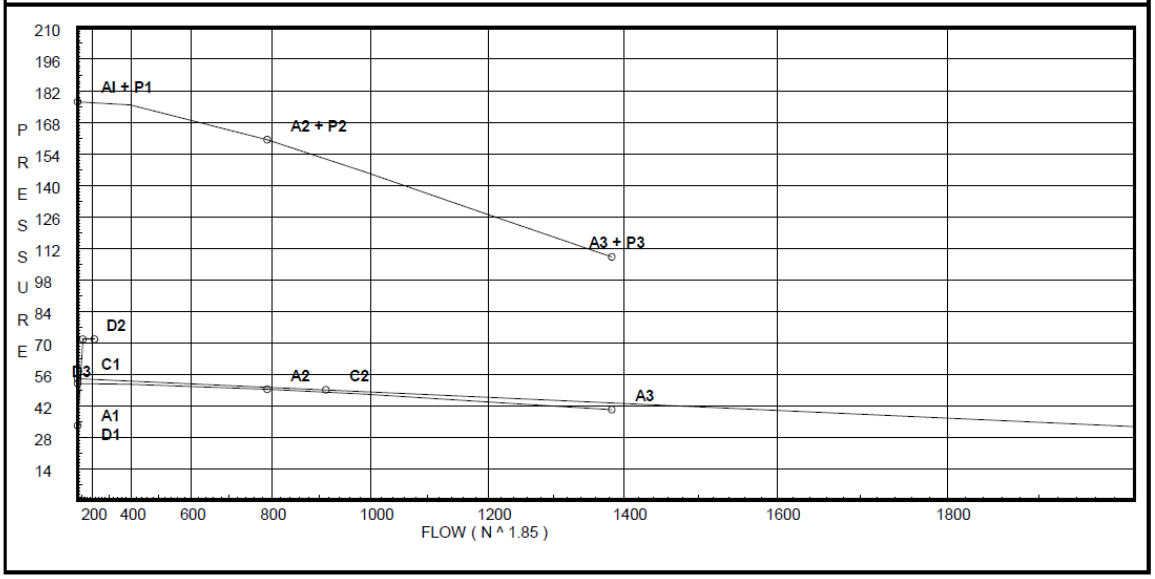
Page 2
Date 9-25-11

City Water Supply:
C1 - Static Pressure : 54
C2 - Residual Pressure: 49
C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet
for Pf - Elev - Hose Flow
A1 - Adjusted Static: 51.872
A2 - Adj Resid : 49.314 @ 790.2
A3 - Adj Resid : 40.224 @ 1382.9

Pump Data:
P1 - Pump Churn Pressure : 125.2
P2 - Pump Rated Pressure : 110.9
P2 - Pump Rated Flow : 790.2
P3 - Pump Pressure @ Max Flow : 67.9
P3 - Pump Max Flow : 1382.9
City Residual Flow @ 0 = 3307.91
City Residual Flow @ 20 = 2576.03
City Water @ 150% of Pump = 43.24

Demand:
D1 - Elevation : 33.132
D2 - System Flow : 113.099
D2 - System Pressure : 71.563
Hose (Adj City) :
Hose (Demand) : 100
D3 - System Demand : 213.099
Safety Margin : 105.185



Aero Automatic Sprinkler Co.
Cal Poly Center for Science LVL 6 [R/A=3]

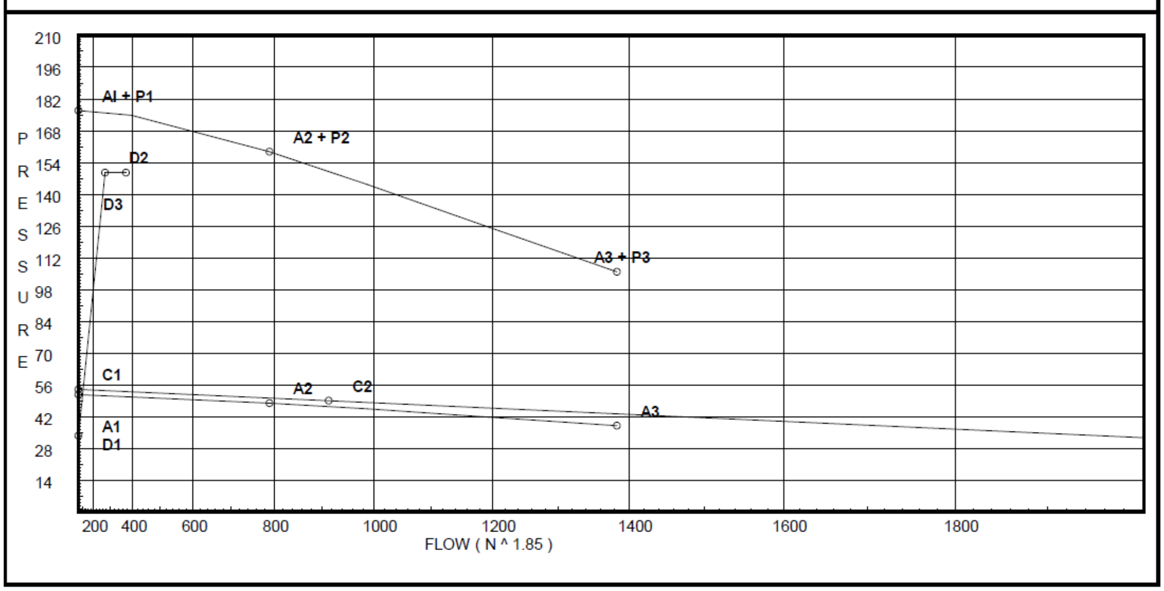
Page 2
Date 9-25-11

City Water Supply:
C1 - Static Pressure : 54
C2 - Residual Pressure: 49
C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet
for Pf - Elev - Hose Flow
A1 - Adjusted Static: 51.696
A2 - Adj Resid : 47.866 @ 790.2
A3 - Adj Resid : 37.967 @ 1382.9

Pump Data:
P1 - Pump Churn Pressure : 125.2
P2 - Pump Rated Pressure : 110.9
P2 - Pump Rated Flow : 790.2
P3 - Pump Pressure @ Max Flow : 67.9
P3 - Pump Max Flow : 1382.9
City Residual Flow @ 0 = 3307.91
City Residual Flow @ 20 = 2576.03
City Water @ 150% of Pump = 43.24

Demand:
D1 - Elevation : 33.565
D2 - System Flow : 273.395
D2 - System Pressure : 149.546
Hose (Adj City) : 150
Hose (Demand) : 100
D3 - System Demand : 373.395
Safety Margin : 25.499



Aero Automatic Sprinkler Co.
Cal Poly Center for Science LVL 6 [R/A=4]

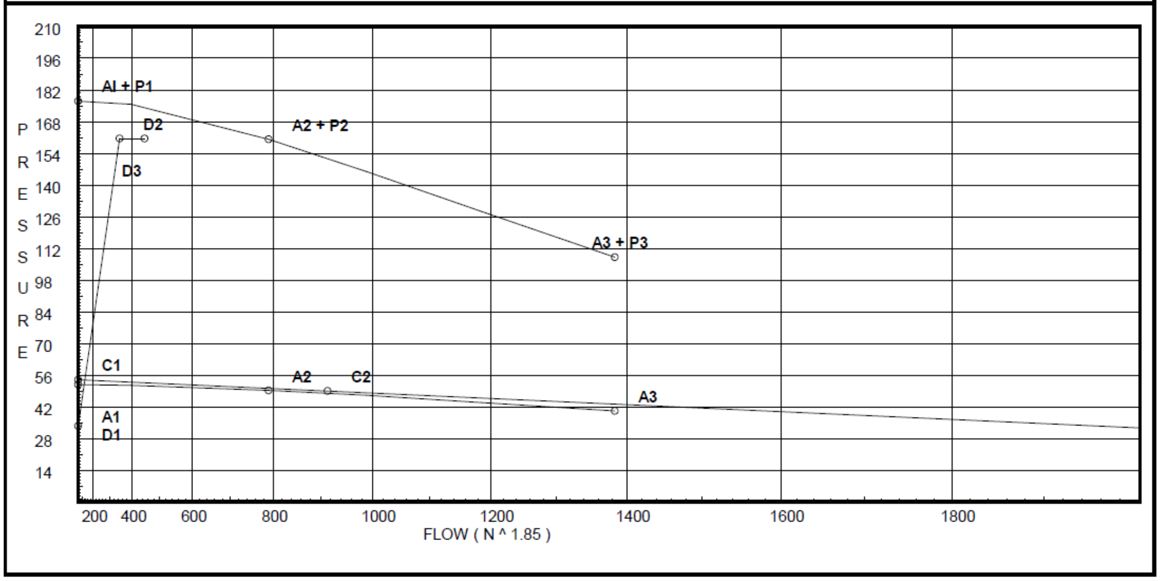
Page 2
Date 9-25-11

City Water Supply:
C1 - Static Pressure : 54
C2 - Residual Pressure: 49
C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet
for Pf - Elev - Hose Flow
A1 - Adjusted Static: 51.872
A2 - Adj Resid : 49.314 @ 790.2
A3 - Adj Resid : 40.224 @ 1382.9

Pump Data:
P1 - Pump Churn Pressure : 125.2
P2 - Pump Rated Pressure : 110.9
P2 - Pump Rated Flow : 790.2
P3 - Pump Pressure @ Max Flow : 67.9
P3 - Pump Max Flow : 1382.9
City Residual Flow @ 0 = 3307.91
City Residual Flow @ 20 = 2576.03
City Water @ 150% of Pump = 43.24

Demand:
D1 - Elevation : 33.565
D2 - System Flow : 347.282
D2 - System Pressure : 160.618
Hose (Adj City) : _______
Hose (Demand) : 100
D3 - System Demand : 447.282
Safety Margin : 13.576



Aero Automatic Sprinkler Co.
Cal Poly Center for Science SP 1-1 [1000 GPM]

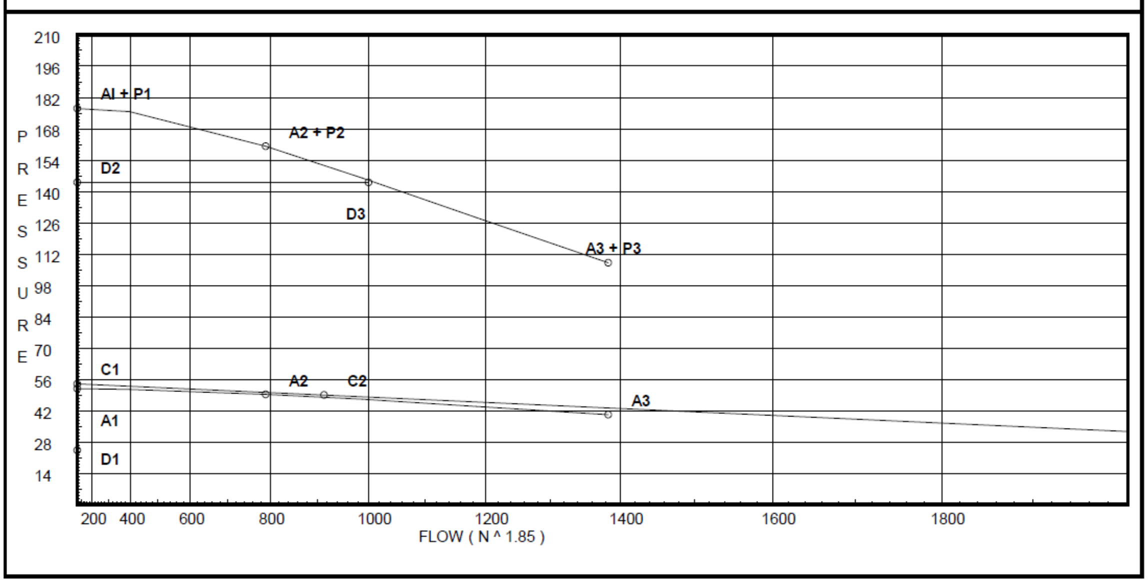
Page 2
Date 9-25-11

City Water Supply:
C1 - Static Pressure : 54
C2 - Residual Pressure: 49
C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet
for Pf - Elev - Hose Flow
A1 - Adjusted Static: 51.872
A2 - Adj Resid : 49.314 @ 790.2
A3 - Adj Resid : 40.224 @ 1382.9

Pump Data:
P1 - Pump Churn Pressure : 125.2
P2 - Pump Rated Pressure : 110.9
P2 - Pump Rated Flow : 790.2
P3 - Pump Pressure @ Max Flow : 67.9
P3 - Pump Max Flow : 1382.9
City Residual Flow @ 0 = 3307.91
City Residual Flow @ 20 = 2576.03
City Water @ 150% of Pump = 43.24

Demand:
D1 - Elevation : 24.254
D2 - System Flow : _______
D2 - System Pressure : 144.081
Hose (Adj City) : _______
Hose (Demand) : 1000
D3 - System Demand : 1000
Safety Margin : 0.911



Aero Automatic Sprinkler Co.
Cal Poly Center for Science SP 1-2 [750 GPM]

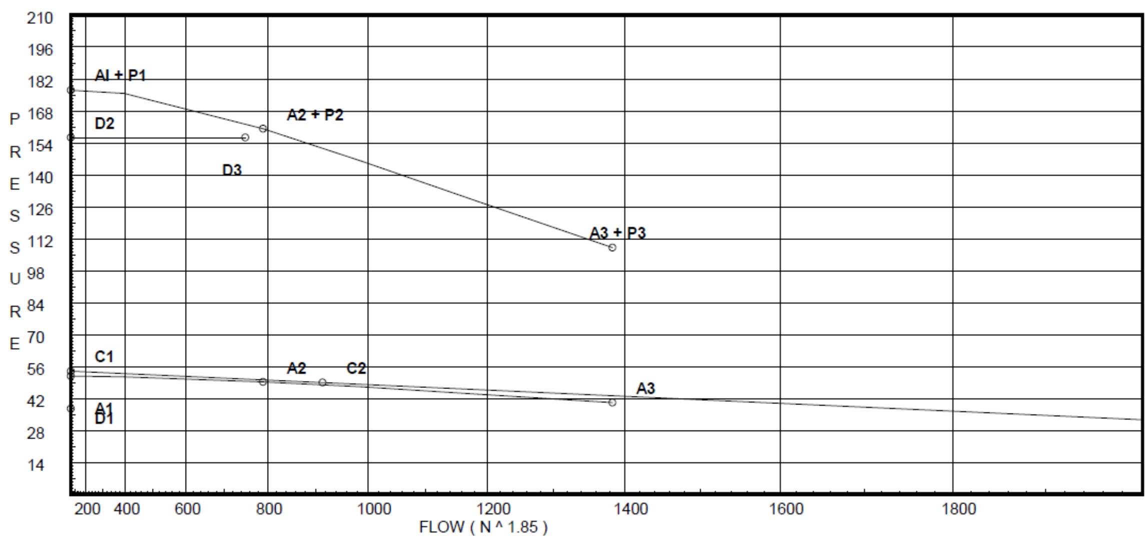
Page 2
Date 9-25-11

City Water Supply:
C1 - Static Pressure : 54
C2 - Residual Pressure: 49
C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet
for Pf - Elev - Hose Flow
A1 - Adjusted Static: 51.872
A2 - Adj Resid : 49.314 @ 790.2
A3 - Adj Resid : 40.224 @ 1382.9

Pump Data:
P1 - Pump Churn Pressure : 125.2
P2 - Pump Rated Pressure : 110.9
P2 - Pump Rated Flow : 790.2
P3 - Pump Pressure @ Max Flow : 67.9
P3 - Pump Max Flow : 1382.9
City Residual Flow @ 0 = 3307.91
City Residual Flow @ 20 = 2576.03
City Water @ 150% of Pump = 43.24

Demand:
D1 - Elevation : 37.571
D2 - System Flow :
D2 - System Pressure : 156.367
Hose (Adj City) :
Hose (Demand) : 750
D3 - System Demand : 750
Safety Margin : 5.795



Aero Automatic Sprinkler Co.
Cal Poly Center for Science SP 4 [1000 GPM]

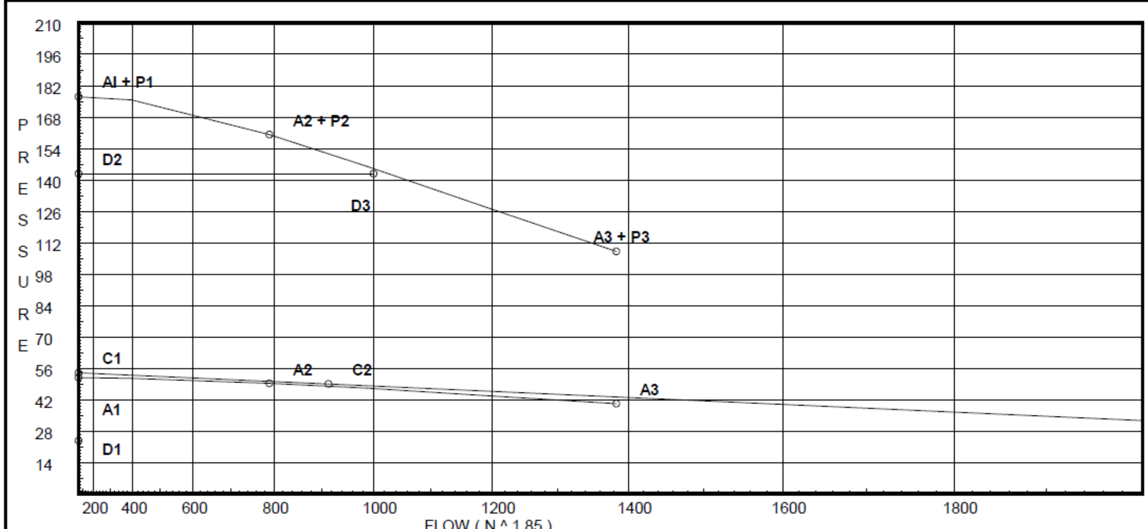
Page 2
Date 9-25-11

City Water Supply:
C1 - Static Pressure : 54
C2 - Residual Pressure: 49
C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet
for Pf - Elev - Hose Flow
A1 - Adjusted Static: 51.872
A2 - Adj Resid : 49.314 @ 790.2
A3 - Adj Resid : 40.224 @ 1382.9

Pump Data:
P1 - Pump Churn Pressure : 125.2
P2 - Pump Rated Pressure : 110.9
P2 - Pump Rated Flow : 790.2
P3 - Pump Pressure @ Max Flow : 67.9
P3 - Pump Max Flow : 1382.9
City Residual Flow @ 0 = 3307.91
City Residual Flow @ 20 = 2576.03
City Water @ 150% of Pump = 43.24

Demand:
D1 - Elevation : 23.712
D2 - System Flow :
D2 - System Pressure : 142.748
Hose (Adj City) :
Hose (Demand) : 1000
D3 - System Demand : 1000
Safety Margin : 2.244



Aero Automatic Sprinkler Co.
Cal Poly Center for Science SP 5 [1000 GPM]

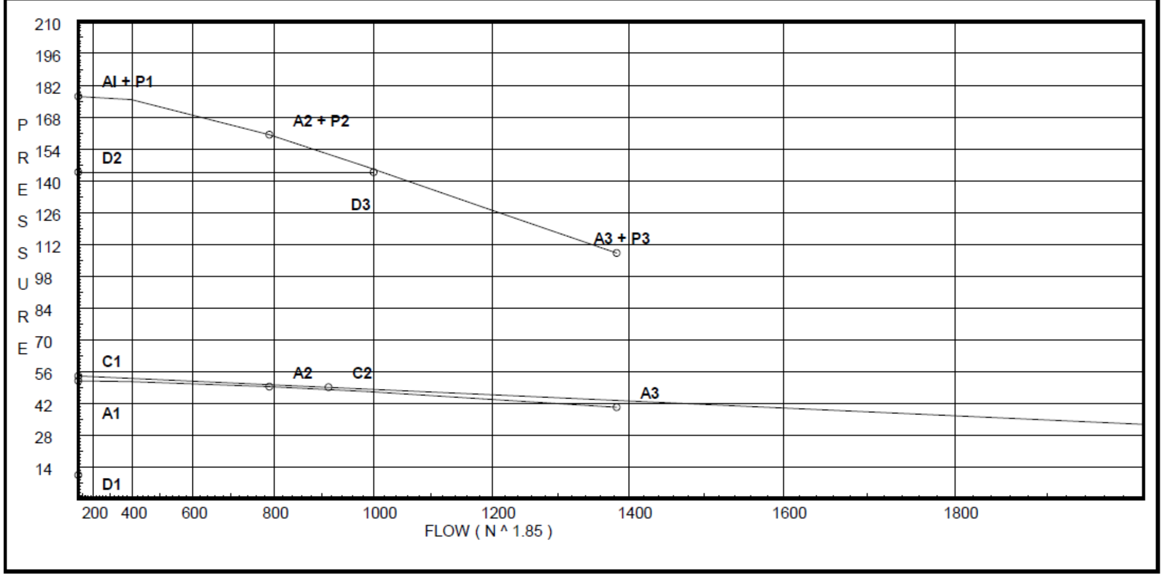
Page 2
Date 9-25-11

City Water Supply:
- C1 - Static Pressure : 54
- C2 - Residual Pressure: 49
- C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet
for Pf - Elev - Hose Flow
- A1 - Adjusted Static: 51.872
- A2 - Adj Resid : 49.314 @ 790.2
- A3 - Adj Resid : 40.224 @ 1382.9

Pump Data:
- P1 - Pump Churn Pressure : 125.2
- P2 - Pump Rated Pressure : 110.9
- P2 - Pump Rated Flow : 790.2
- P3 - Pump Pressure @ Max Flow : 67.9
- P3 - Pump Max Flow : 1382.9
  - City Residual Flow @ 0 = 3307.91
  - City Residual Flow @ 20 = 2576.03
  - City Water @ 150% of Pump = 43.24

Demand:
- D1 - Elevation : 10.394
- D2 - System Flow : ______
- D2 - System Pressure : 143.705
- Hose (Adj City) : ______
- Hose (Demand) : 1000
- D3 - System Demand : 1000
- Safety Margin : 1.287



9.12 Travel Time Calculated Using the Hydraulic Model - SFPE Handbook[50]

Assuming the incorporation of a “staged evacuation” plan (as described in Section 4.3.4 of this report), the travel time can be calculated for the atrium as the time when all occupants are evacuated out of Zone 1 (Figure 53).

The following conditions are commonly assumed for predicting the flow of occupants in emergencies:

- All persons will start to evacuate at the same instant.
- Occupant flow will not involve any interruptions caused by decisions of the individuals involved.
- All or most of the persons involved are free of disabilities that would significantly impede
- their ability to keep up with the movement of the group.

The travel time for occupants to evacuate Zone 1 depends on the density of occupants in the space. Figure 53 shows the evacuation speed as a function of density.

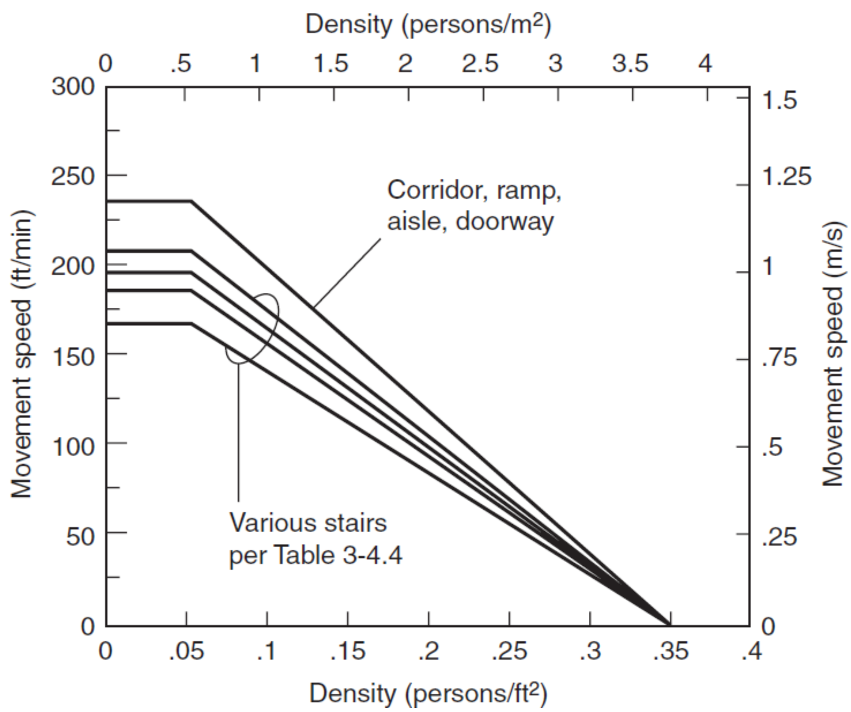


Figure 53 –Evacuation Speed as a Function of density

Ref. Nelson, et.al., SFPE Handbook, figure 3-14.4

50 SFPE Handbook, 2002

The equation[51] for the functions graphed in Figure 53 is detailed below:

$$S = k - akD$$

Where,
S = speed along the line of travel
D = density in persons/square feet
k = 275 (constant from SFPE Hbk. Sec. 3, Ch. 14, Table 3-14.2)
a = 2.86 (constant from SFPE Hbk. Sec. 3, Ch. 14)

The travel time to evacuate each level of the atrium is calculated in Table 25. The density (D) is determined by dividing the occupant load by the area. The walking speed is determined by converting the density into movement speed using Figure 53 or the above equation. The travel distance is assumed to be the most remote location within the atrium space for each level (based in maximum travel distance). The time to evacuate is calculated by dividing the travel distance by the walking speed of the occupants.

51 Nelson, et. al., SFPE Handbook.

9.13 Travel time Calculated using Pathfinder Software

As explained in 5.3.4, each Level of the atrium space is designed with Pathfinder based on the floor plan layout provided in the architectural plans. The occupant load for each level is also based on the occupant load of each individual room specified in the architectural plans.

The Pathfinder model analyzes occupant evacuation times when all occupants on Level 2 through Level 6 evacuate simultaneously, which represent a realistic approach to building evacuation within the controlled area of the atrium space.

The travel time was determined for each level, based on the demographics specified in Table 26 and the two evacuation alternatives for disabled persons, described in 5.3.4. The scenarios evaluated are summarized in Table 45.

Table 45- Travel time scenarios evaluated with Pathfinder

Scenario A		Scenario B		Scenario C	
Demographic (%)	**Evacuation Alternative**	**Demographic (%)**	**Evacuation Alternative**	**Demographic (%)**	**Evacuation Alternative**
Young: 15 Middle: 63 Old: 16 Disabled: 6	Young, Middle, Old and Disabled occupants programmed to exit towards any exit (**Go to Any Exit**)	Young: 15 Middle: 63 Old: 16 Disabled: 6	Young, Middle and Old occupants programmed to exit towards the any exit (**Go to Any Exit**) and Disabled occupants programmed to exit to the area of refuge (**Go to Refuge Area**) for Levels 3, 4, 5 & 6.	Young: 9 Middle: 47 Old: 32 Disabled: 12	Young, Middle, Old and Disabled occupants programmed to exit towards any exit (**Go to Any Exit)**

All figures presented in this appendix correspond to the results obtained for Scenario B. Tables show the travel time results for all scenarios evaluated.

Stairway #3 of the CSM discharges to the atrium's Level 2, so people using the area of refuge will exit the building through the atrium's second level. For the Pathfinder model implemented for this project with the alternative of disabled persons using the area of refuge, Stairway #3 discharges to the Level 2, as whether this stairway discharges directly to the external part of the building. This model was implemented in that way, because the travel distance is considered until people get the area of refuge (get out of the smoke area) and not until they completely leave the building. This assumption is also supported by the results obtained with FDS, which show that tenability conditions are maintained in Level 2 during the 20 minutes simulated.

9.13.1 Level 2

For level 2, a background layer of the atrium architectural plan was imported into Pathfinder to scale the model appropriately. Each room/space that is identified with an occupant load on the architectural plans is modeled in Pathfinder with the corresponding occupant load.

The exits in Level 2 are composed of two double doors of 144 inches each on the North and South sides of the atrium. The 96 inch doors located on the East and West wings of the atrium space are not considered exits in the Pathfinder model because egress will flow into the atrium from the East and West wings of the building. Stairway #2 is not considered an exit because it is an open stairway and is assumed to be affected by fire, therefore is not considered an accessible means of egress. Figure 54 shows the Level 2 model in Pathfinder and Table 46 the travel times obtained for the different scenarios evaluated.

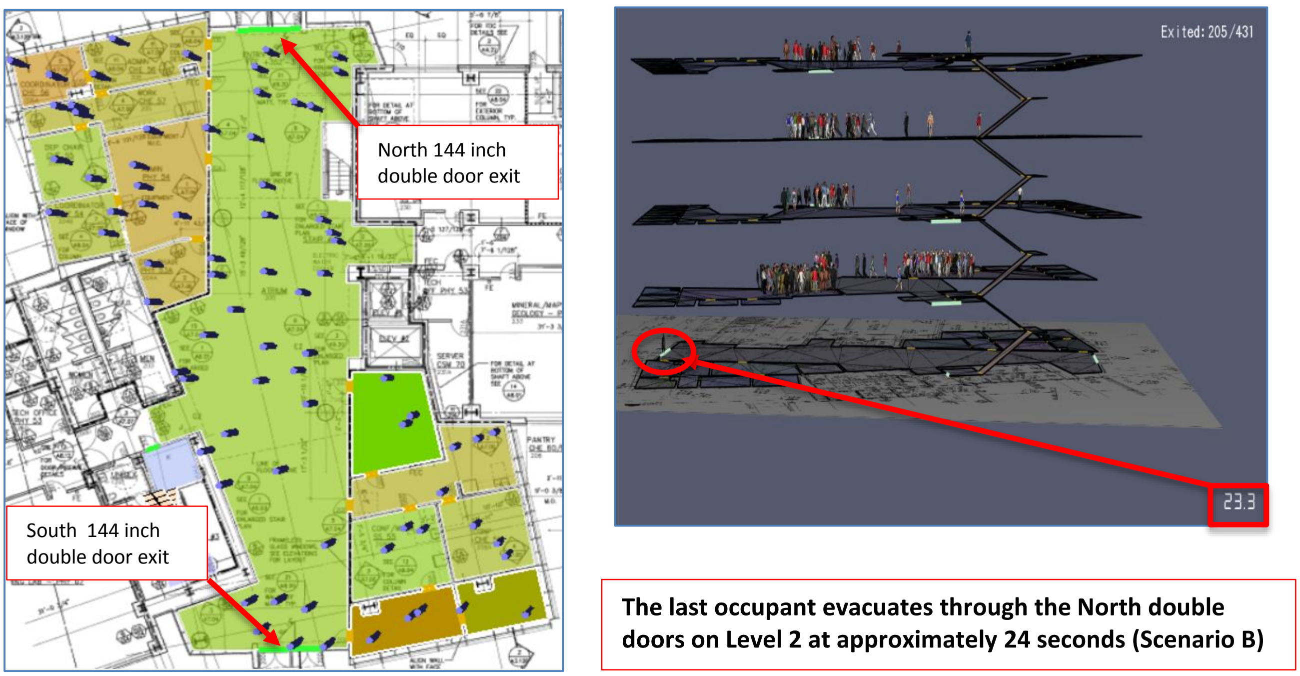


Figure 54 –Level 2 Pathfinder Evacuation Model

Table 46- Travel time for Atrium Level 2 – Pathfinder					
Level	**Area (ft^2)**	**Occupant Load**	**t_e Scenario A**	**t_e Scenario B**	**t_e Scenario C**
2	6,656	77	38	24	38

9.13.2 Level 3

For level 3, a background layer of the atrium architectural plan was imported into Pathfinder at a floor height of 16 feet . This background layer was aligned with the layer in level two to scale the model appropriately. Each room/space that is identified with an occupant load on the architectural plans is modeled in Pathfinder with the corresponding occupant load. Once the level geometry was drawn in Pathfinder, the background layer was deleted of the model in order to have a better sight of the atrium.

The exits in Level 3 are composed of the 96 inch double doors located on the East and West sides of the atrium space and the 36 inch door located on the area of refuge (Stairway #3). Stairway #2 is not considered an exit because it is an open stairway and is assumed to be affected by fire, therefore is not considered an accessible means of egress. Figure 55 shows the Level 3 model in Pathfinder and Table 47 shows the travel times obtained for the different scenarios evaluated.

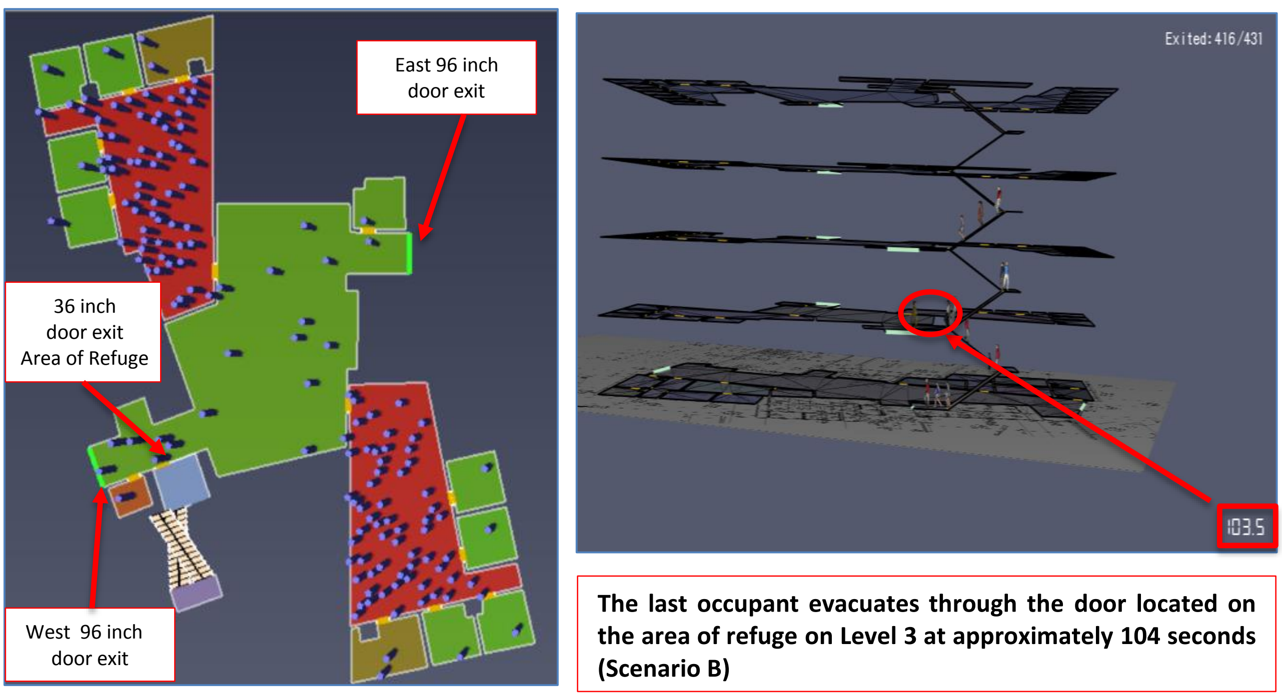


Figure 55 –Level 3 Pathfinder Evacuation Model

Table 47- Travel time for Atrium Level 3 – Pathfinder					
Level	**Area (ft^2)**	**Occupant Load**	**t_e Scenario A**	**t_e Scenario B**	**t_e Scenario C**
3	6,247	155	104	104	104

9.13.3 Level 3 – Reduced occupant load

A second approach to the design of Level 3 excludes the student work spaces from evacuating because a 1- hour fire rated wall separates the atrium space from all other areas on this Level. In this case only the occupants located at the atrium lobby (21 occupants) are considered for evacuation as shown in Figure 56. Table 48 shows the travel times obtained for the different scenarios evaluated.

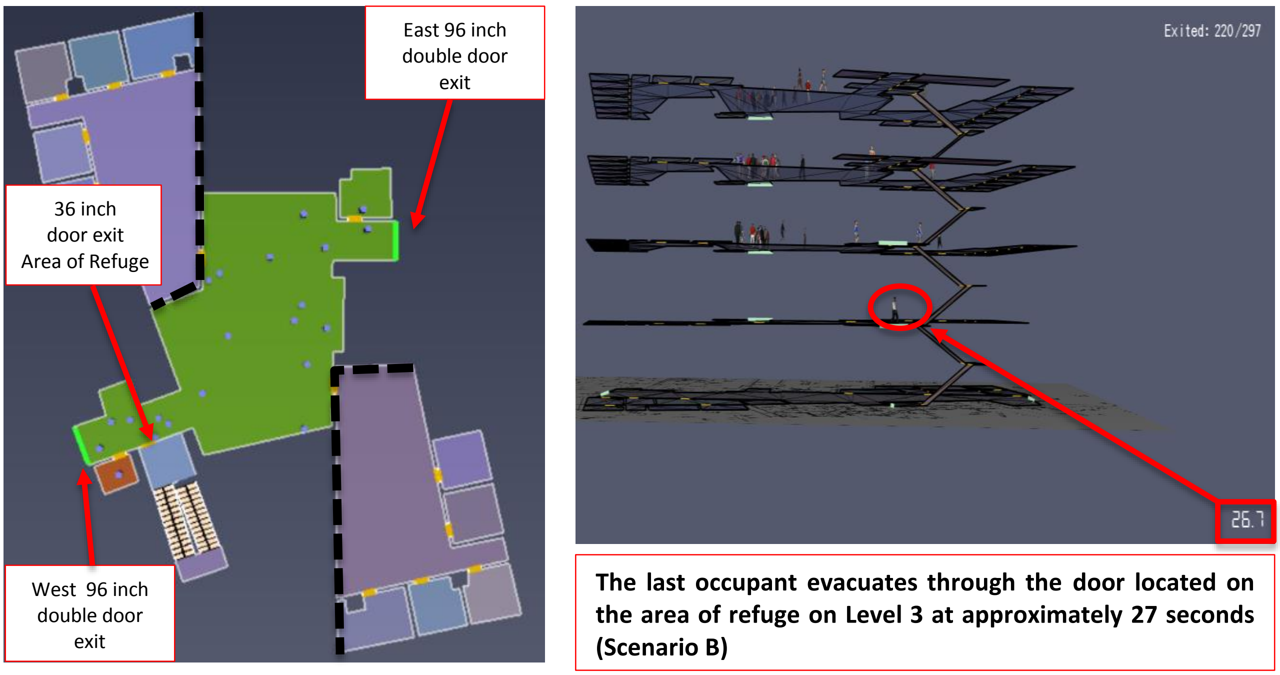


Figure 56 –Level 3 Pathfinder Evacuation Model – Reduced Occupant Load

Table 48- Travel time for Atrium Level 3 (ROL) – Pathfinder					
Level	**Area (ft^2)**	**Occupant Load**	**t_e Scenario A**	**t_e Scenario B**	**t_e Scenario C**
3*	6,247 (1,535)	155 (21)	16	27	24

9.13.4 Level 4

For level 4, a background layer of the atrium architectural plan was imported into Pathfinder at a floor height of 32 feet . This background layer was aligned with the layer in level three to scale the model appropriately. Each room/space that is identified with an occupant load on the architectural plans is modeled in Pathfinder with the corresponding occupant load. Once the level geometry was drawn in Pathfinder, the background layer was deleted of the model to have a better sight of the atrium.

The exits in Level 4 are composed of the 96 inch double doors located on the East and West sides of the atrium space and the 36 inch door located on the area of refuge (Stairway #3). Stairway #2 is not considered an exit because it is an open stairway and is assumed to be affected by fire, therefore is not considered an accessible means of egress. Figure 57 shows the Level 4 model in Pathfinder and Table 49 shows the travel times obtained for the different scenarios evaluated.

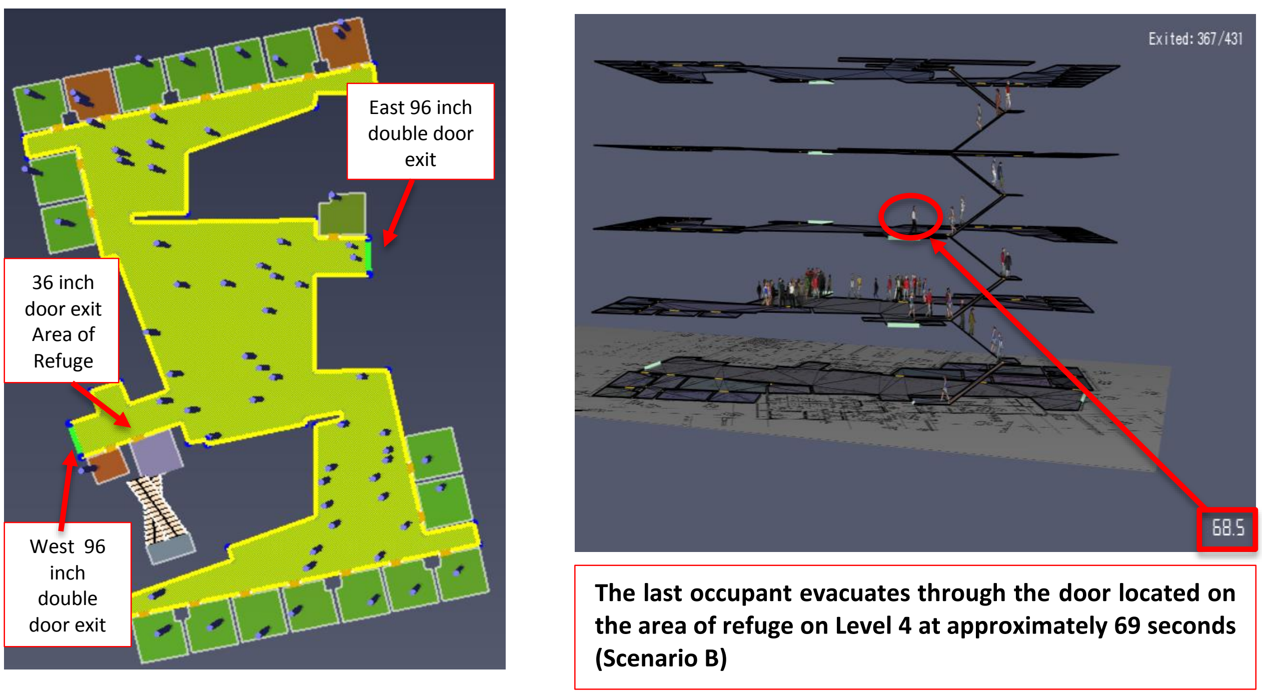


Figure 57 –Level 4 Pathfinder Evacuation Model

Table 49- Travel time for Atrium Level 4 – Pathfinder					
Level	**Area (ft^2)**	**Occupant Load**	**t_e Scenario A**	**t_e Scenario B**	**t_e Scenario C**
4	6,641	64	69	69	69

9.13.5 Level 5

For level 5, a background layer of the atrium architectural plan was imported into Pathfinder at a floor height of 48 feet . This background layer was aligned with the layer in level three to scale the model appropriately. Each room/space that is identified with an occupant load on the architectural plans is modeled in Pathfinder with the corresponding occupant load. Once the level geometry was drawn in Pathfinder, the background layer was deleted of the model to have a better sight of the atrium.

The exits in Level 5 are composed of the 96 inch double door located on the East side of the atrium space and the 36 inch door located on the area of refuge (Stairway #3). Stairway #2 is not considered an exit because it is an open stairway and is assumed to be affected by fire, therefore is not considered an accessible means of egress. Figure 58 shows the Level 5 model in Pathfinder and Table 50 shows the travel times obtained for the different scenarios evaluated.

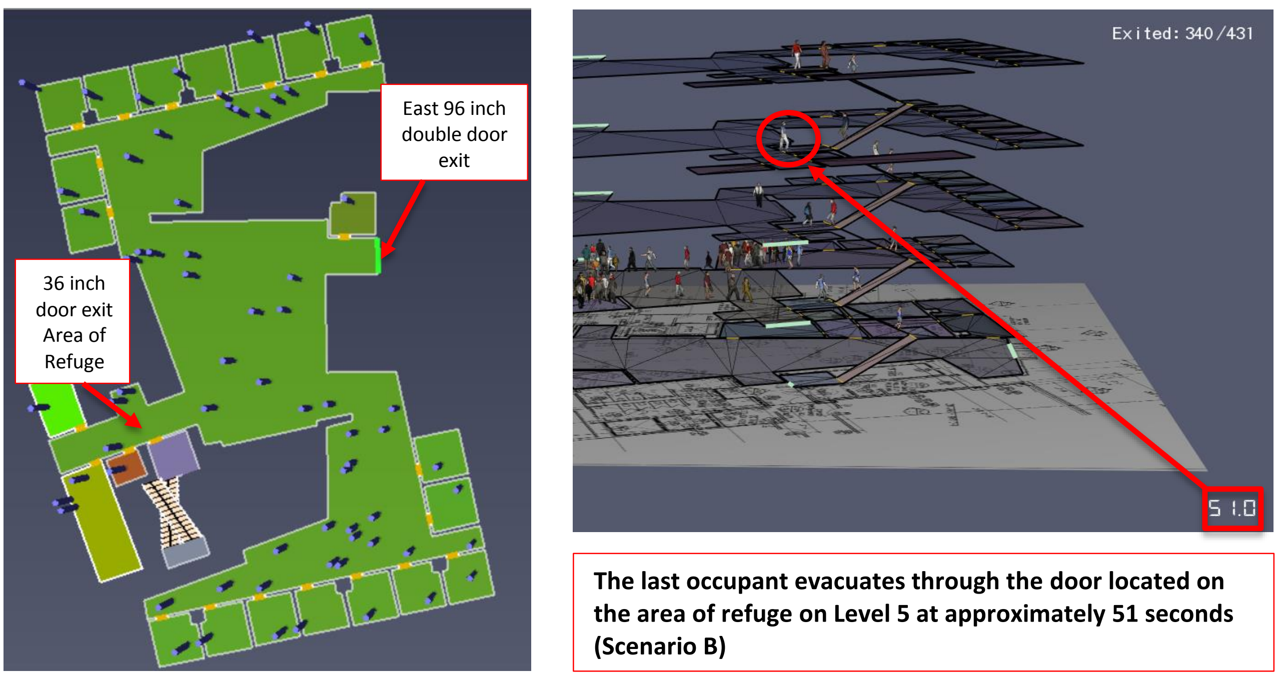


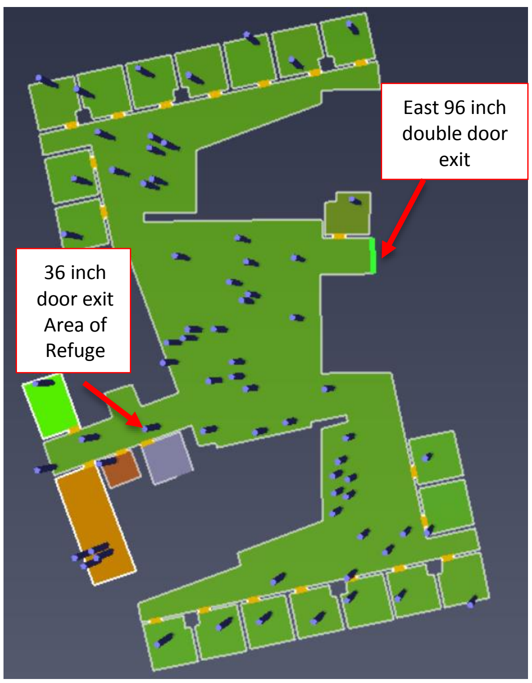
Figure 58 –Level 5 Pathfinder Evacuation Model

Table 50- Travel time for Atrium Level 5 – Pathfinder					
Level	Area (ft^2)	Occupant Load	t_e Scenario A	t_e Scenario B	t_e Scenario C
5	6,641	67	52	51	52

9.13.6 Level 6

For level 6, a background layer of the atrium architectural plan was imported into Pathfinder at a floor height of 64 feet . This background layer was aligned with the layer in level three to scale the model appropriately. Each room/space that is identified with an occupant load on the architectural plans is modeled in Pathfinder with the corresponding occupant load. Once the level geometry was drawn in Pathfinder, the background layer was deleted of the model to have a better sight of the atrium.

The exits in Level 6 are composed of the 96 inch double door located on the East side of the atrium space and the 36 inch door located on the area of refuge (Stairway #3). Stairway #2 is not considered an exit because it is an open stairway and is assumed to be affected by fire, therefore is not considered an accessible means of egress. Figure 59 shows the Level 6 model in Pathfinder and Table 51 shows the travel times obtained for the different scenarios evaluated.



The last occupant evacuates through the door located on the area of refuge on Level 6 at approximately 49 seconds (Scenario B)

Figure 59 –Level 6 Pathfinder Evacuation Model

Table 51- Travel time for Atrium Level 6 – Pathfinder

Level	Area (ft^2)	Occupant Load	t_e Scenario A	t_e Scenario B	t_e Scenario C
6	6,641	68	56	49	56

9.13.7 Travel time calculations – Pathfinder Results Summary

Table 52 summarizes the results obtained with Pathfinder for all Levels of the atrium.

Table 52- Travel time for Atrium Levels 2 to 6 – Pathfinder

Level	Area (ft^2)	Occupant Load	t_e Scenario A	t_e Scenario B	t_e Scenario C
2	6,656	77	38	24	38
3	6,247	155	104	104	104
3*	6,247 (1,535)	155 (21)	16	27	24
4	6,641	64	69	69	69
5	6,641	67	52	51	52
6	6,641	68	56	49	56

Table 52 shows that there is no significant differences between the results obtained with the three scenarios. This means that even doubling the percent of persons with lower velocity (Disabled and Old), the travel time is very similar. The same occurs with the alternatives for disabled persons evacuating the atrium using any exit or using the area of refuge, where again the results are not affected in an important manner.

The most important difference observed in Table 52 is the one between the results obtained for Level 3 if the reduced occupant load due to 1-hour fire rated wall is considered or not. This important difference is due to bottleneck formed in the 36 inch door, between the student work spaces and the atrium lobby, when the reduced occupant load due to 1-hour fire rated wall is not considered, as shown in Figure 56.

Based upon the above results, the RSET analysis is conducted using the travel times obtained for Scenario B. This scenario consider the demographic from in the Smoke Management Study and the alternative where disabled persons exit toward the area of refuge, which is a reasonable assumption in case of fire in the atrium.

Figure 60 –Bottleneck formed in Level 3

9.14 Sprinkler activation calculation using DETACT model.

The DETACT model predicts sprinkler/heat detector activation for transient (power law) fires. In this case the fire is assumed as a fast growth t-squared fire, in accordance with the following equation, (NFPA Handbook, Chapter 4, Section 2):

$Q = \alpha t^2$

Where,
Q = rate of heat release (kW)
α = a constant describing the speed of growth. For a fast growth fire, α = 0.0469 kW/s^2.
t = time (s)

The maximum sprinkler separation on the atrium identified in the shop drawings (Ref. Aero Automatic Sprinkler Co. 2011-SD) is 14'-6'' as shown in Figure 61. Therefore, the radial distance, r = 10.3 ft (3.14 m). The ceiling height (H) is 3.8 m (12.46 feet), as shown in Figure 40 .

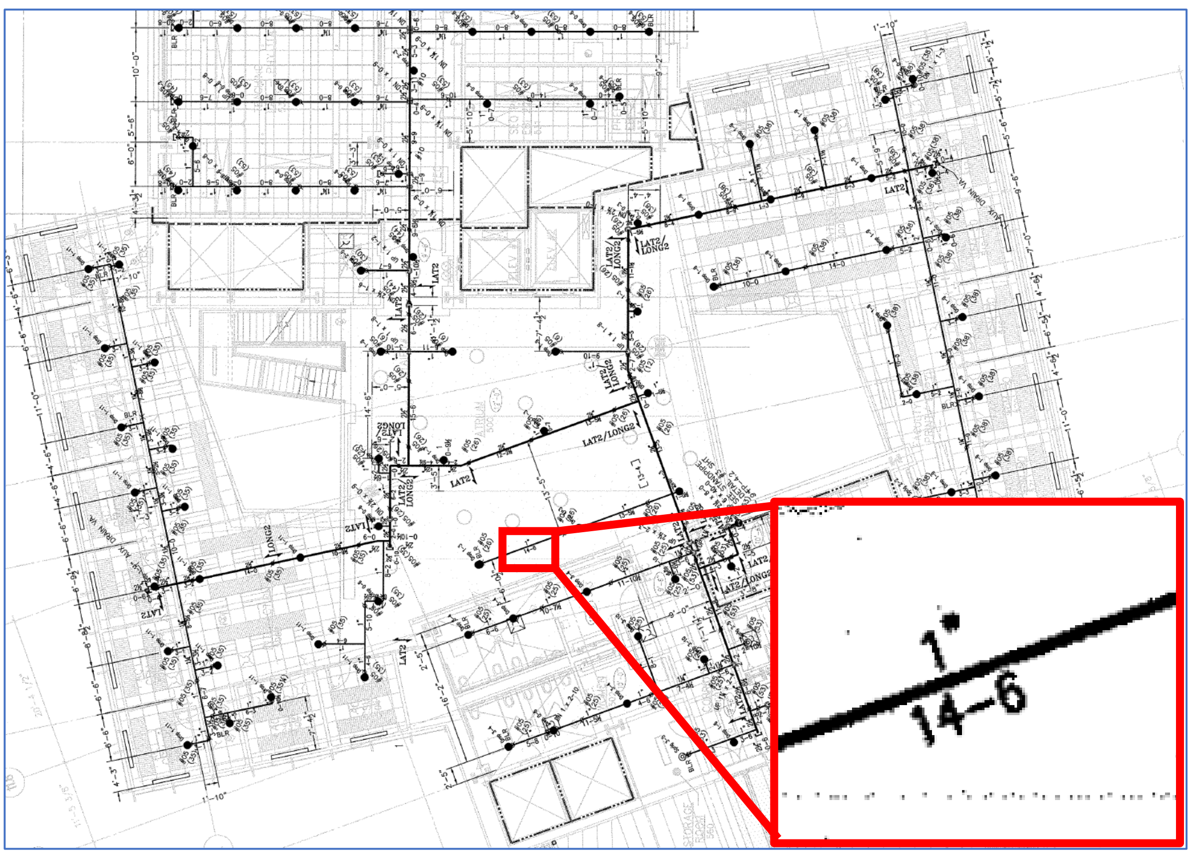
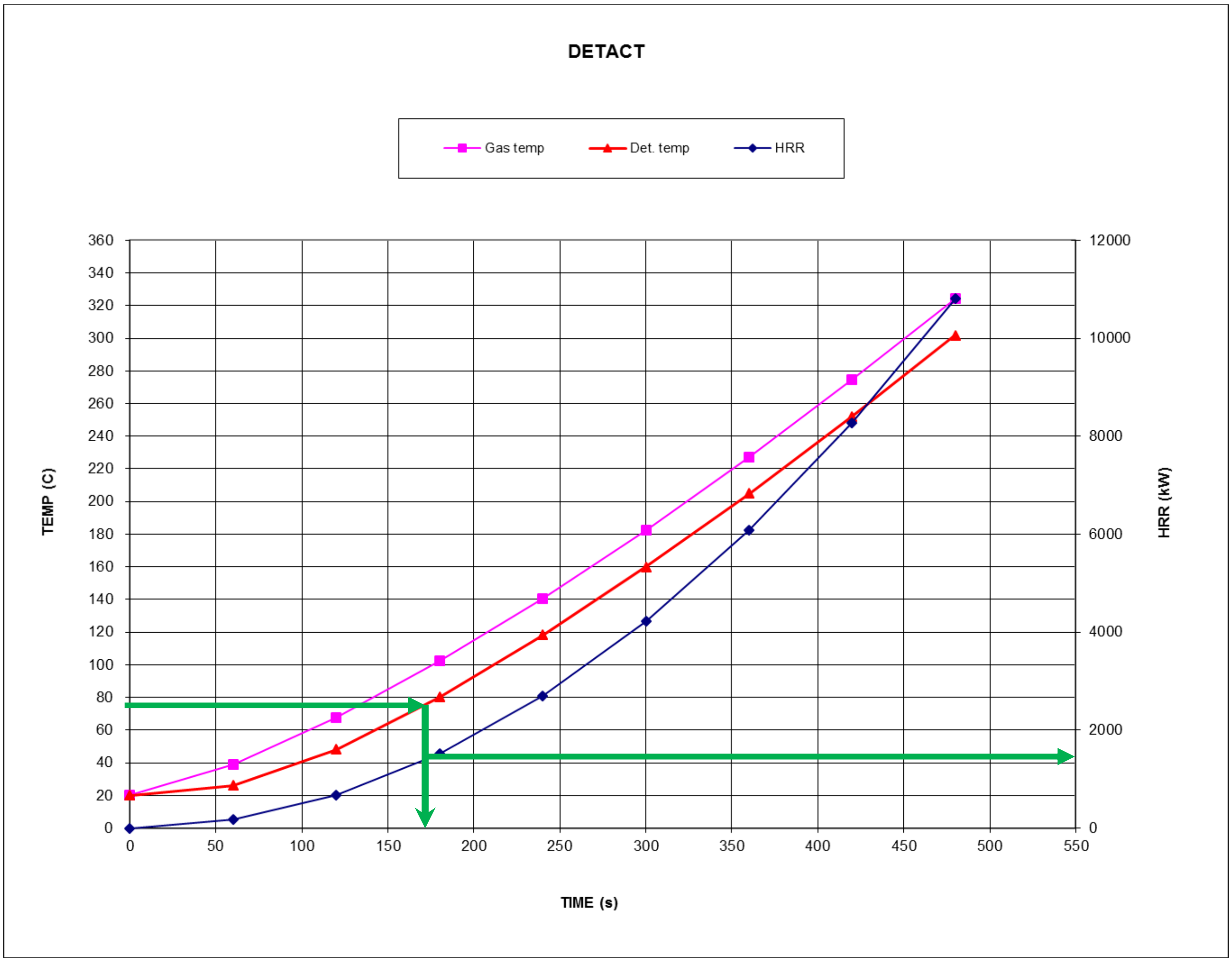


Figure 61 – Maximum sprinkler separation in the Atrium

The RTI considered for the sprinkles in this case is 50 $(m\text{-}s)^{1/2}$ (Ref. ZFG, 2009), with an activation temperature of 165 °F (73.88 °C).

With the above assumptions and data, the results obtained with the DETACT algorithm provided in the course FPE-522 are shown below.

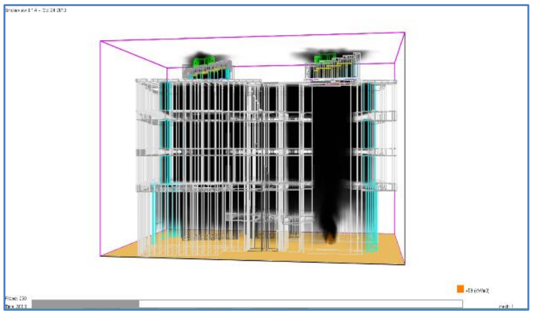
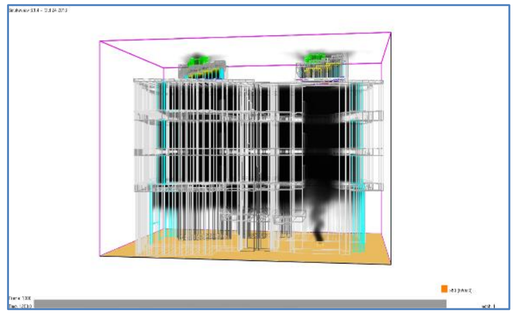


INPUT PARAMETERS			CALCULATED PARAMETERS		
Calculation reset	1	0 or 1	R/H	0.8263	-
Ceiling height (H)	3.8	m	W/H	5.2632	-
Room width (W)	20	m	Temperature factor	0.3407	-
Radial distance (R)	3.14	m	Velocity factor	0.2345	-
Ambient temperature (To)	20	C	Calculation time (t)	501	s
Actuation temperature (Ta)	73.88	C	Fire HRR (Q)	11772	kW
Rate of rise rating (ROR)		C/min	Gas temperature (Tg)	341.99	C
Response time index (RTI)	50	(m-s)1/2	Gas velocity (Ug)	3.4179	m/s
Fire growth power (n)	2	-	ROR at detector	51.433	C/min
Fire growth coefficient (k)	0.0469	kW/s^n	Detector temp (Td)	319.66	C
Fire location factor (kLF)	1	-	Detection trigger	332	500

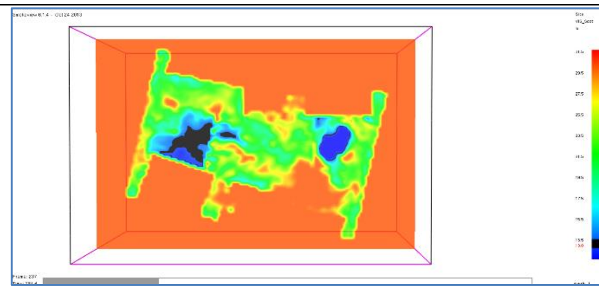
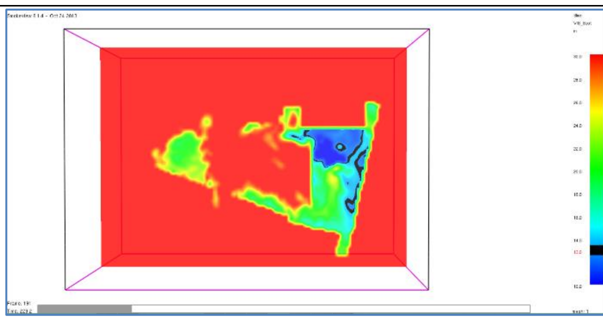
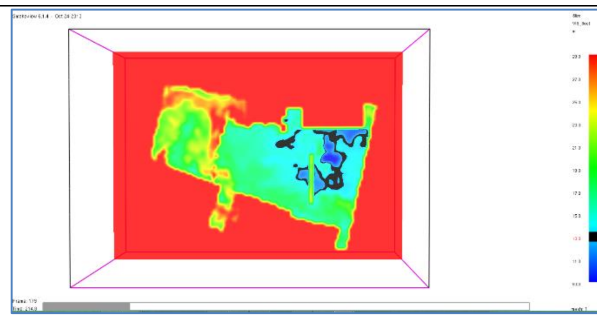
Results summary:

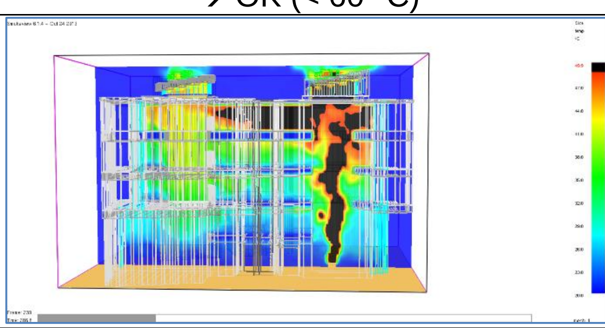
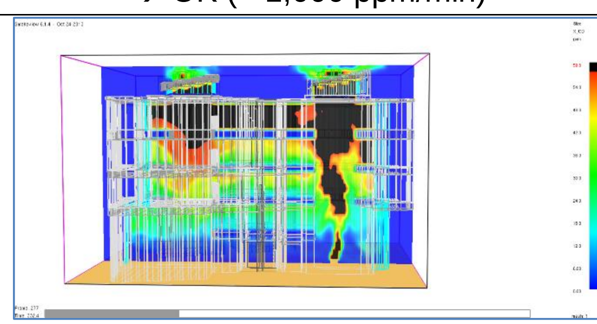
Detection time: 170 seconds.
HRR at detection: 1,355 kW.

9.15 FDS Simulation Results for DF#2 with Maximum HRR – 3,100 kW

Smoke view pictures at 300 (left) and 1200 seconds (right).

Visibility: < 13 meter	
Level 2: 1200 seconds Level 3: 1200 seconds	 285 seconds at Level 4
 230 seconds at Level 5	 215 seconds at Level 6

Temperature: 49.9 °C Maximum at 286 seconds → OK (< 60 °C)	Carbon Monoxide: 60 ppm Maximum at 332 seconds → OK (< 1,000 ppm/min)
	

9.16 Code Requirement for Smoke Control Systems[52]

Code Requirements The California Building Code (CBC), Section 404.4 requires atriums greater than two stories to be protected with a smoke control system in accordance with Section 909. Section 909 provides design requirements for smoke control systems and refers to NFPA 92B, Standard for Smoke Management Systems in Malls, Atria, and Large Spaces, for the design of smoke control systems in atriums.

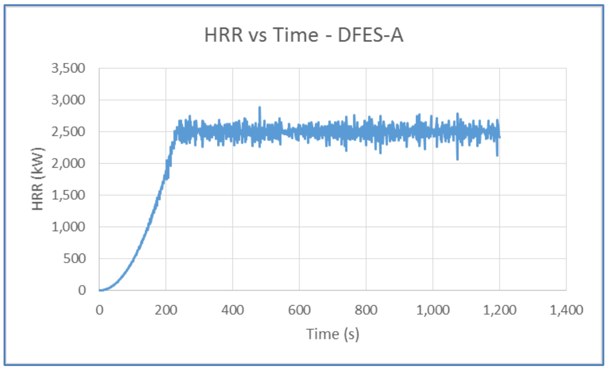
- Section 909 Smoke Control Systems. Section 909 of the CBC on Smoke Control Systems requires a passive or mechanical smoke control system to provide tenable conditions for evacuating occupants in a building with an atrium that connects more than two stories.
- Section 909.4 Analysis. Section 909.4 of the CBC requires a rational analysis to support the type of smoke control system to be employed, its method of operation, the system supporting it and the method of construction to be utilized. Sub-section 909.4.6 requires the smoke control system to be operable for at least 20 minutes after detection of a fire, or 1.5 times the calculated egress time, whichever is less.
- Section 909.8 Exhaust method. Section 909.8 of the CBC allows smoke control systems that have been approved by the fire code official to use mechanical smoke control for atriums by means of the exhaust method. Sub-section 909.8.1 requires the smoke layer to be maintained above 6 feet of any walking surface that is required for building egress. The exhaust method must be designed in accordance with NFPA 92B.
- Section 1.3 Purpose. The purpose of NFPA 92B is to provide guidance on how to implement smoke management systems to maintain a tenable environment when evacuating large volume building spaces
- A.2.4.1.3. Annex A of NFPA 92B explains how a computer model can be constructed to calculate the smoke layer position over time, with and without smoke exhaust. This approach is considered performance-based design and relies on a computer model to justify that the smoke control system proposed provides a level of fire life safety that satisfies the intent of the CBC.

In addition to the performance-based design provisions permitted under Section 104.11 of the CBC, specific requirements for the analysis in selecting the design fire are included in Section 909.9.

- Section 909.9 Design fire. Section 909.9 of the CBC requires a design fire based on a rational analysis performed by a registered design professional and approved by the fire code official.Sub-section 909.9.1 of the CBC requires an engineering analysis to include whether the fire is likely to be steady or unsteady.

52 Ref. CBC-2007; NFPA 92B-2005, and Radle, L., 2013.

9.17 FDS Results - Design Fire Exhaust System A



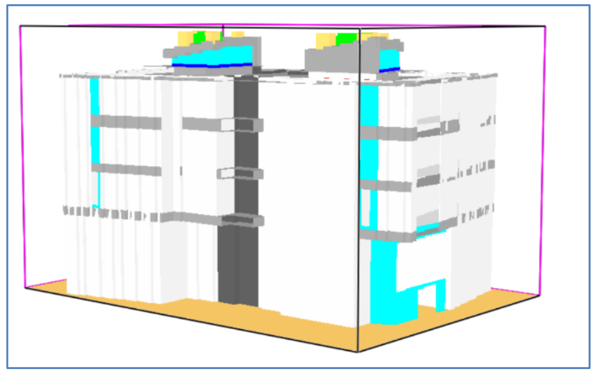


Figure 62 – HRR curve and FDS mode for DFES-A

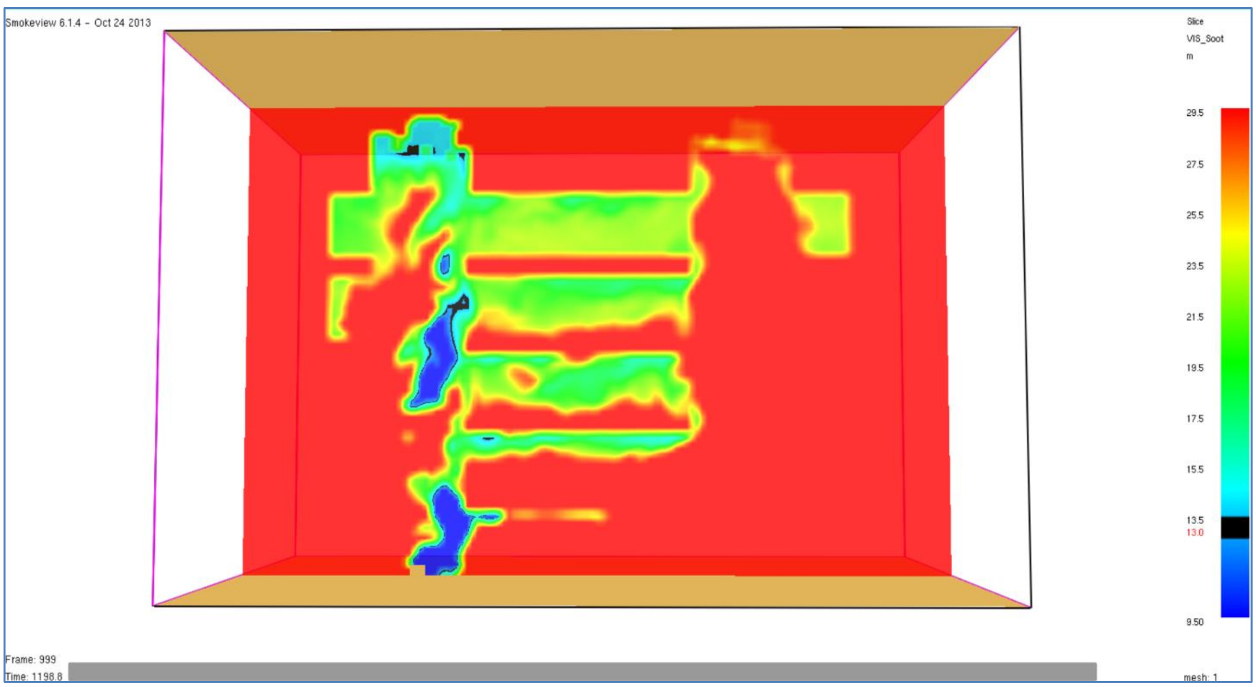


Figure 63 – Visibility Slice File for DFES-A at 1200 seconds

Note: Visibility is always over 13 m a height of 6 feet above each finished floor level (out of the fire plume), during 1200 seconds.

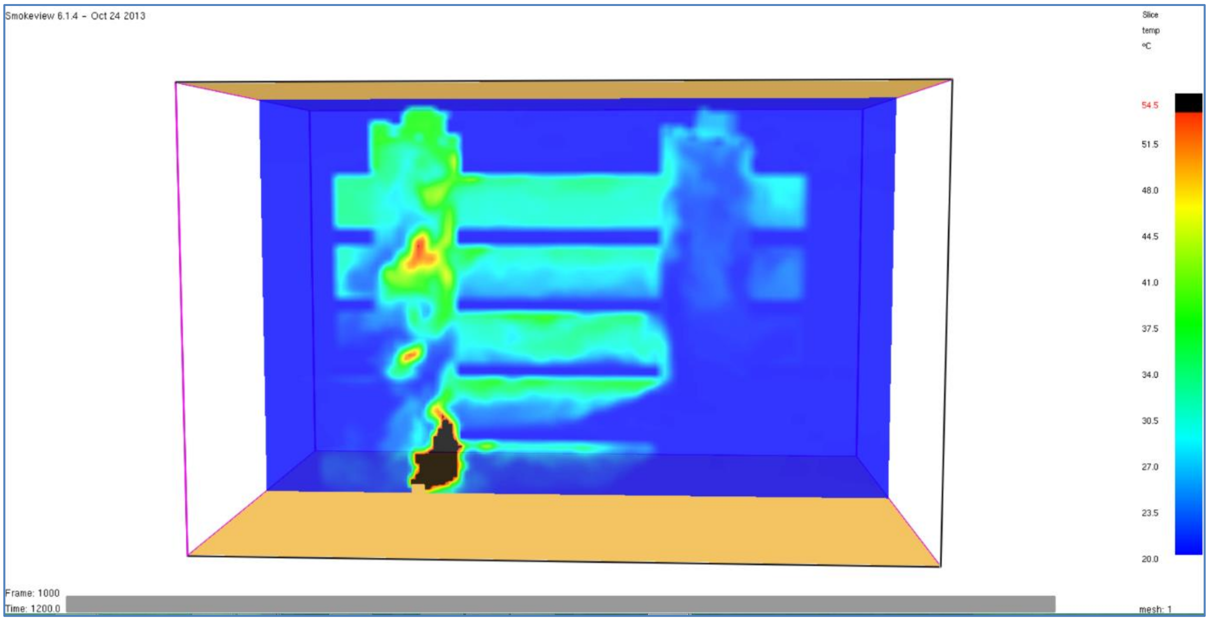


Figure 64 – Temperature Slice File for DFES-A at 1200 seconds

Note: Temperature is always under 60 °C above each finished floor level (out of the fire plume), during 1200 seconds.

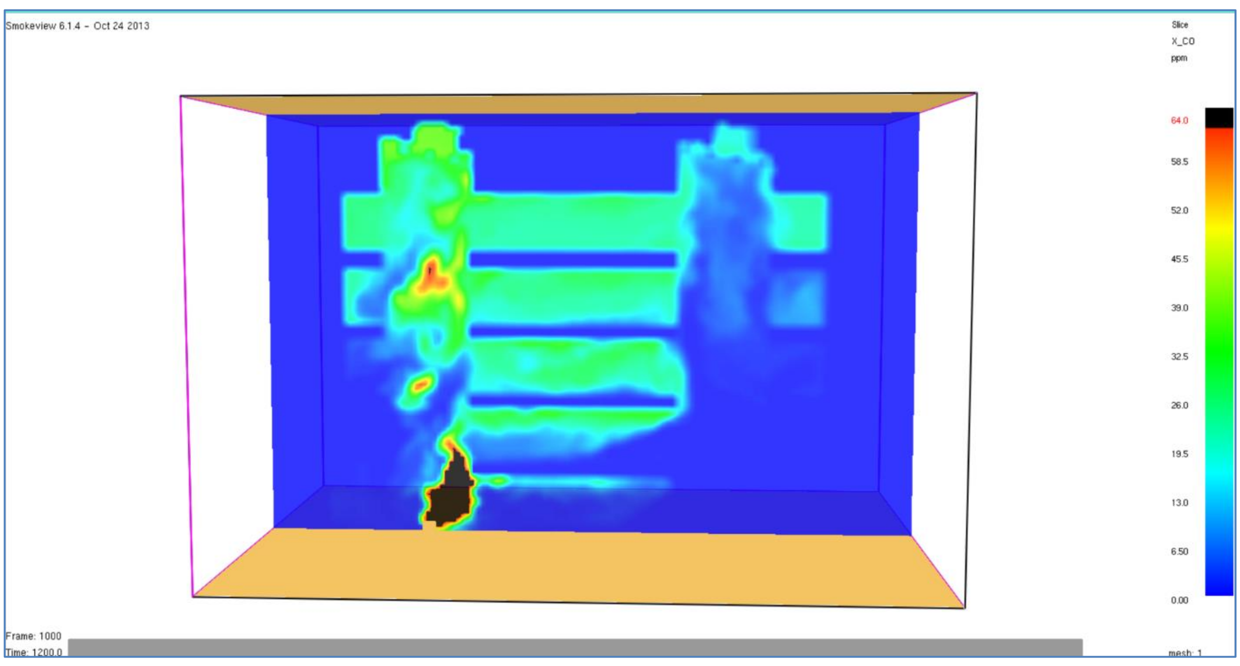


Figure 65 – CO concentration Slice File for DFES-A at 1200 seconds

Note: CO concentration is always under 1000 ppm above each finished floor level (out of the fire plume), during 1200 seconds.

9.18 FDS Results - Design Fire Exhaust System B

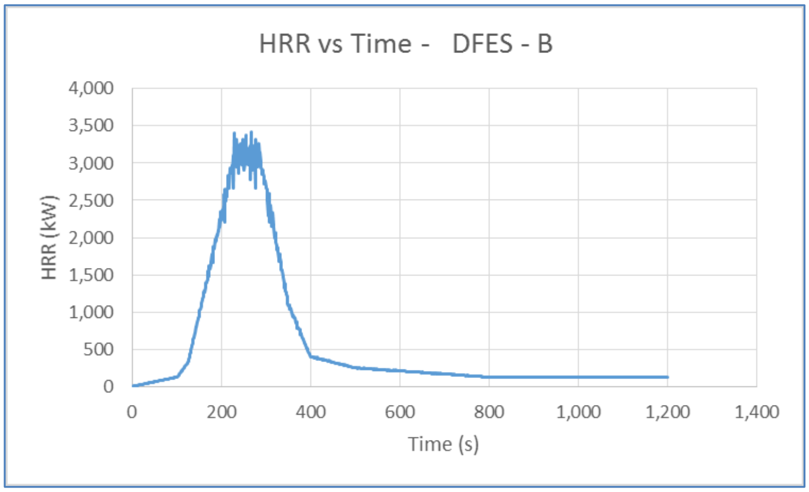


Figure 66 – HRR curve mode for DFES- B

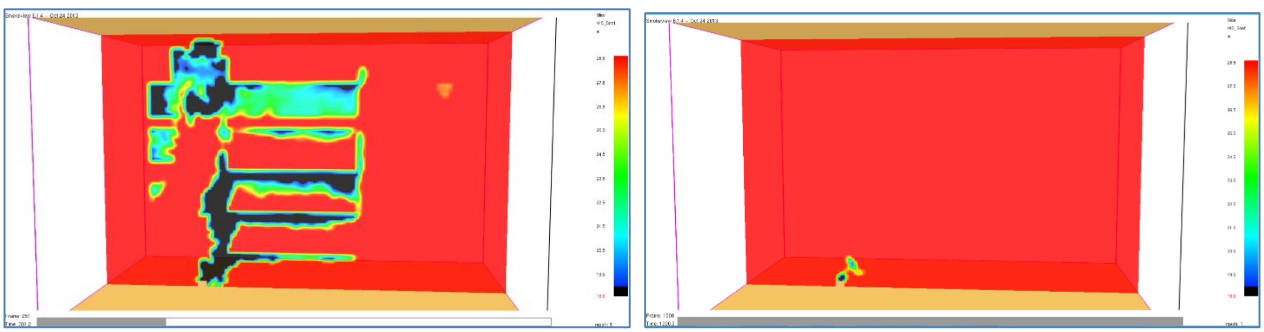


Figure 67 – Visibility Slice File for DFES-B at 300 and 1200 seconds

Note: Visibility is always over 13 m a height of 6 feet above each finished floor level (out of the fire plume), during 1200 seconds. Figure 67 shows a slice file at 300 second (left) because it is approximately the moment with the lowest visibility in this scenario (see the HRR curve), and even in that case the visibility is over 16 meter. Right picture show the visibility at 1200 seconds (also over 16 meters within all atrium)

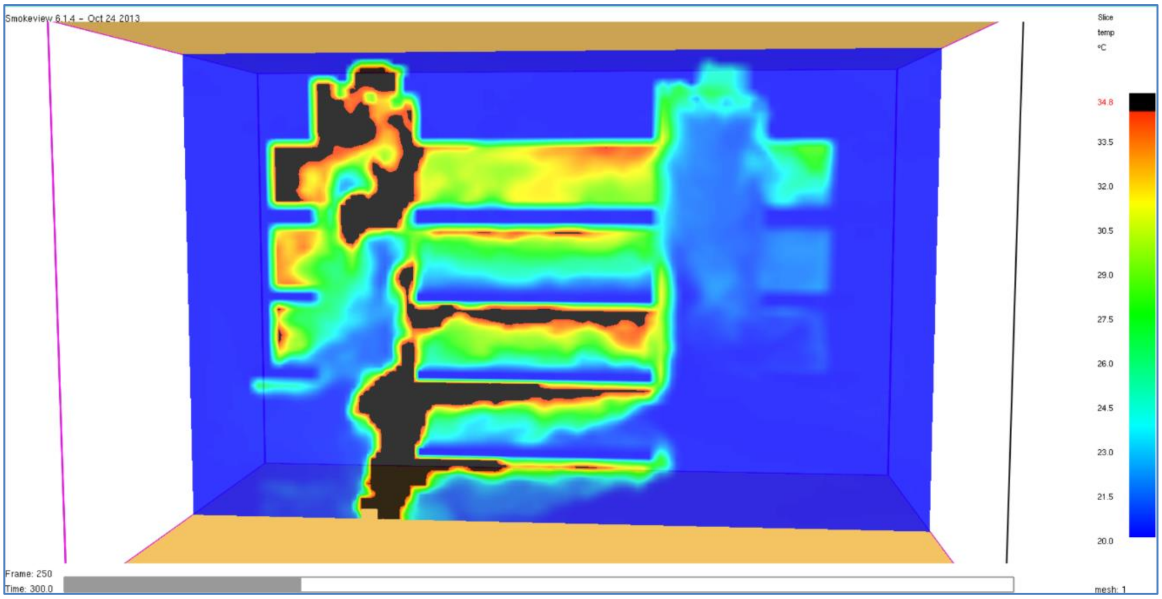


Figure 68 – Temperature Slice File for DFES-B at 300 seconds

Note: Temperature is always under 60 °C above each finished floor level (out of the fire plume), during 1200 seconds. Figure 68 shows a slice file at 300 second because it is approximately the moment with the highest temperature in this scenario (see the HRR curve), and even in that case the temperature is below 35 °C.

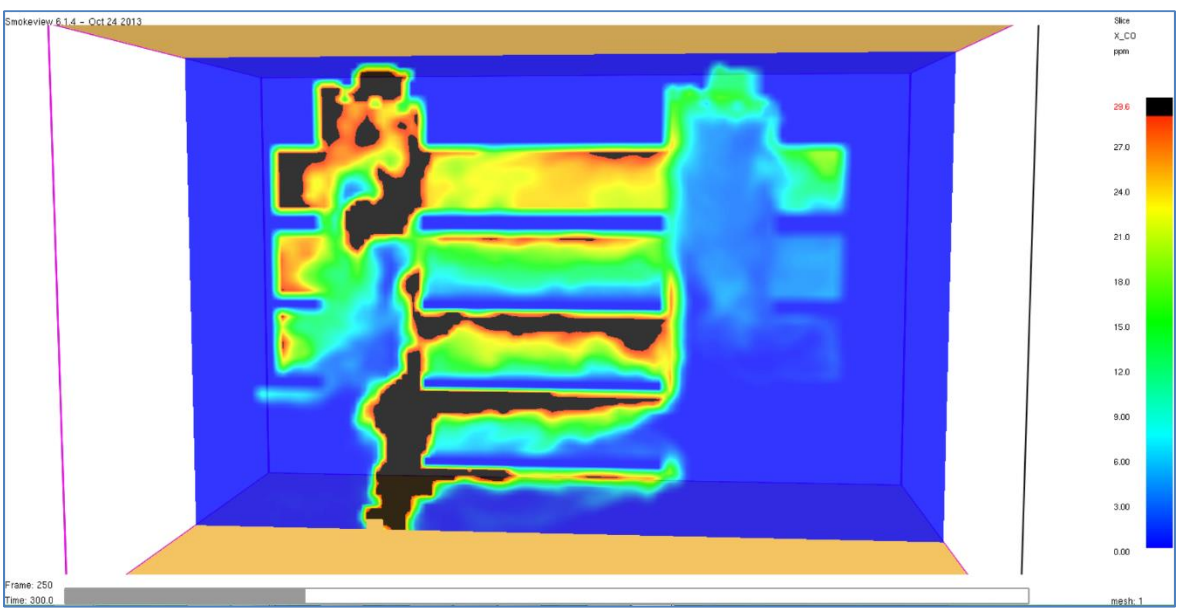


Figure 69 – CO concentration Slice File for DFES-B at 300 seconds

Note: CO concentration is always under 1000 ppm above each finished floor level (out of the fire plume), during 1200 seconds. Figure 69 shows a slice file at 300 second because it is approximately the moment with the highest CO concentration in this scenario (see the HRR curve), and even in that case the CO concentration is below 30 ppm.

9.19 FDS Results - Design Fire Exhaust System C

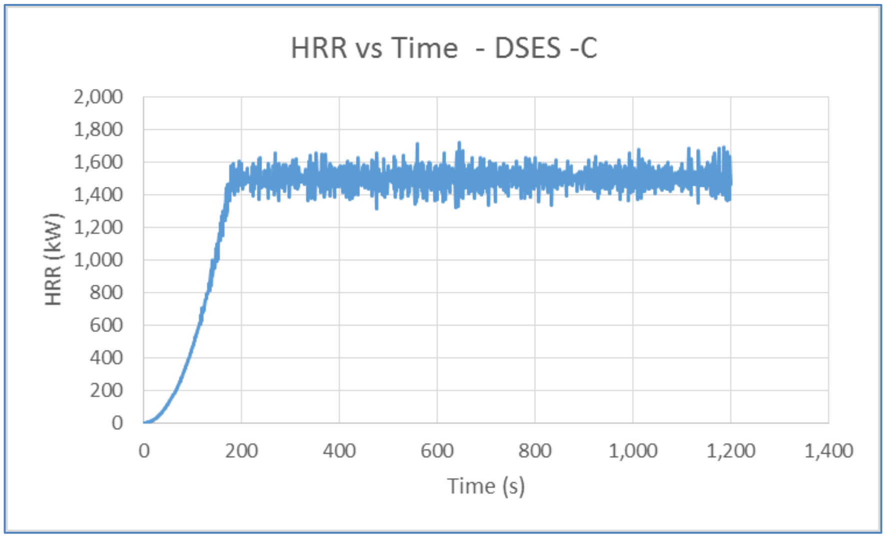


Figure 70 – HRR curve mode for DFES- C

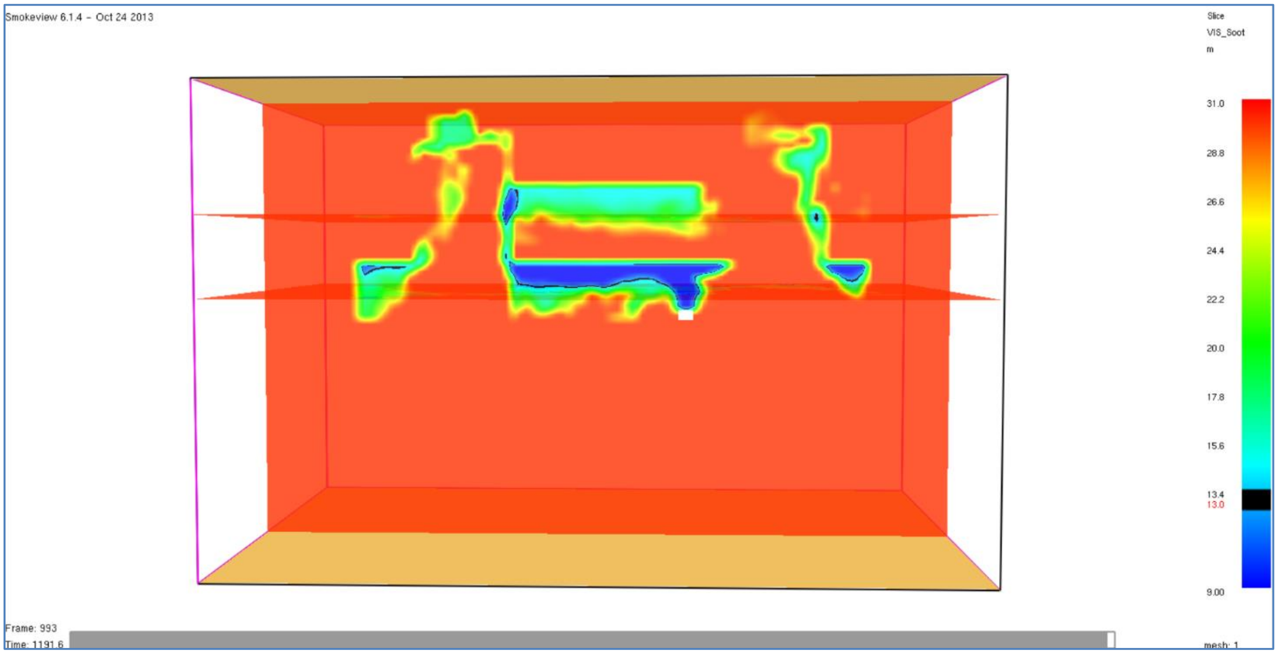


Figure 71 – Visibility Slice File for DFES-C at 1200 seconds

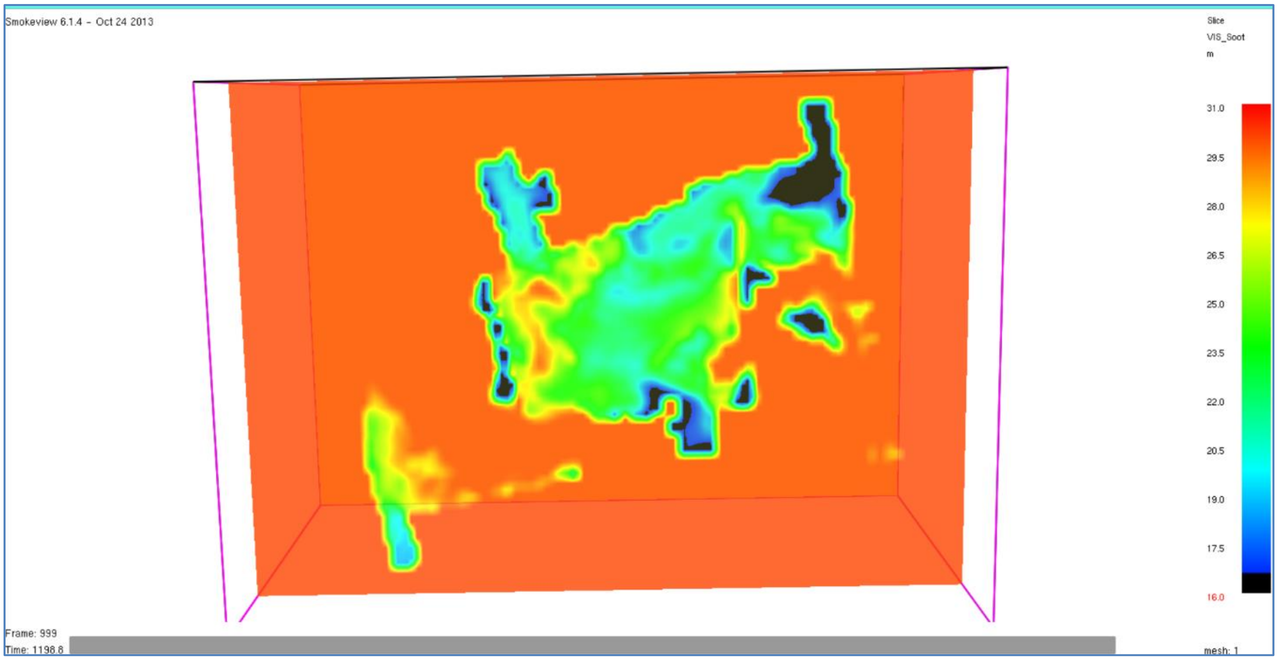


Figure 72 – Visibility Slice File for DFES-C at 1200 seconds at Level 6

Note: Visibility is always over 13 m a height of 6 feet above each finished floor level (out of the fire plume), during 1200 seconds.

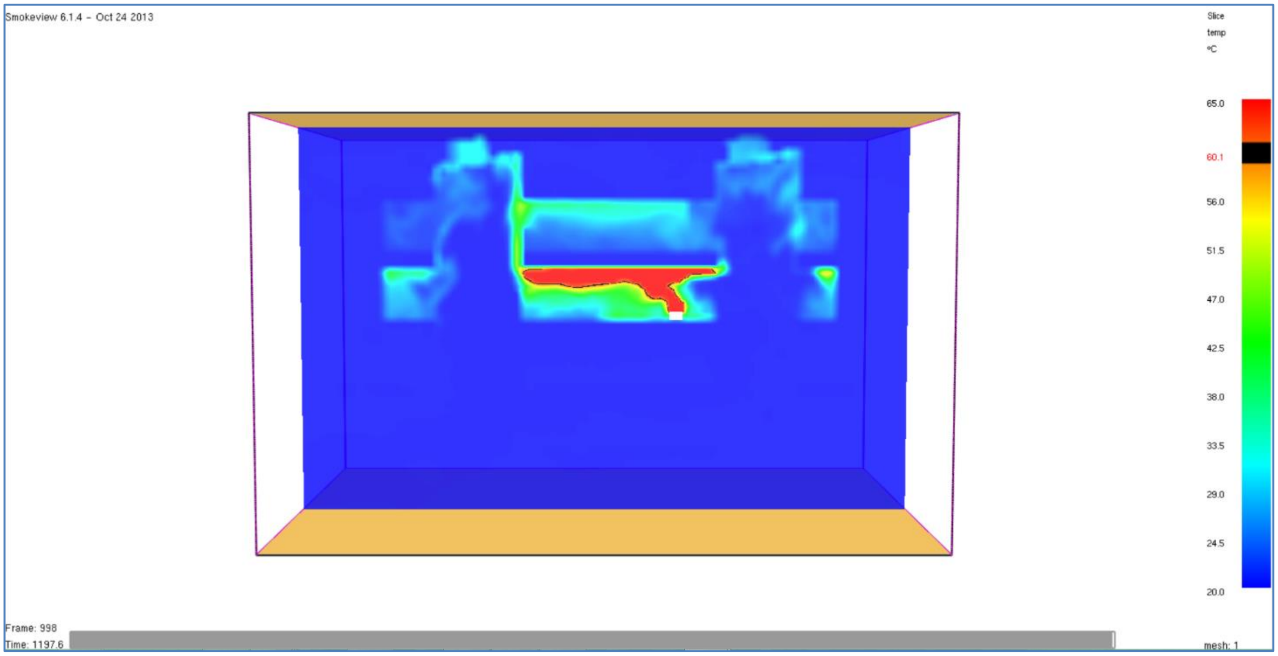


Figure 73 – Temperature Slice File for DFES-C at 1200 seconds

Note: Temperature is always under 60 °C above each finished floor level (out of the fire plume), during 1200 seconds.

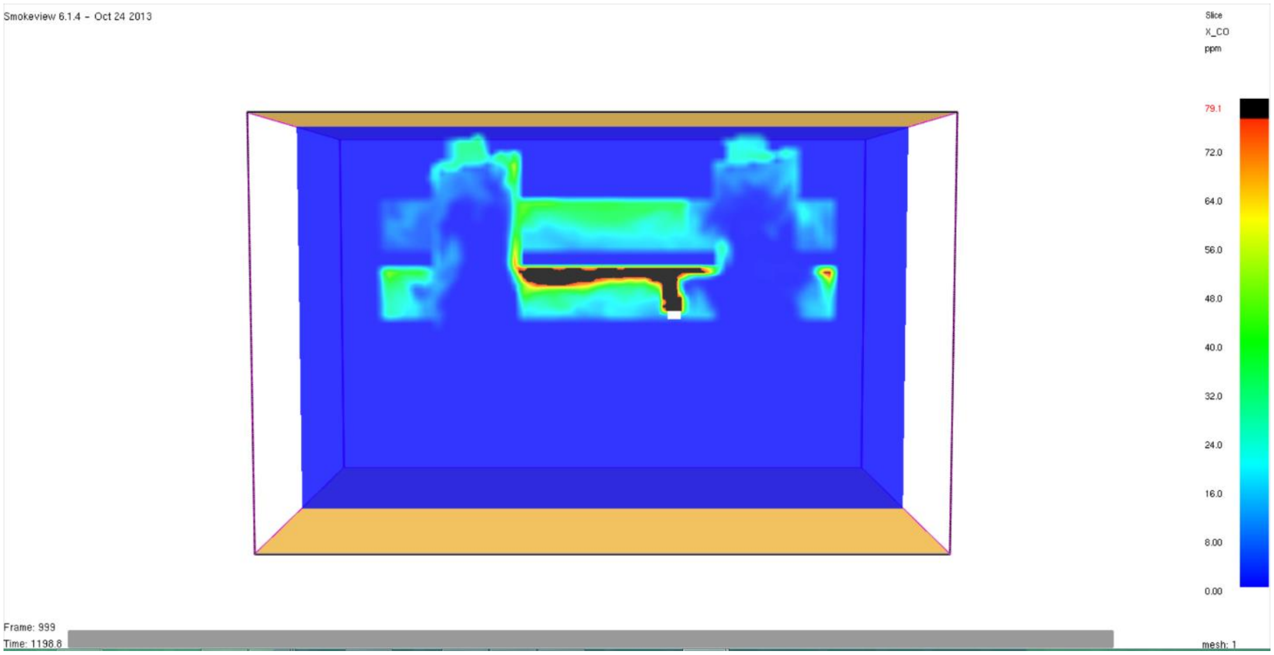


Figure 74 – CO concentration Slice File for DFES-C at 1200 seconds

Note: CO concentration is always under 1000 ppm above each finished floor level (out of the fire plume), during 1200 seconds

9.20 Requirements of Fire Safety and Evacuation Plans

The International Fire Code 2012 (IFC), Section 404 states the requirements of Fire Safety and Evacuation Plans for Group B buildings having an occupant load of 500 or more persons, or more than 100 persons above or below the lowest level of exit discharge.

The contents for Life Safety or Evacuation Plans are specified in Section 404.3 as follows:

Fire evacuation plans.

- Emergency egress or escape routes and whether evacuation of the building is to be complete or, where approved, by selected floors or areas only.
- Procedures for employees who must remain to operate critical equipment before evacuating.
- Procedures for assisted rescue for persons unable to use the general means of egress unassisted.
- Procedures for accounting for employees and occupants after evacuation has been completed.
- Identification and assignment of personnel responsible for rescue or emergency medical aid.
- The preferred and any alternative means of notifying occupants of a fire or emergency.
- The preferred and any alternative means of reporting fires and other emergencies to the fire department or designated emergency response organization.
- Identification and assignment of personnel who can be contacted for further information or explanation of duties under the plan.
- A description of the emergency voice/alarm communication system alert tone and preprogrammed voice messages, where provided.

Fire safety plans.

- The procedure for reporting a fire or other emergency.
- The life safety strategy and procedures for notifying, relocating or evacuating occupants, including occupants who need assistance.
- Site plans indicating the following:
    - The occupancy assembly point.
    - The locations of fire hydrants.
    - The normal routes of fire department vehicle access.
- Floor plans identifying the locations of the following:
    - Exits.

- Primary evacuation routes.
- Secondary evacuation routes.
- Accessible egress routes.
- Areas of refuge.
- Exterior areas for assisted rescue.
- Manual fire alarm boxes.
- Portable fire extinguishers.
- Occupant-use hose stations.
- Fire alarm annunciators and controls.

- A list of major fire hazards associated with the normal use and occupancy of the premises, including maintenance and housekeeping procedures.
- Identification and assignment of personnel responsible for maintenance of systems and equipment installed to prevent or control fires.
- Identification and assignment of personnel responsible for maintenance, housekeeping and controlling fuel hazard sources.

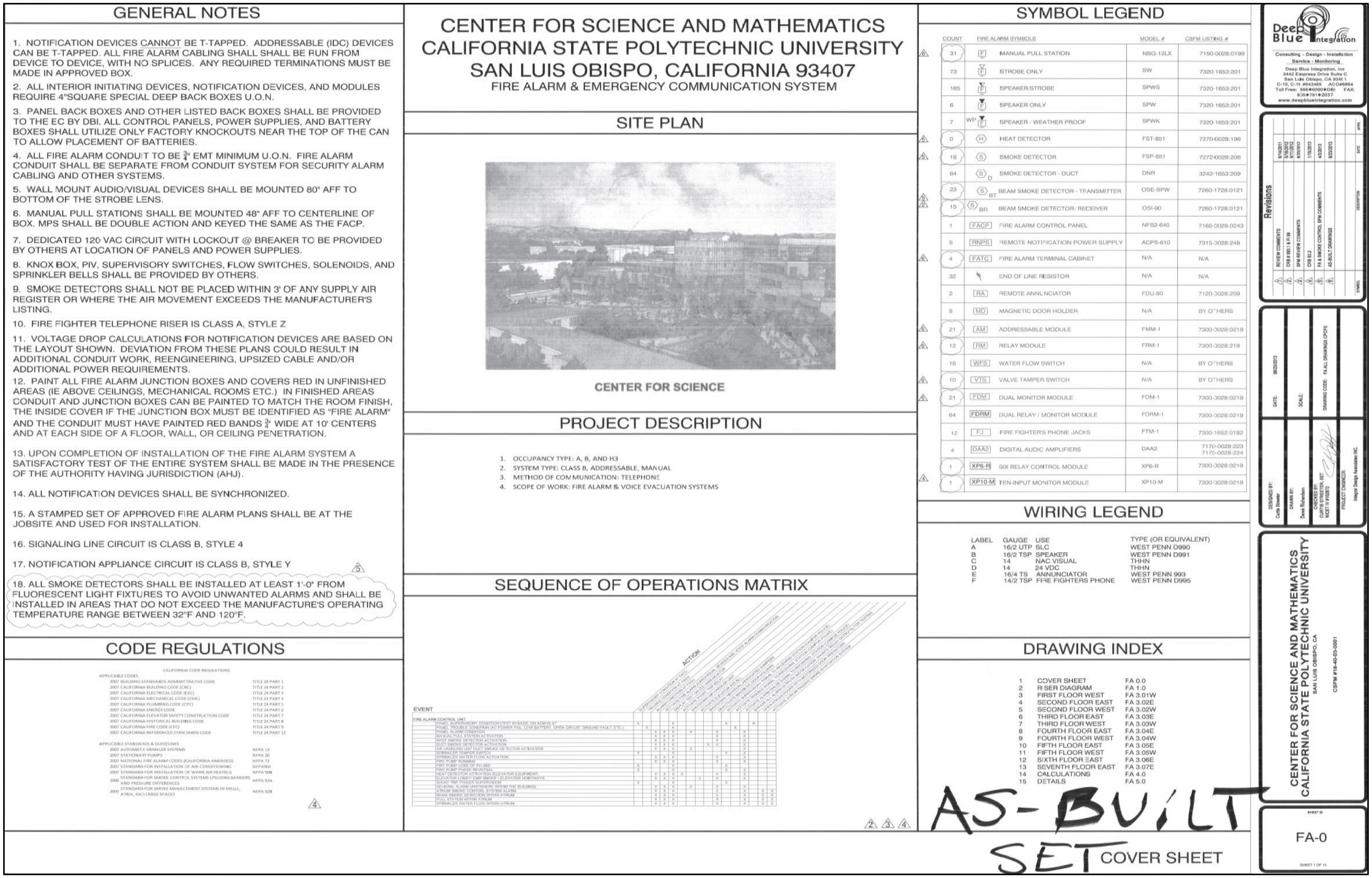
Maintenance: Fire safety and evacuation plans must be reviewed or updated annually or as necessitated by changes in staff assignments, occupancy or the physical arrangement of the building.

Availability: Fire safety and evacuation plans must be available in the workplace for reference and review by employees, and copies must be furnished to the fire code official for review upon request.

Distribution: The fire safety and evacuation plans must be distributed to the tenants and building service employees by the owner or owner’s agent. Tenants must distribute to their employees applicable parts of the fire safety plan affecting the employees’ actions in the event of a fire or other emergency.

10. Annexes

10.1 Fire Alarm and Detection System Design



GENERAL NOTES

1. NOTIFICATION DEVICES CANNOT BE T-TAPPED. ADDRESSABLE (IDC) DEVICES CAN BE T-TAPPED. ALL FIRE ALARM CABLING SHALL SHALL BE RUN FROM DEVICE TO DEVICE, WITH NO SPLICES. ANY REQUIRED TERMINATIONS MUST BE MADE IN APPROVED BOX.
2. ALL INTERIOR INITIATING DEVICES, NOTIFICATION DEVICES, AND MODULES REQUIRE 4"SQUARE SPECIAL DEEP BACK BOXES U.O.N.
3. PANEL BACK BOXES AND OTHER LISTED BACK BOXES SHALL BE PROVIDED TO THE EC BY DBI. ALL CONTROL PANELS, POWER SUPPLIES, AND BATTERY BOXES SHALL UTILIZE ONLY FACTORY KNOCKOUTS NEAR THE TOP OF THE CAN TO ALLOW PLACEMENT OF BATTERIES.
4. ALL FIRE ALARM CONDUIT TO BE ¾" EMT MINIMUM U.O.N. FIRE ALARM CONDUIT SHALL BE SEPARATE FROM CONDUIT SYSTEM FOR SECURITY ALARM CABLING AND OTHER SYSTEMS.
5. WALL MOUNT AUDIO/VISUAL DEVICES SHALL BE MOUNTED 80" AFF TO BOTTOM OF THE STROBE LENS.
6. MANUAL PULL STATIONS SHALL BE MOUNTED 48" AFF TO CENTERLINE OF BOX. MPS SHALL BE DOUBLE ACTION AND KEYED THE SAME AS THE FACP.
7. DEDICATED 120 VAC CIRCUIT WITH LOCKOUT @ BREAKER TO BE PROVIDED BY OTHERS AT LOCATION OF PANELS AND POWER SUPPLIES.
8. KNOX BOX, PIV, SUPERVISORY SWITCHES, FLOW SWITCHES, SOLENOIDS, AND SPRINKLER BELLS SHALL BE PROVIDED BY OTHERS.
9. SMOKE DETECTORS SHALL NOT BE PLACED WITHIN 3' OF ANY SUPPLY AIR REGISTER OR WHERE THE AIR MOVEMENT EXCEEDS THE MANUFACTURER'S LISTING.
10. FIRE FIGHTER TELEPHONE RISER IS CLASS A, STYLE Z
11. VOLTAGE DROP CALCULATIONS FOR NOTIFICATION DEVICES ARE BASED ON THE LAYOUT SHOWN. DEVIATION FROM THESE PLANS COULD RESULT IN ADDITIONAL CONDUIT WORK, REENGINEERING, UPSIZED CABLE AND/OR ADDITIONAL POWER REQUIREMENTS.
12. PAINT ALL FIRE ALARM JUNCTION BOXES AND COVERS RED IN UNFINISHED AREAS (IE ABOVE CEILINGS, MECHANICAL ROOMS ETC.) IN FINISHED AREAS CONDUIT AND JUNCTION BOXES CAN BE PAINTED TO MATCH THE ROOM FINISH, THE INSIDE COVER IF THE JUNCTION BOX MUST BE IDENTIFIED AS "FIRE ALARM" AND THE CONDUIT MUST HAVE PAINTED RED BANDS ¾" WIDE AT 10' CENTERS AND AT EACH SIDE OF A FLOOR, WALL, OR CEILING PENETRATION.
13. UPON COMPLETION OF INSTALLATION OF THE FIRE ALARM SYSTEM A SATISFACTORY TEST OF THE ENTIRE SYSTEM SHALL BE MADE IN THE PRESENCE OF THE AUTHORITY HAVING JURISDICTION (AHJ).
14. ALL NOTIFICATION DEVICES SHALL BE SYNCHRONIZED.
15. A STAMPED SET OF APPROVED FIRE ALARM PLANS SHALL BE AT THE JOBSITE AND USED FOR INSTALLATION.
16. SIGNALING LINE CIRCUIT IS CLASS B, STYLE 4
17. NOTIFICATION APPLIANCE CIRCUIT IS CLASS B, STYLE Y
18. ALL SMOKE DETECTORS SHALL BE INSTALLED AT LEAST 1'-0" FROM FLUORESCENT LIGHT FIXTURES TO AVOID UNWANTED ALARMS AND SHALL BE INSTALLED IN AREAS THAT DO NOT EXCEED THE MANUFACTURE'S OPERATING TEMPERATURE RANGE BETWEEN 32°F AND 120°F.

CODE REGULATIONS

CENTER FOR SCIENCE AND MATHEMATICS
CALIFORNIA STATE POLYTECHNIC UNIVERSITY
SAN LUIS OBISPO, CALIFORNIA 93407
FIRE ALARM & EMERGENCY COMMUNICATION SYSTEM

SITE PLAN

CENTER FOR SCIENCE

PROJECT DESCRIPTION

1. OCCUPANCY TYPE: A, B, AND H3
2. SYSTEM TYPE: CLASS B, ADDRESSABLE, MANUAL
3. METHOD OF COMMUNICATION: TELEPHONE
4. SCOPE OF WORK: FIRE ALARM & VOICE EVACUATION SYSTEMS

SEQUENCE OF OPERATIONS MATRIX

SYMBOL LEGEND

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

WIRING LEGEND

LABEL	GAUGE	USE	TYPE (OR EQUIVALENT)
A	16/2 UTP	SLC	WEST PENN D990
B	16/2 TSP	SPEAKER	WEST PENN D991
C	14	NAC VISUAL	THHN
D	14	24 VDC	THHN
E	16/4 TS	ANNUNCIATOR	WEST PENN 993
F	14/2 TSP	FIRE FIGHTERS PHONE	WEST PENN D995

DRAWING INDEX

1	COVER SHEET	FA 0.0
2	RISER DIAGRAM	FA 1.0
3	FIRST FLOOR WEST	FA 3.01W
4	SECOND FLOOR EAST	FA 3.02E
5	SECOND FLOOR WEST	FA 3.02W
6	THIRD FLOOR EAST	FA 3.03E
7	THIRD FLOOR WEST	FA 3.03W
8	FOURTH FLOOR EAST	FA 3.04E
9	FOURTH FLOOR WEST	FA 3.04W
10	FIFTH FLOOR EAST	FA 3.05E
11	FIFTH FLOOR WEST	FA 3.05W
12	SIXTH FLOOR EAST	FA 3.06E
13	SEVENTH FLOOR EAST	FA 3.07E
14	CALCULATIONS	FA 4.0
15	DETAILS	FA 5.0

AS-BUILT SET

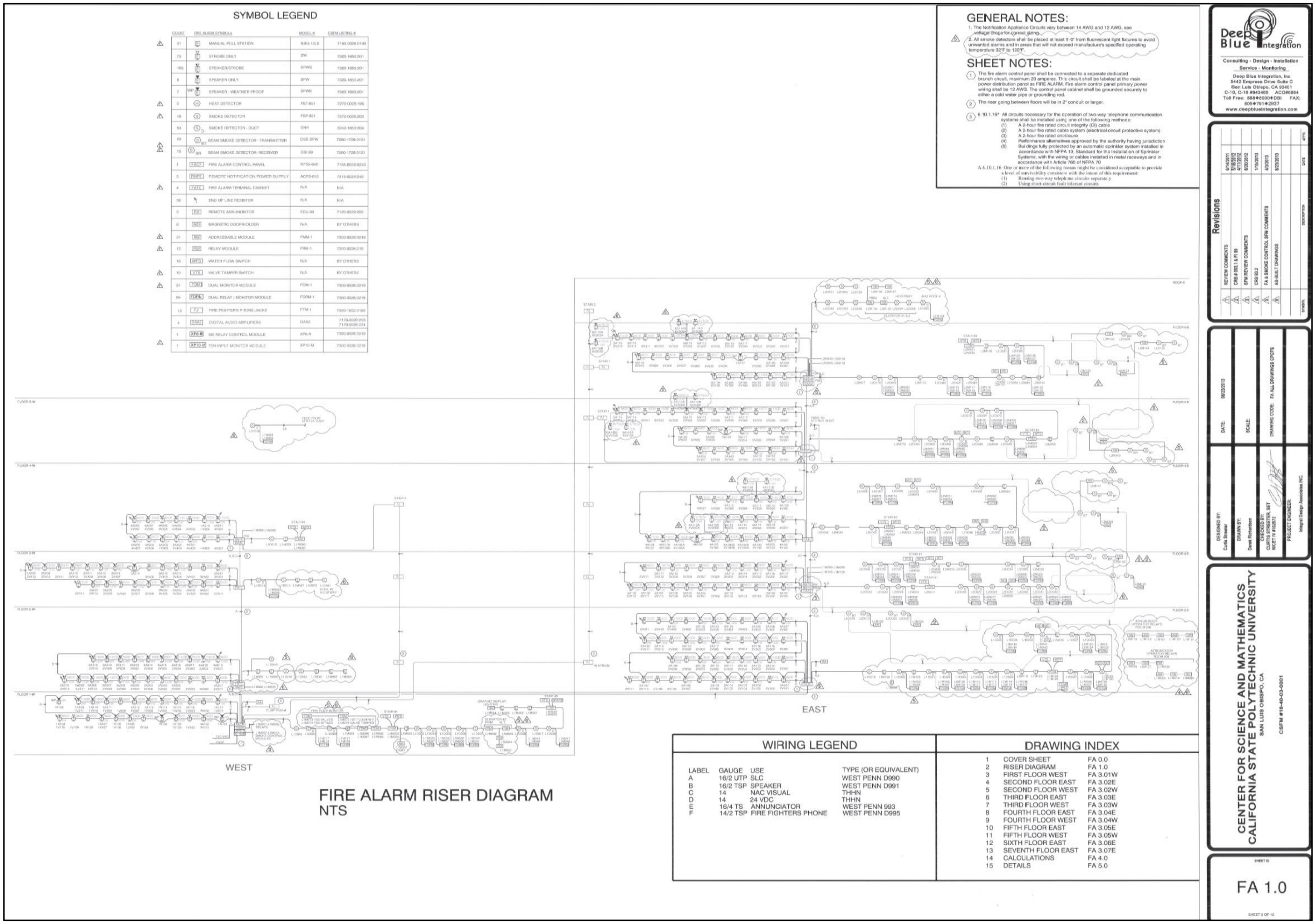
COVER SHEET

Deep Blue Integration

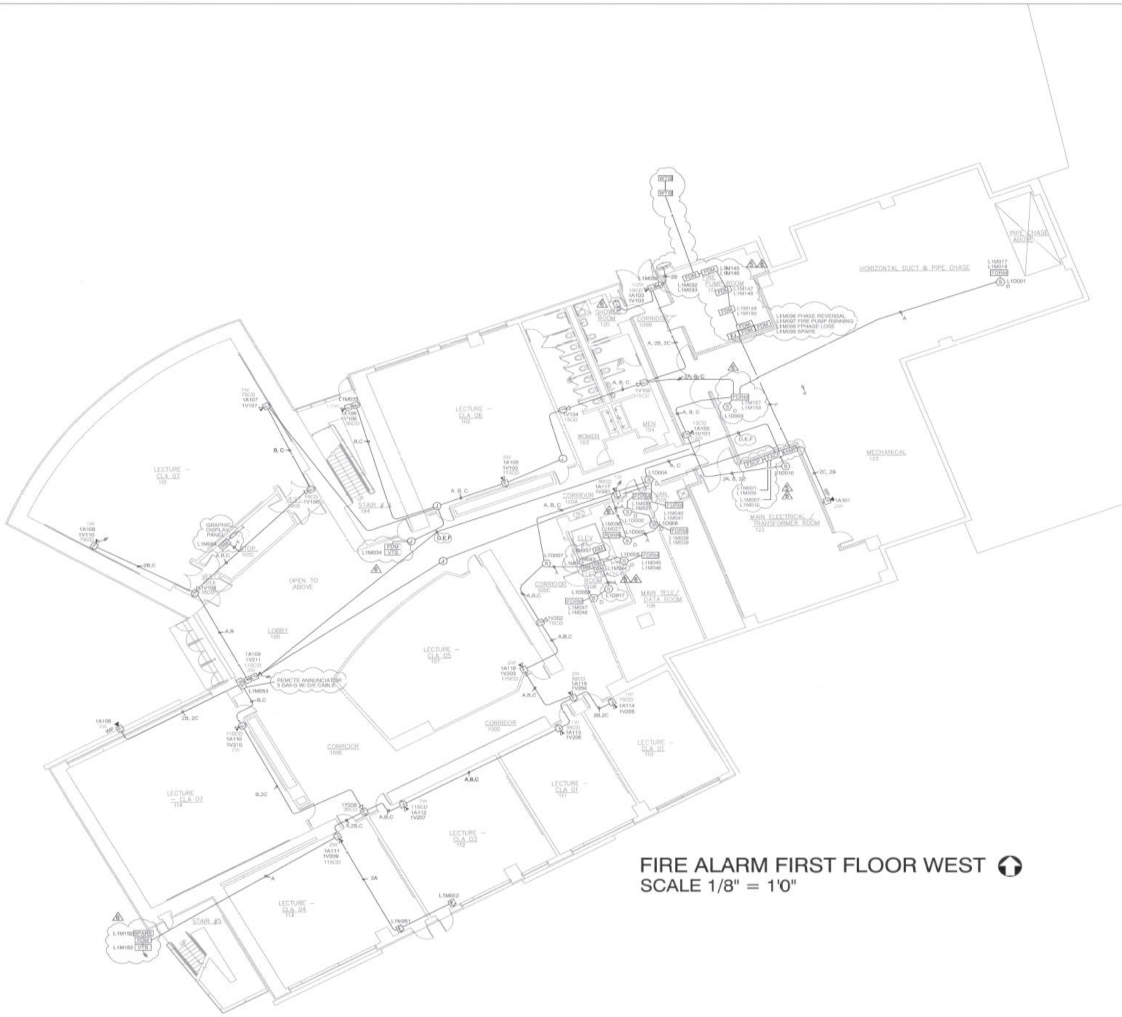
Revisions

CENTER FOR SCIENCE AND MATHEMATICS
CALIFORNIA STATE POLYTECHNIC UNIVERSITY

FA-0



SYMBOL LEGEND
GENERAL NOTES:
1. The Notification Appliance Circuits vary between 14 AWG and 12 AWG. see voltage drops for correct sizing.
2. All smoke detectors shall be placed at least 1'-0" from fluorescent light fixtures to avoid unwanted alarms and in areas that will not exceed manufacture's specified operating temperature 32°F to 120°F.
SHEET NOTES:
1 The fire alarm control panel shall be connected to a separate dedicated branch circuit, maximum 20 amperes. This circuit shall be labeled at the main power distribution panel as FIRE ALARM. Fire alarm control panel primary power wiring shall be 12 AWG. The control panel cabinet shall be grounded securely to either a cold water pipe or grounding rod.
2 The riser going between floors will be in 2" conduit or larger.
3 6.10.1.16* All circuits necessary for the operation of two-way telephone communication systems shall be installed using one of the following methods:
(1) A 2-hour fire rated circuit integrity (CI) cable
(2) A 2-hour fire rated cable system (electrical circuit protective system)
(3) A 2-hour fire rated enclosure
(4) Performance alternatives approved by the authority having jurisdiction
(5) Buildings fully protected by an automatic sprinkler system installed in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems, with the wiring or cables installed in metal raceways and in accordance with Article 760 of NFPA 70
A.6.10.1.16 One or more of the following means might be considered acceptable to provide a level of survivability consistent with the intent of this requirement:
(1) Routing two-way telephone circuits separately
(2) Using short-circuit fault tolerant circuits
Deep Blue Integration
Consulting - Design - Installation
Service - Monitoring
Deep Blue Integration, Inc
3442 Empresa Drive Suite C
San Luis Obispo, CA 93401
C-10, C-16 #943465 ACO#6864
Toll Free: 888♦6000♦DBI FAX: 805♦791♦2037
www.deepblueintegration.com
Revisions
EAST
WEST
FIRE ALARM RISER DIAGRAM
NTS
WIRING LEGEND
LABEL GAUGE USE TYPE (OR EQUIVALENT)
A 16/2 UTP SLC WEST PENN D990
B 16/2 TSP SPEAKER WEST PENN D991
C 14 NAC VISUAL THHN
D 14 24 VDC THHN
E 16/4 TS ANNUNCIATOR WEST PENN 993
F 14/2 TSP FIRE FIGHTERS PHONE WEST PENN D995
DRAWING INDEX
1 COVER SHEET FA 0.0
2 RISER DIAGRAM FA 1.0
3 FIRST FLOOR WEST FA 3.01W
4 SECOND FLOOR EAST FA 3.02E
5 SECOND FLOOR WEST FA 3.02W
6 THIRD FLOOR EAST FA 3.03E
7 THIRD FLOOR WEST FA 3.03W
8 FOURTH FLOOR EAST FA 3.04E
9 FOURTH FLOOR WEST FA 3.04W
10 FIFTH FLOOR EAST FA 3.05E
11 FIFTH FLOOR WEST FA 3.05W
12 SIXTH FLOOR EAST FA 3.06E
13 SEVENTH FLOOR EAST FA 3.07E
14 CALCULATIONS FA 4.0
15 DETAILS FA 5.0
CENTER FOR SCIENCE AND MATHEMATICS
CALIFORNIA STATE POLYTECHNIC UNIVERSITY
FA 1.0



FIRE ALARM FIRST FLOOR WEST
SCALE 1/8" = 1'0"

SYMBOL LEGEND

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

WIRING LEGEND

LABEL	GAUGE	USE	TYPE (OR EQUIVALENT)
A	16/2 UTP	SLC	WEST PENN D990
B	16/2 TSP	SPEAKER	WEST PENN D991
C	14	NAC VISUAL	THHN
D	14	24 VDC	THHN
E	16/4 TS	ANNUNCIATOR	WEST PENN 993
F	14/2 TSP	FIRE FIGHTERS PHONE	WEST PENN D995

DRAWING INDEX

1	COVER SHEET	FA 0.0
2	RISER DIAGRAM	FA 1.0
3	FIRST FLOOR WEST	FA 3.01W
4	SECOND FLOOR EAST	FA 3.02E
5	SECOND FLOOR WEST	FA 3.02W
6	THIRD FLOOR EAST	FA 3.03E
7	THIRD FLOOR WEST	FA 3.03W
8	FOURTH FLOOR EAST	FA 3.04E
9	FOURTH FLOOR WEST	FA 3.04W
10	FIFTH FLOOR EAST	FA 3.05E
11	FIFTH FLOOR WEST	FA 3.05W
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13	SEVENTH FLOOR EAST	FA 3.07E
14	CALCULATIONS	FA 4.0
15	DETAILS	FA 5.0

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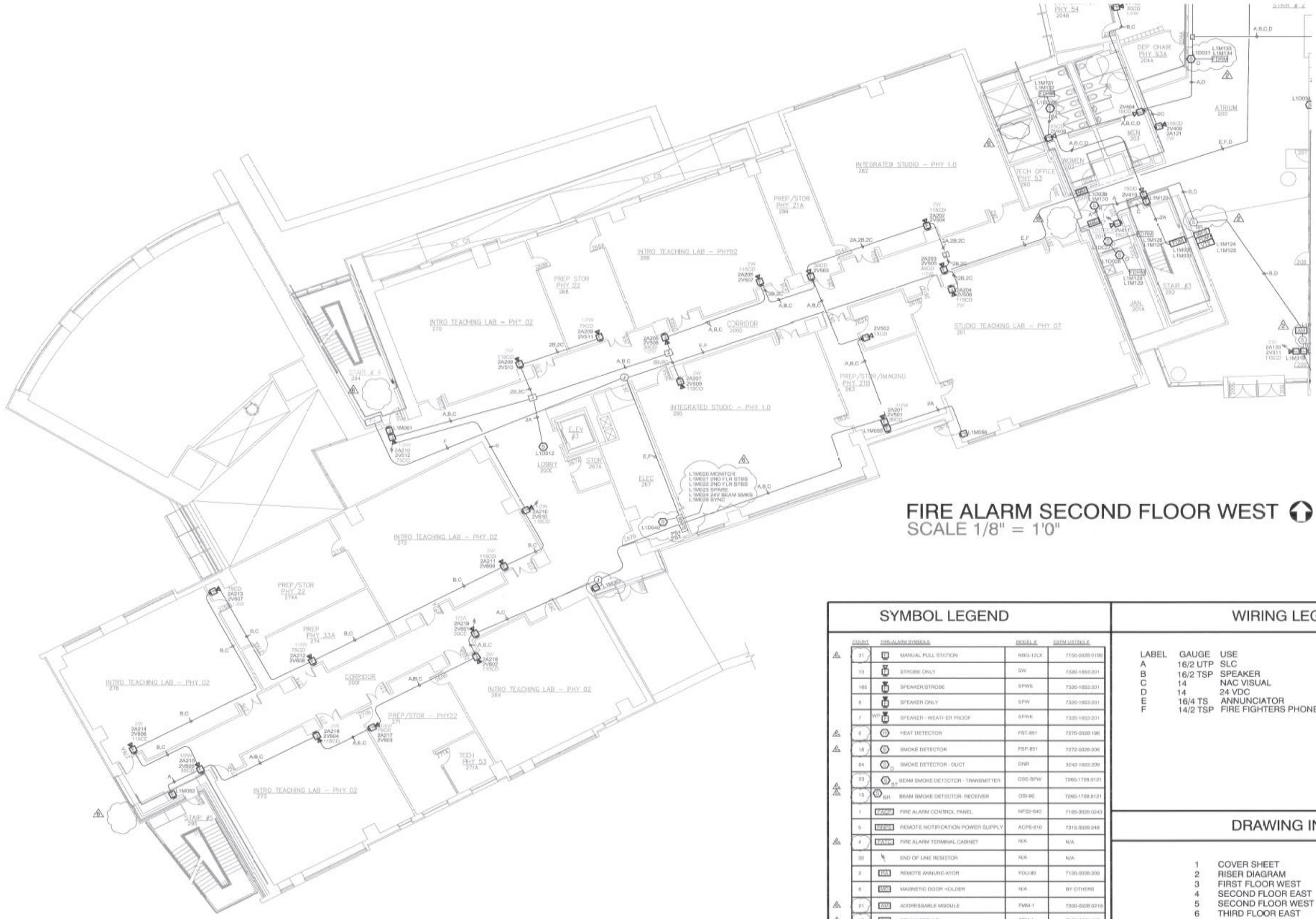
FA 3.01W



SYMBOL LEGEND

COUNT	FIRE ALARM SYMBOLS	MODEL #	CSFM LISTING #
31	MANUAL PULL STATION	NBG-12LX	7150-0028:0199
73	STROBE ONLY	SW	7320-1653:201
165	SPEAKER/STROBE	SPWS	7320-1653:201
6	SPEAKER ONLY	SPW	7320-1653:201
7	SPEAKER - WEATHER PROOF	SPWK	7320-1653:201
0	HEAT DETECTOR	FST-851	7270-0028:196
18	SMOKE DETECTOR	FSP-851	7272-0028:206
64	SMOKE DETECTOR - DUCT	DNR	3242-1653:209
23	BEAM SMOKE DETECTOR - TRANSMITTER	OSE-SPW	7260-1728:0121
15	BEAM SMOKE DETECTOR- RECEIVER	OSI-90	7260-1728:0121
1	FIRE ALARM CONTROL PANEL	NFS2-640	7165-0028:0243
5	REMOTE NOTIFICATION POWER SUPPLY	ACPS-610	7315-0028:246
4	FIRE ALARM TERMINAL CABINET	N/A	N/A
32	END OF LINE RESISTOR	N/A	N/A
2	REMOTE ANNUNCIATOR	FDU-80	7120-0028:209
8	MAGNETIC DOOR HOLDER	N/A	BY OTHERS
21	ADDRESSABLE MODULE	FMM-1	7300-0028:0219
12	RELAY MODULE	FRM-1	7300-0028:219
16	WATER FLOW SWITCH	N/A	BY OTHERS
10	VALVE TAMPER SWITCH	N/A	BY OTHERS
21	DUAL MONITOR MODULE	FDM-1	7300-0028:0219
64	DUAL RELAY / MONITOR MODULE	FDRM-1	7300-0028:0219
12	FIRE FIGHTER'S PHONE JACKS	FTM-1	7300-1652:0182
4	DIGITAL AUDIO AMPLIFIERS	DAA2	7170-0028:223 7170-0028:224
1	SIX RELAY CONTROL MODULE	XP6-R	7300-0028:0219
1	TEN-INPUT MONITOR MODULE	XP10-M	7300-0028:0219

WIRING LEGEND

LABEL	GAUGE	USE	TYPE (OR EQUIVALENT)
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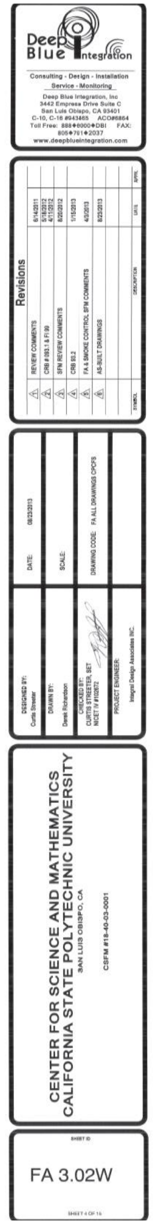

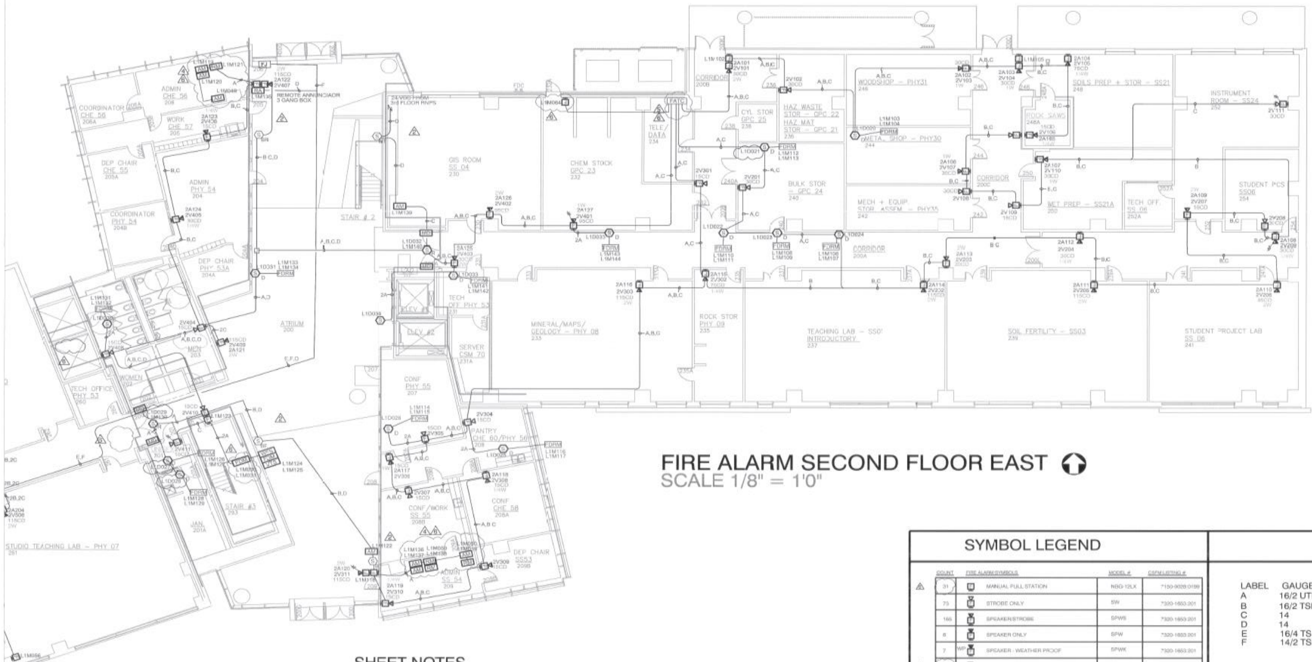

SHEET NOTES

1. PROVIDE FIRE ALARM BEAM DETECTORS TRANSMITTER AND RECEIVER. INTERLOCK WITH SMOKE EVACUATION SYSTEM SUCH THAT WHEN BEAM DETECTOR IS ACTIVATED, SMOKE EVACUATION SYSTEM IS ACTIVATED. REFER TO DETAIL 4 & 5/FA5.0.
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7	WP SPEAKER - WEATHER PROOF	SPWK	7320-1653:201
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18	SMOKE DETECTOR	FSP-851	7272-0028:206
64	SMOKE DETECTOR - DUCT	DNR	3242-1653:209
23	BEAM SMOKE DETECTOR - TRANSMITTER	OSE-SPW	7260-1728:0121
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9	RNPS REMOTE NOTIFICATION POWER SUPPLY	ACPS-610	7315-0028:246
4	FATC FIRE ALARM TERMINAL CABINET	N/A	N/A
32	END OF LINE RESISTOR	N/A	N/A
2	RA REMOTE ANNUNCIATOR	FDU-80	7120-0028:209
6	MD MAGNETIC DOOR HOLDER	N/A	BY OTHERS
21	AM ADDRESSABLE MODULE	FMM-1	7300-0028:0219
12	RM RELAY MODULE	FRM-1	7300-0028:219
16	WFS WATER FLOW SWITCH	N/A	BY OTHERS
10	VTS VALVE TAMPER SWITCH	N/A	BY OTHERS
21	FDM DUAL MONITOR MODULE	FDM-1	7300-0028:0219
64	FDRM DUAL RELAY / MONITOR MODULE	FDRM-1	7300-0028:0219
12	FJ FIRE FIGHTER'S PHONE JACKS	FTM-1	7300-1652:0182
4	DAA2 DIGITAL AUDIO AMPLIFIERS	DAA2	7170-0028:223 7170-0028:224
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E	16/4 TS	ANNUNCIATOR	WEST PENN 993
F	14/2 TSP	FIRE FIGHTERS PHONE	WEST PENN D995

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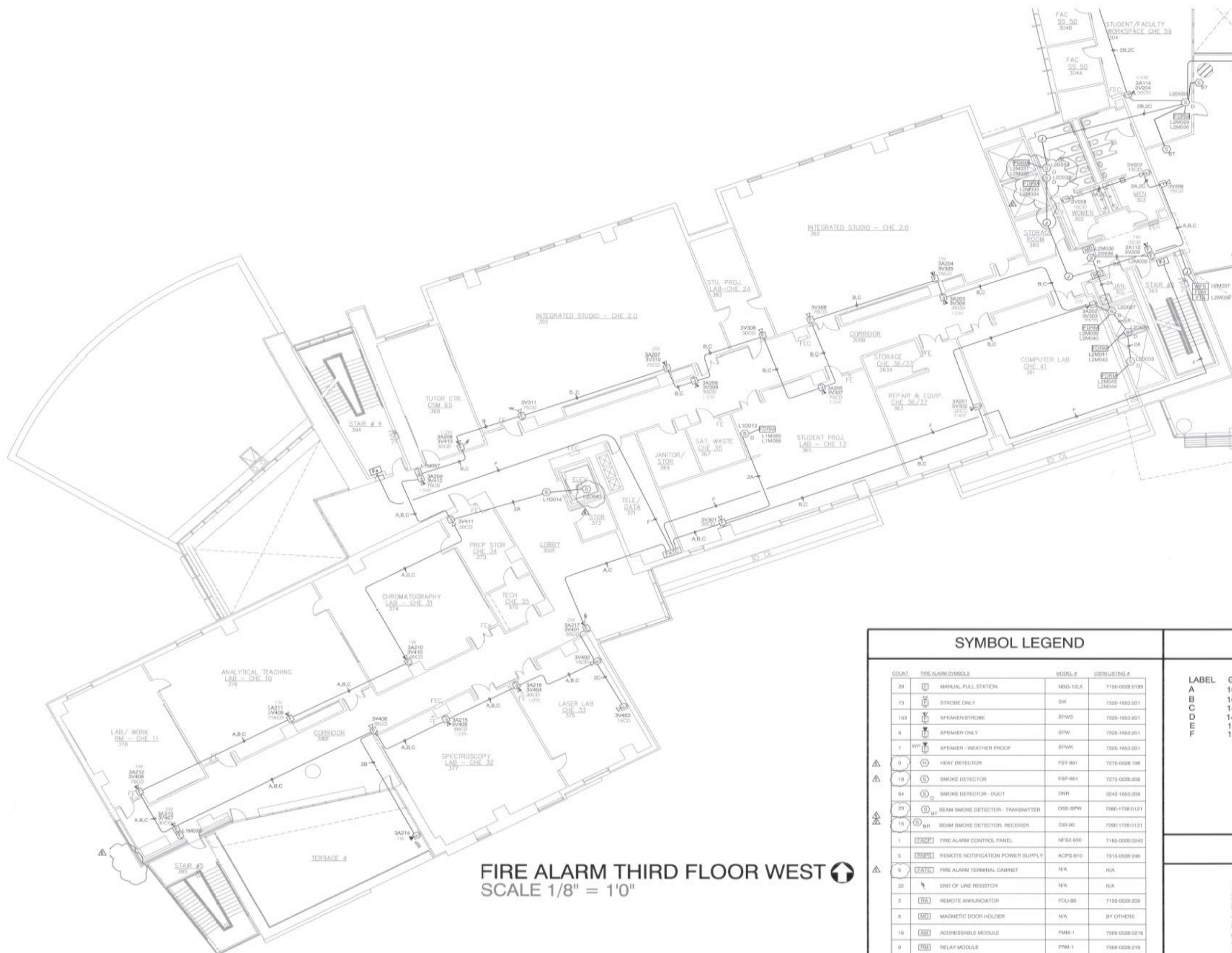
FA 3.02E



FIRE ALARM THIRD FLOOR WEST
SCALE 1/8" = 1'0"

SYMBOL LEGEND

COUNT	FIRE ALARM SYMBOLS	MODEL #	CSFM LISTING #
28	MANUAL PULL STATION	NBG-12LX	7150-0028:0199
73	STROBE ONLY	SW	7320-1653:201
153	SPEAKER/STROBE	SPWS	7320-1653:201
8	SPEAKER ONLY	SPW	7320-1653:201
7	WP SPEAKER - WEATHER PROOF	SPWK	7320-1653:201
9	HEAT DETECTOR	FST-851	7270-0028:198
18	SMOKE DETECTOR	FSP-851	7272-0028:206
64	SMOKE DETECTOR - DUCT	DNR	3242-1653:209
23	BEAM SMOKE DETECTOR - TRANSMITTER	OSE-SPW	7260-1728:0121
15	BEAM SMOKE DETECTOR- RECEIVER	OSI-90	7260-1728:0121
1	FACP FIRE ALARM CONTROL PANEL	NFS2-640	7165-0028:0243
5	RNPS REMOTE NOTIFICATION POWER SUPPLY	ACPS-610	7315-0028:248
5	FATC FIRE ALARM TERMINAL CABINET	N/A	N/A
32	END OF LINE RESISTOR	N/A	N/A
2	RA REMOTE ANNUNCIATOR	FDU-80	7120-0028:209
8	MD MAGNETIC DOOR HOLDER	N/A	BY OTHERS
19	AM ADDRESSABLE MODULE	FMM-1	7300-0028:0219
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16	WFS WATER FLOW SWITCH	N/A	BY OTHERS
22	VTS VALVE TAMPER SWITCH	N/A	BY OTHERS
21	FDM DUAL MONITOR MODULE	FDM-1	7300-0028:0219
64	FDRM DUAL RELAY / MONITOR MODULE	FDRM-1	7300-0028:0219
12	FJ FIRE FIGHTERS PHONE JACKS	FTM-1	7300-1652:0182
4	DAA2 DIGITAL AUDIO AMPLIFIERS	DAA2	7170-0028:223 7170-0028:224
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LABEL	GAUGE	USE	TYPE (OR EQUIVALENT)
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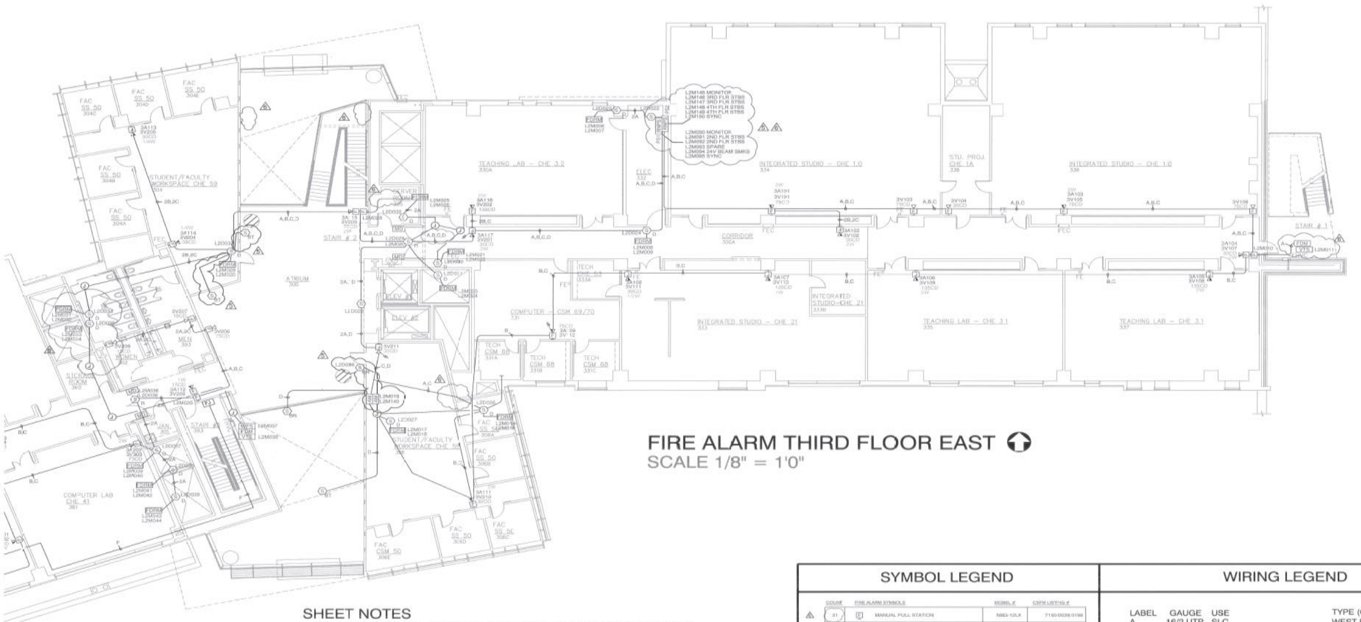
CSFM #18-40-03-0001

FA 3.03W



FIRE ALARM THIRD FLOOR EAST

SCALE 1/8" = 1'0"

SHEET NOTES

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4	FIRE ALARM TERMINAL CABINET	N/A	N/A
32	END OF LINE RESISTOR	N/A	N/A
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LABEL	GAUGE	USE	TYPE (OR EQUIVALENT)
A	16/2 UTP	SLC	WEST PENN D990
B	16/2 TSP	SPEAKER	WEST PENN D991
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C-10, C-16 #943465 ACO#6864
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Revisions

SYMBOL	DESCRIPTION	DATE	APPR.
1	REVIEW COMMENTS	6/14/2011	
2	CRB # 050.1 & FI 99	5/18/2012 4/11/2012	
3	SFM REVIEW COMMENTS	8/20/2012	
4	CRB 93.2	1/15/2013	
5	FA & SMOKE CONTROL SFM COMMENTS	4/3/2013	
6	AS BUILT DRAWINGS	8/23/2013	

DESIGNED BY: Curtis Streeter
DRAWN BY: Derek Richardson
CHECKED BY: CURTIS STREETER, SET NICET IV #102672
PROJECT ENGINEER: Integral Design Associates INC.
DATE: 08/23/2013
SCALE:
DRAWING CODE: FA ALL DRAWINGS CPCFS

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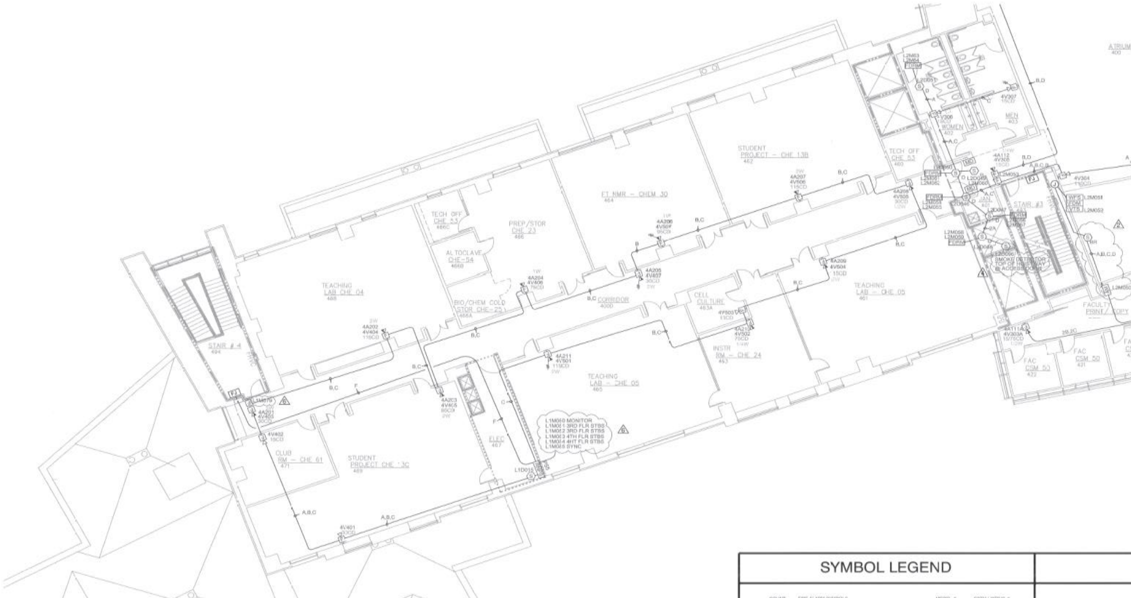
SHEET ID
FA 3.03E
SHEET 7 OF 16



FIRE ALARM FOURTH FLOOR WEST
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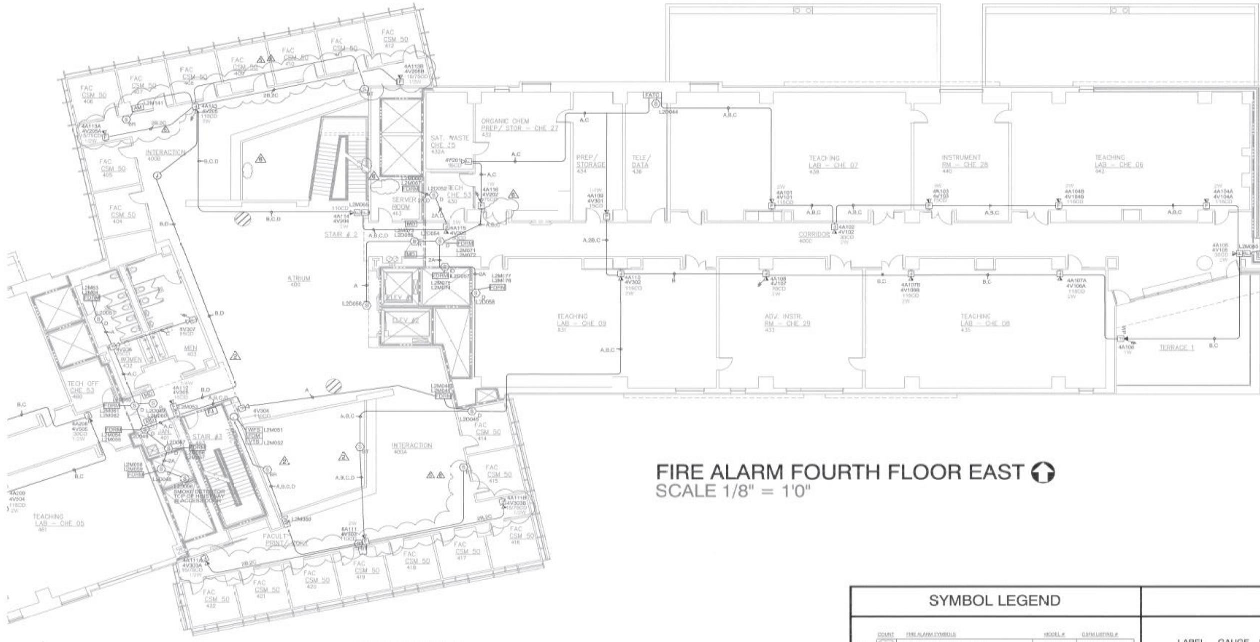

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64	FDRM DUAL RELAY / MONITOR MODULE	FDRM-1	7300-0028:0219
12	FJ FIRE FIGHTERS PHONE JACKS	FTM-1	7300-1852:0102
4	DAA2 DIGITAL AUDIO AMPLIFIERS	DAA2	7170-0028:223 7170-0028:224
1	XP6-R SIX RELAY CONTROL MODULE	XP6-R	7300-0028:0219
1	XP10-M TEN-INPUT MONITOR MODULE	XP10-M	7300-0028:0219

WIRING LEGEND

LABEL	GAUGE	USE	TYPE (OR EQUIVALENT)
A	16/2 UTP	SLC	WEST PENN D990
B	16/2 TSP	SPEAKER	WEST PENN D991
C	14	NAC VISUAL	THHN
D	14	24 VDC	THHN
E	16/4 TS	ANNUNCIATOR	WEST PENN 993
F	14/2 TSP	FIRE FIGHTERS PHONE	WEST PENN D995

DRAWING INDEX

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C-10, C-16 #943465 ACO#6864
Toll Free: 888♦6000♦DBI FAX: 805♦791♦2037
www.deepblueintegration.com

Revisions

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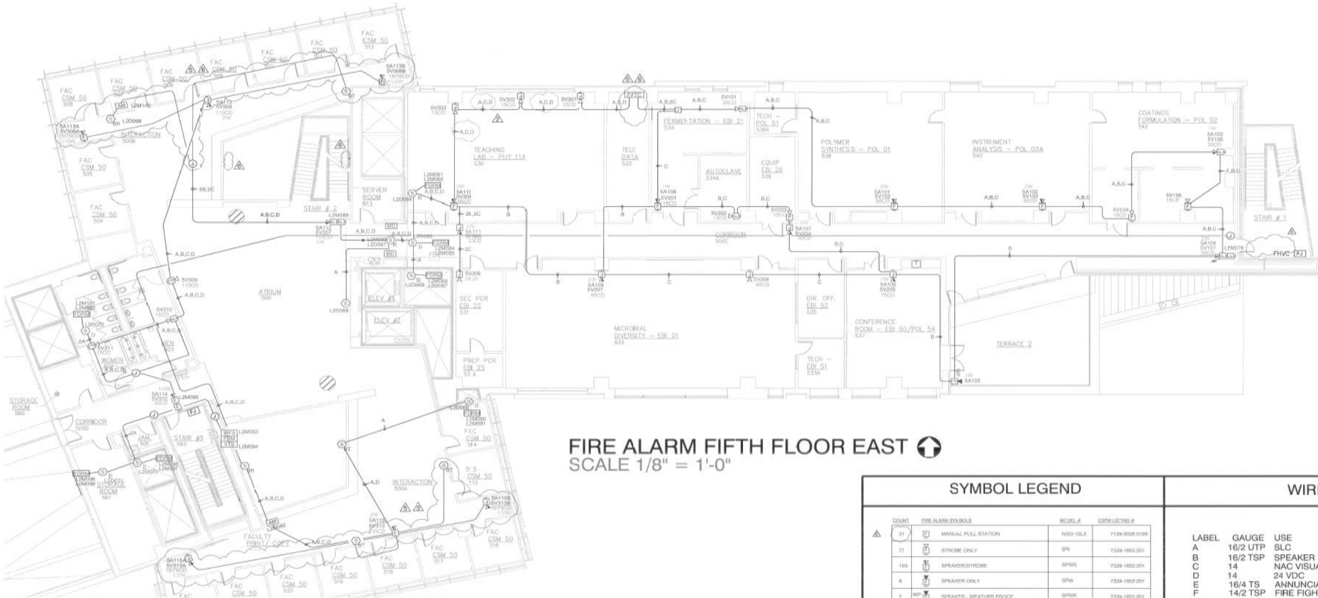
FA 3.04E



FIRE ALARM FIFTH FLOOR EAST

SCALE 1/8" = 1'-0"

SHEET NOTES

1 PROVIDE FIRE ALARM BEAM DETECTORS TRANSMITTER AND RECEIVER. INTERLOCK WITH SMOKE EVACUATION SYSTEM SUCH THAT WHEN BEAM DETECTOR IS ACTIVATED, SMOKE EVACUATION SYSTEM IS ACTIVATED. REFER TO DETAIL 4 & 5/FA5.0.

2 ACTIVATION OF A MANUAL PULL STATION, BEAM DETECTOR OR SPRINKLER WATER FLOW WITHIN THE ATRIUM SHALL ACTIVATE ATRIUM SMOKE EVACUATION SYSTEM. SMOKE EVACUATION SYSTEM SHALL FUNCTION AS DIRECTED BY MECHANICAL DOCUMENTS. REFER TO DETAIL 9/M5.05 FOR ADDITIONAL INFORMATION.

3 ACTIVATION OF AN ALARM ANYWHERE WITHIN THE BUILDING SHALL SHUT DOWN ALL AIR HANDLING UNITS.

4 ACTIVATION OF THE ATRIUM SMOKE CONTROL SYSTEM SHALL OPEN ALL ATRIUM DOORS WITH MOTORIZED DOOR OPERATORS.

SYMBOL LEGEND

COUNT	FIRE ALARM SYMBOLS		MODEL #	CSFM LISTING #
31	F	MANUAL PULL STATION	NBG-12LX	7150-0028:0199
72		STROBE ONLY	SW	7320-1653:201
165		SPEAKER/STROBE	SPWS	7320-1653:201
8		SPEAKER ONLY	SPW	7320-1653:201
7	WP	SPEAKER - WEATHER PROOF	SPWK	7320-1653:201
0	H	HEAT DETECTOR	FST-851	7270-0028:198
11	S	SMOKE DETECTOR	FSP-851	7272-0028:206
64	S D	SMOKE DETECTOR - DUCT	DNR	3242-1653:209
22	S BT	BEAM SMOKE DETECTOR - TRANSMITTER	OSE-SPW	7260-1728:0121
12	S BR	BEAM SMOKE DETECTOR- RECEIVER	OSI-90	7260-1728:0121
1	FACP	FIRE ALARM CONTROL PANEL	NFS2-640	7165-0028:0243
5	RNPS	REMOTE NOTIFICATION POWER SUPPLY	ACPS-610	7315-0028:246
4	FATC	FIRE ALARM TERMINAL CABINET	N/A	N/A
32		END OF LINE RESISTOR	N/A	N/A
2	RA	REMOTE ANNUNCIATOR	FDU-80	7120-0028:209
8	MD	MAGNETIC DOOR HOLDER	N/A	BY OTHERS
21	AM	ADDRESSABLE MODULE	FMM-1	7300-0028:0219
12	RM	RELAY MODULE	FRM-1	7300-0028:219
18	WFS	WATER FLOW SWITCH	N/A	BY OTHERS
10	VTS	VALVE TAMPER SWITCH	N/A	BY OTHERS
21	FDM	DUAL MONITOR MODULE	FDM-1	7300-0028:0219
64	FDRM	DUAL RELAY / MONITOR MODULE	FDRM-1	7300-0028:0219
12	FJ	FIRE FIGHTERS PHONE JACKS	FTM-1	7300-1652:0182
4	DAA2	DIGITAL AUDIO AMPLIFIERS	DAA2	7170-0028:223 7170-0028:224
1	XP6-R	SIX RELAY CONTROL MODULE	XP6-R	7300-0028:0218
1	XP10-M	TEN-INPUT MONITOR MODULE	XP10-M	7300-0028:0219

WIRING LEGEND

LABEL	GAUGE	USE	TYPE (OR EQUIVALENT)
A	16/2 UTP	SLC	WEST PENN D990
B	16/2 TSP	SPEAKER	WEST PENN D991
C	14	NAC VISUAL	THHN
D	14	24 VDC	THHN
E	16/4 TS	ANNUNCIATOR	WEST PENN 993
F	14/2 TSP	FIRE FIGHTERS PHONE	WEST PENN D995

DRAWING INDEX

1	COVER SHEET	FA 0.0
2	RISER DIAGRAM	FA 1.0
3	FIRST FLOOR WEST	FA 3.01W
4	SECOND FLOOR EAST	FA 3.02E
5	SECOND FLOOR WEST	FA 3.02W
6	THIRD FLOOR EAST	FA 3.03E
7	THIRD FLOOR WEST	FA 3.03W
8	FOURTH FLOOR EAST	FA 3.04E
9	FOURTH FLOOR WEST	FA 3.04W
10	FIFTH FLOOR EAST	FA 3.05E
11	FIFTH FLOOR WEST	FA 3.05W
12	SIXTH FLOOR EAST	FA 3.06E
13	SEVENTH FLOOR EAST	FA 3.07E
14	CALCULATIONS	FA 4.0
15	DETAILS	FA 5.0

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Revisions

SYMBOL	DESCRIPTION	DATE	APPR.
1	REVIEW COMMENTS	6/14/2011	
2	CRB # 093.1 & FI 99	5/18/2012 4/11/2012	
3	SFM REVIEW COMMENTS	8/20/2012	
4	CRB 93.2	1/15/2013	
5	FA & SMOKE CONTROL SFM COMMENTS	4/3/2013	
6	AS-BUILT DRAWINGS	8/23/2013	

DESIGNED BY: Curtis Streeter
DRAWN BY: Derek Richardson
CHECKED BY: CURTIS STREETER, SET NICET IV #102672
PROJECT ENGINEER: Integral Design Associates INC.
DATE: 08/23/2013
SCALE:
DRAWING CODE: FA ALL DRAWINGS CPCFS

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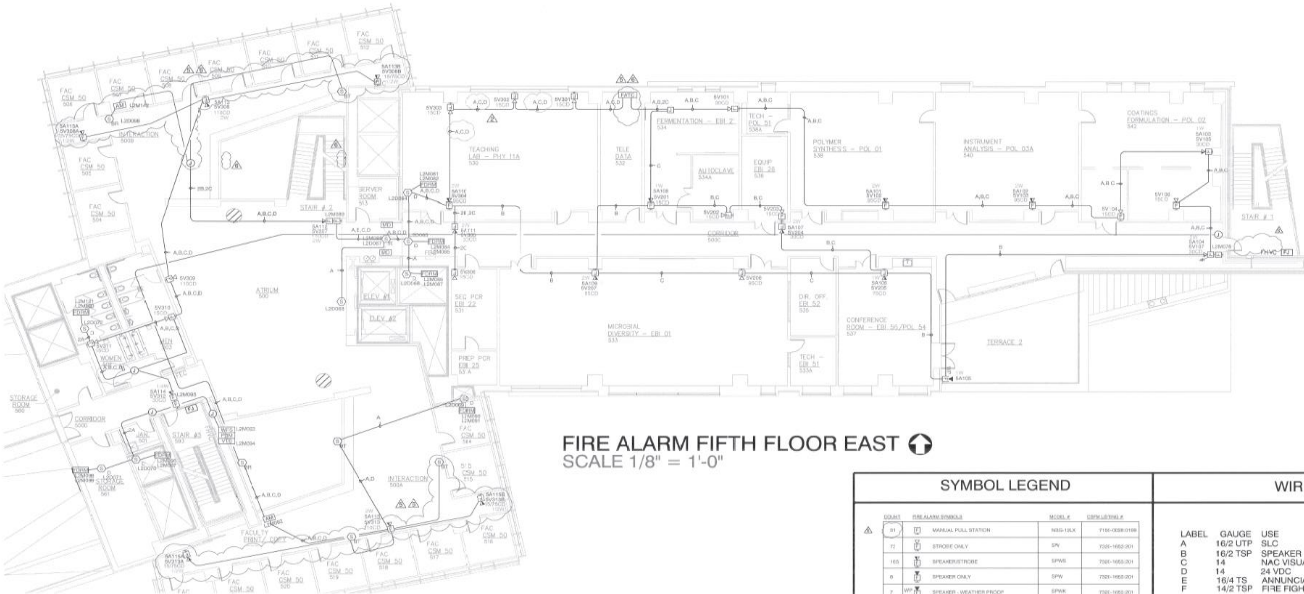
CSFM #18-40-03-0001

SHEET ID
FA 3.05E
SHEET 11 OF 15



FIRE ALARM FIFTH FLOOR EAST
SCALE 1/8" = 1'-0"

SHEET NOTES

1 PROVIDE FIRE ALARM BEAM DETECTORS TRANSMITTER AND RECEIVER. INTERLOCK WITH SMOKE EVACUATION SYSTEM SUCH THAT WHEN BEAM DETECTOR IS ACTIVATED SMOKE EVACUATION SYSTEM IS ACTIVATED. REFER TO DETAIL 4 & 5/FA5.0.

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SYMBOL LEGEND

COUNT	FIRE ALARM SYMBOLS	MODEL #	CSFM LISTING #
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72	STROBE ONLY	SPV	7320-1653:201
165	SPEAKER/STROBE	SPWS	7320-1653:201
6	SPEAKER ONLY	SPW	7320-1653:201
7	WP SPEAKER - WEATHER PROOF	SPWK	7320-1653:201
0	HEAT DETECTOR	FST-851	7270-0028:198
12	SMOKE DETECTOR	FSP-851	7272-0028:206
64	SMOKE DETECTOR - DUCT	DHR	3242-1653:209
20	BEAM SMOKE DETECTOR - TRANSMITTER	OSE-SPW	7260-1728:0121
16	BEAM SMOKE DETECTOR - RECEIVER	OSI-90	7260-1728:0121
1	FACP FIRE ALARM CONTROL PANEL	NFS2-640	7165-0028:0243
5	RNPS REMOTE NOTIFICATION POWER SUPPLY	ACPS-610	7312-0028:248
4	FATC FIRE ALARM TERMINAL CABINET	N/A	N/A
32	END OF LINE RESISTOR	N/A	N/A
2	RA REMOTE ANNUNCIATOR	FDU-80	7120-0028:209
8	MD MAGNETIC DOOR HOLDER	N/A	BY OTHERS
21	AM ADDRESSABLE MODULE	FMM-1	7300-0028:0219
12	RM RELAY MODULE	FRM-1	7300-0028:219
16	WFS WATER FLOW SWITCH	N/A	BY OTHERS
10	VTS VALVE TAMPER SWITCH	N/A	BY OTHERS
21	FDM DUAL MONITOR MODULE	FDM-1	7300-0028:0219
64	FDRM DUAL RELAY / MONITOR MODULE	FDRM-1	7300-0028:0219
12	FJ FIRE FIGHTER'S PHONE JACKS	FTM-1	7300-1652:0162
4	DAA2 DIGITAL AUDIO AMPLIFIERS	DAA2	7170-0028:223 7170-0028:224
1	XP6-R SIX RELAY CONTROL MODULE	XP6-R	7300-0028:0219
1	XP10-M TEN-INPUT MONITOR MODULE	XP10-M	7300-0028:0219

WIRING LEGEND

LABEL	GAUGE	USE	TYPE (OR EQUIVALENT)
A	16/2 UTP	SLC	WEST PENN D990
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C	14	NAC VISUAL	THHN
D	14	24 VDC	THHN
E	16/4 TS	ANNUNCIATOR	WEST PENN 993
F	14/2 TSP	FIRE FIGHTERS PHONE	WEST PENN D995

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7	THIRD FLOOR WEST	FA 3.03W
8	FOURTH FLOOR EAST	FA 3.04E
9	FOURTH FLOOR WEST	FA 3.04W
10	FIFTH FLOOR EAST	FA 3.05E
11	FIFTH FLOOR WEST	FA 3.05W
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13	SEVENTH FLOOR EAST	FA 3.07E
14	CALCULATIONS	FA 4.0
15	DETAILS	FA 5.0

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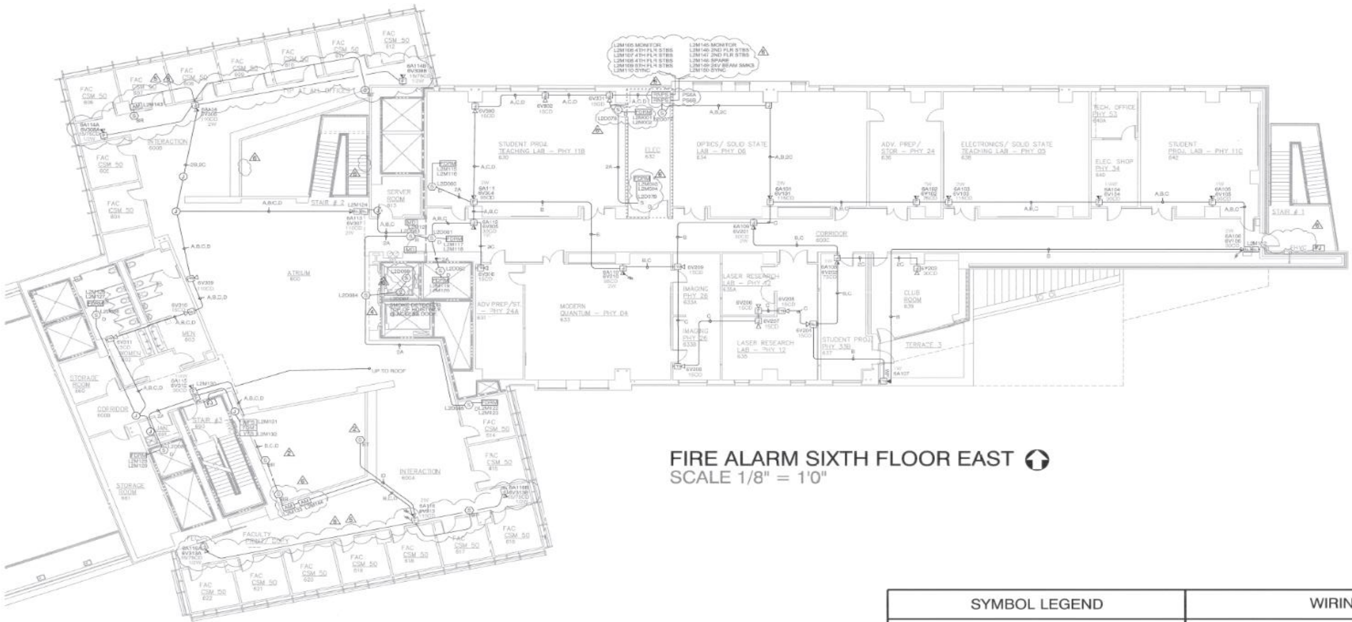

FIRE ALARM SIXTH FLOOR EAST
SCALE 1/8" = 1'0"

SHEET NOTES

1. PROVIDE FIRE ALARM BEAM DETECTORS TRANSMITTER AND RECEIVER. INTERLOCK WITH SMOKE EVACUATION SYSTEM SUCH THAT WHEN BEAM DETECTOR IS ACTIVATED, SMOKE EVACUATION SYSTEM IS ACTIVATED. REFER TO DETAIL 4 & 5/FA5.0.
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SYMBOL LEGEND

COUNT		FIRE ALARM SYMBOLS	MODEL #	CSFM LISTING #
91	F	MANUAL PULL STATION	MBG-12LX	7150-0028:0199
73		STROBE ONLY	SW	7320-1653:201
60		SPEAKER/STROBE	SPWS	7320-1653:201
6		SPEAKER ONLY	SPW	7320-1653:201
7	WP	SPEAKER - WEATHER PROOF	SPWK	7320-1653:201
8	H	HEAT DETECTOR	FST-851	7270-0028:198
18	S	SMOKE DETECTOR	FSP-851	7272-0028:206
84	S D	SMOKE DETECTOR - DUCT	DNR	3242-1653:209
20	S BT	BEAM SMOKE DETECTOR - TRANSMITTER	OSE-SPW	7260-1728:0121
5	S BR	BEAM SMOKE DETECTOR- RECEIVER	OSI-90	7260-1728:0121
1	FACP	FIRE ALARM CONTROL PANEL	NFS2-640	7165-0028:0243
5	RNPS	REMOTE NOTIFICATION POWER SUPPLY	ACPS-610	7315-0028:248
4	FATC	FIRE ALARM TERMINAL CABINET	N/A	N/A
32		END OF LINE RESISTOR	N/A	N/A
2	RA	REMOTE ANNUNCIATOR	FDU-80	7120-0028:209
8	MD	MAGNETIC DOOR HOLDER	N/A	BY OTHERS
21	AM	ADDRESSABLE MODULE	FMM-1	7300-0028:0219
12	RM	RELAY MODULE	FRM-1	7300-0028:219
16	WFS	WATER FLOW SWITCH	N/A	BY OTHERS
16	VTS	VALVE TAMPER SWITCH	N/A	BY OTHERS
21	FDM	DUAL MONITOR MODULE	FDM-1	7300-0028:0219
64	FDRM	DUAL RELAY / MONITOR MODULE	FDRM-1	7300-0028:0219
12	FJ	FIRE FIGHTER'S PHONE JACKS	FTM-1	7300-1653:0192
4	DAA2	DIGITAL AUDIO AMPLIFIERS	DAA2	7170-0028:223 7170-0028:224
	XP6-R	SIX RELAY CONTROL MODULE	XP6-R	7300-0028:0219
	XP10-M	TEN INPUT MONITOR MODULE	XP10-M	7300-0028:0219

WIRING LEGEND

LABEL	GAUGE	USE	TYPE (OR EQUIVALENT)
A	16/2 UTP	SLC	WEST PENN D990
B	16/2 TSP	SPEAKER	WEST PENN D991
C	14	NAC VISUAL	THHN
D	14	24 VDC	THHN
E	16/4 TS	ANNUNCIATOR	WEST PENN 993
F	14/2 TSP	FIRE FIGHTERS PHONE	WEST PENN D995

DRAWING INDEX

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5	SECOND FLOOR WEST	FA 3.02W
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7	THIRD FLOOR WEST	FA 3.03W
8	FOURTH FLOOR EAST	FA 3.04E
9	FOURTH FLOOR WEST	FA 3.04W
10	FIFTH FLOOR EAST	FA 3.05E
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14	CALCULATIONS	FA 4.0
15	DETAILS	FA 5.0

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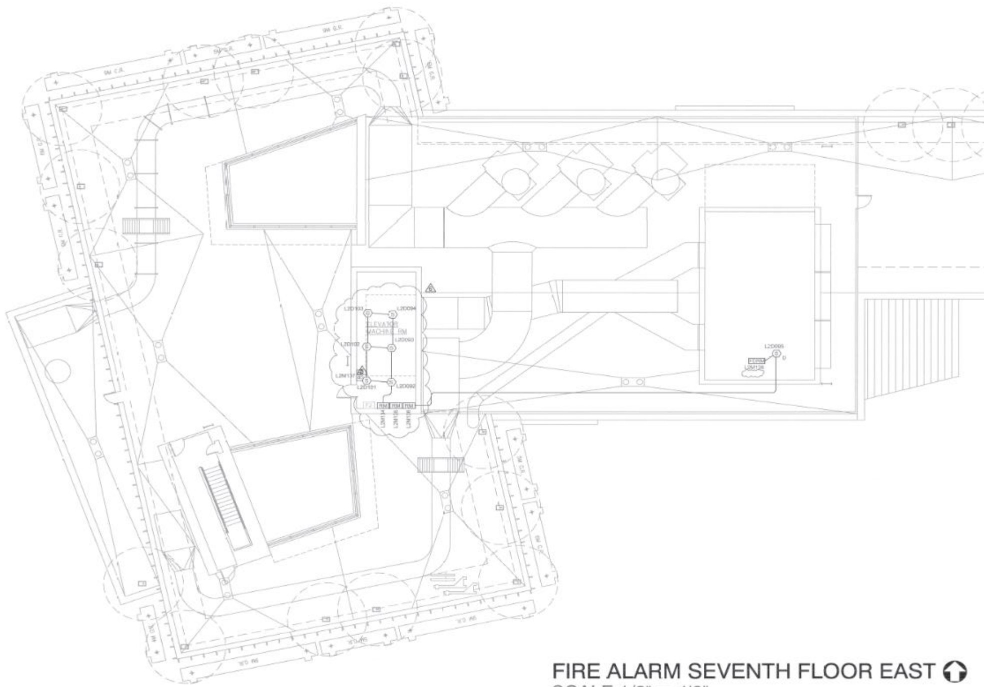

FIRE ALARM SEVENTH FLOOR EAST
SCALE 1/8" = 1'0"

SYMBOL LEGEND

COUNT	FIRE ALARM SYMBOLS	MODEL #	CSFM LISTING #
31	MANUAL PULL STATION	NBG-12LX	7130-0028:0199
73	STROBE ONLY	SW	7320-1653:201
165	SPEAKER/STROBE	SPWS	7320-1653:201
6	SPEAKER ONLY	SPW	7320-1653:201
7	SPEAKER - WEATHER PROOF	SPWK	7320-1653:201
0	HEAT DETECTOR	FST-851	7270-0028:199
16	SMOKE DETECTOR	FSP-851	7272-0028:206
64	SMOKE DETECTOR - DUCT	DNR	3242-1653:209
23	BEAM SMOKE DETECTOR - TRANSMITTER	OSE-SPW	7260-1728:0121
15	BEAM SMOKE DETECTOR- RECEIVER	OSI-90	7260-1728:0121
1	FIRE ALARM CONTROL PANEL	NFS2-640	7165-0028:0243
5	REMOTE NOTIFICATION POWER SUPPLY	ACPS-610	7315-0028:248
4	FIRE ALARM TERMINAL CABINET	N/A	N/A
32	END OF LINE RESISTOR	N/A	N/A
2	REMOTE ANNUNCIATOR	FDU-80	7120-0028:209
8	MAGNETIC DOOR HOLDER	N/A	BY OTHERS
21	ADDRESSABLE MODULE	FMM-1	7300-0028:0219
12	RELAY MODULE	FRM-1	7300-0028:219
16	WATER FLOW SWITCH	N/A	BY OTHERS
10	VALVE TAMPER SWITCH	N/A	BY OTHERS
21	DUAL MONITOR MODULE	FDM-1	7300-0028:0219
64	DUAL RELAY / MONITOR MODULE	FDRM-1	7300-0028:0219
12	FIRE FIGHTERS PHONE JACKS	FTM-1	7300-1652:0152
4	DIGITAL AUDIO AMPLIFIERS	DAA2	7170-0028:233 7170-0028:234
1	SIX RELAY CONTROL MODULE	XP6-R	7300-0028:0219
1	TEN-INPUT MONITOR MODULE	XP10-M	7300-0028:0219

WIRING LEGEND

LABEL	GAUGE	USE	TYPE (OR EQUIVALENT)
A	16/2 UTP	SLC	WEST PENN D990
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D	14	24 VDC	THHN
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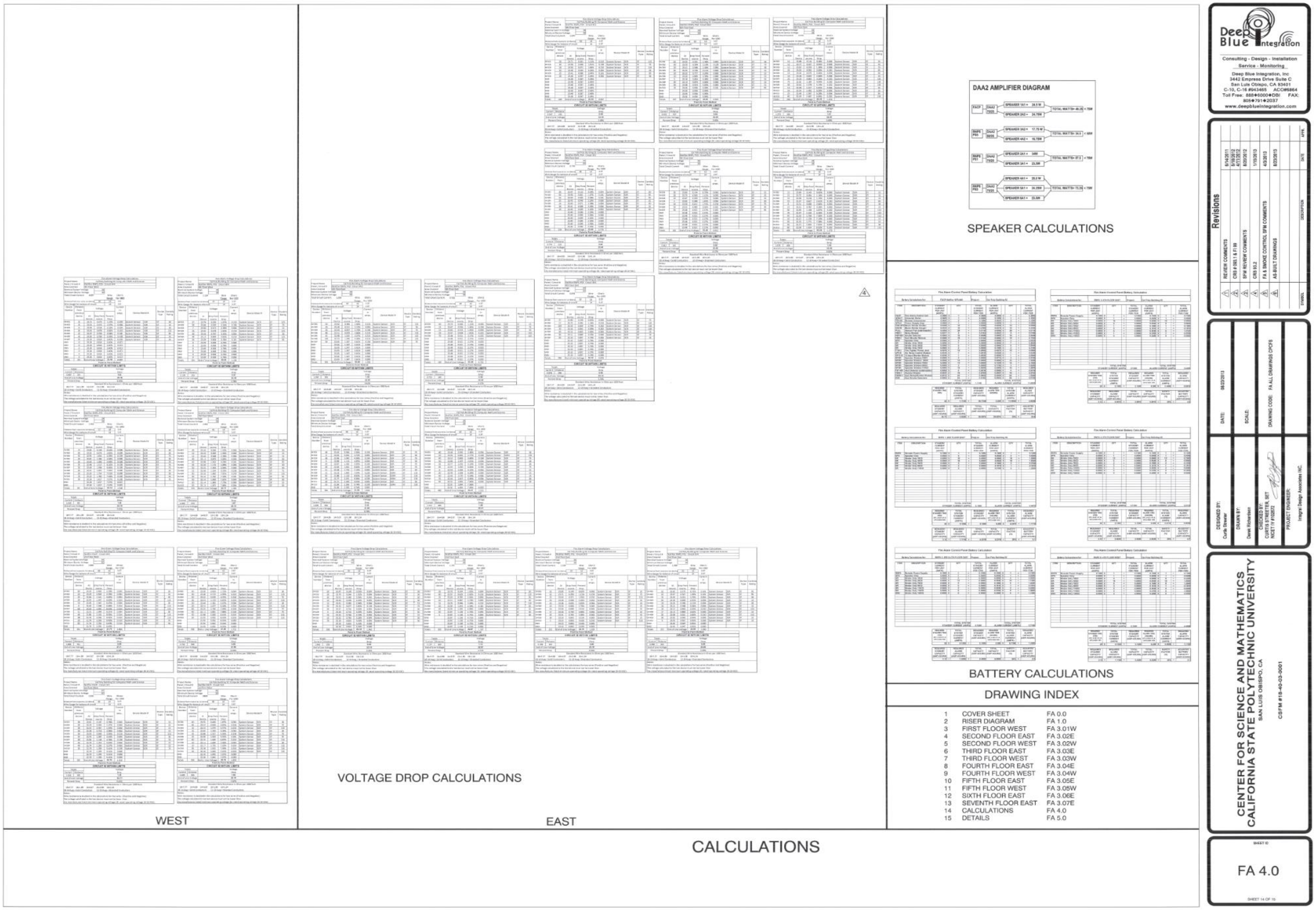
DAA2 AMPLIFIER DIAGRAM
SPEAKER CALCULATIONS
BATTERY CALCULATIONS
DRAWING INDEX
1 COVER SHEET FA 0.0
2 RISER DIAGRAM FA 1.0
3 FIRST FLOOR WEST FA 3.01W
4 SECOND FLOOR EAST FA 3.02E
5 SECOND FLOOR WEST FA 3.02W
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13 SEVENTH FLOOR EAST FA 3.07E
14 CALCULATIONS FA 4.0
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VOLTAGE DROP CALCULATIONS
WEST
EAST
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Revisions
REVIEW COMMENTS 5/14/2011
CRS # 093.1 & FI 99 5/18/2012 4/11/2012
SFM REVIEW COMMENTS 8/20/2012
CRS 93.2 1/10/2013
FA & SMOKE CONTROL SFM COMMENTS 4/3/2013
AS-BUILT DRAWINGS 8/23/2013
SYMBOL DESCRIPTION DATE APPR.
DESIGNED BY: Curtis Streeter
DRAWN BY: Derek Richardson
CHECKED BY: CURTIS STREETER, SET NICET IV #102672
PROJECT ENGINEER: Integral Design Associates INC.
DATE: 08/23/2013
SCALE:
DRAWING CODE: FA ALL DRAWINGS CPCFS
CENTER FOR SCIENCE AND MATHEMATICS
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CSFM #18-40-03-0001
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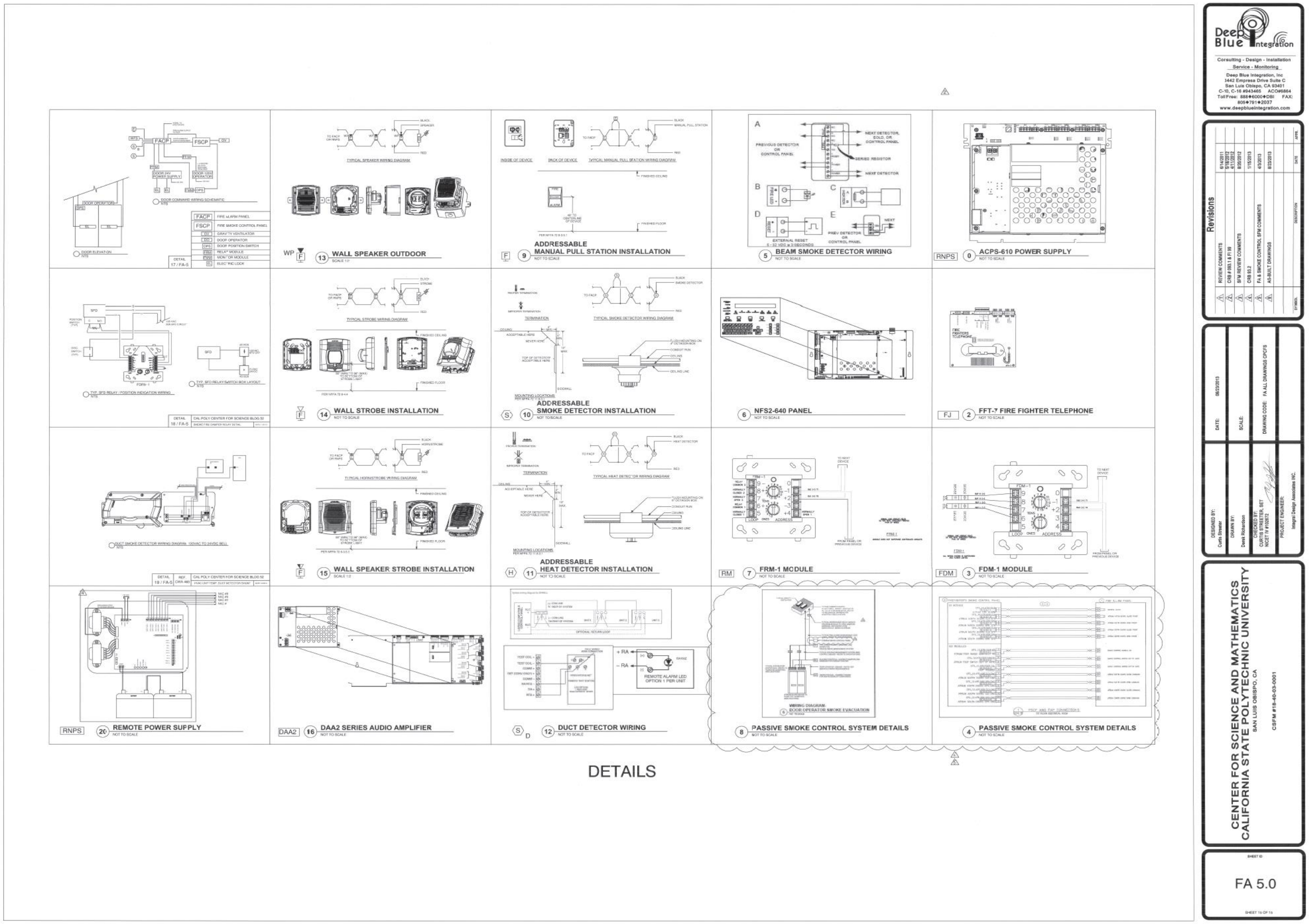
SHEET 14 OF 15


WALL SPEAKER OUTDOOR
ADDRESSABLE MANUAL PULL STATION INSTALLATION
BEAM SMOKE DETECTOR WIRING
ACPS-610 POWER SUPPLY
WALL STROBE INSTALLATION
ADDRESSABLE SMOKE DETECTOR INSTALLATION
NFS2-640 PANEL
FFT-7 FIRE FIGHTER TELEPHONE
WALL SPEAKER STROBE INSTALLATION
ADDRESSABLE HEAT DETECTOR INSTALLATION
FRM-1 MODULE
FDM-1 MODULE
REMOTE POWER SUPPLY
DAA2 SERIES AUDIO AMPLIFIER
DUCT DETECTOR WIRING
PASSIVE SMOKE CONTROL SYSTEM DETAILS
PASSIVE SMOKE CONTROL SYSTEM DETAILS
DETAILS
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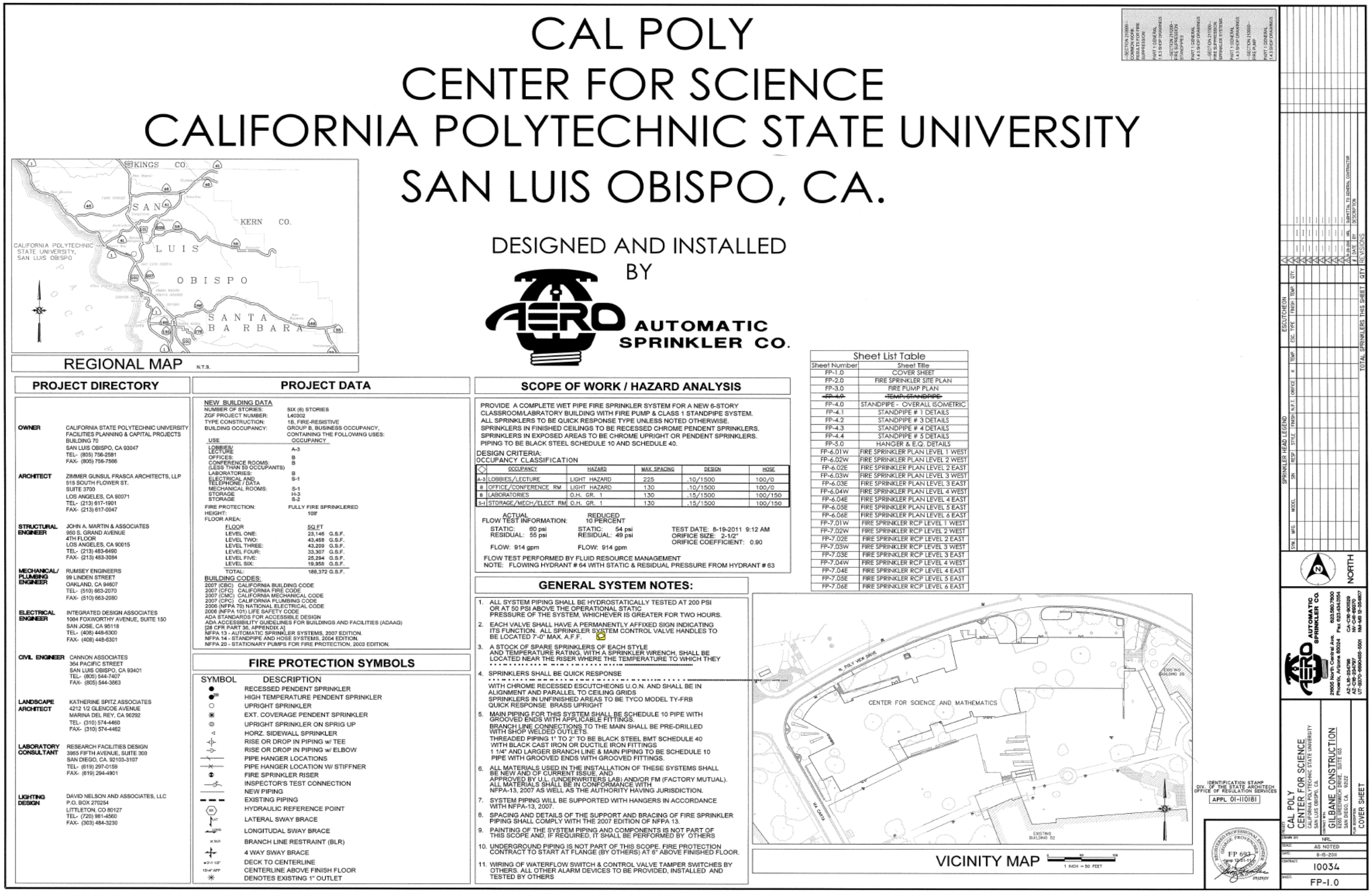
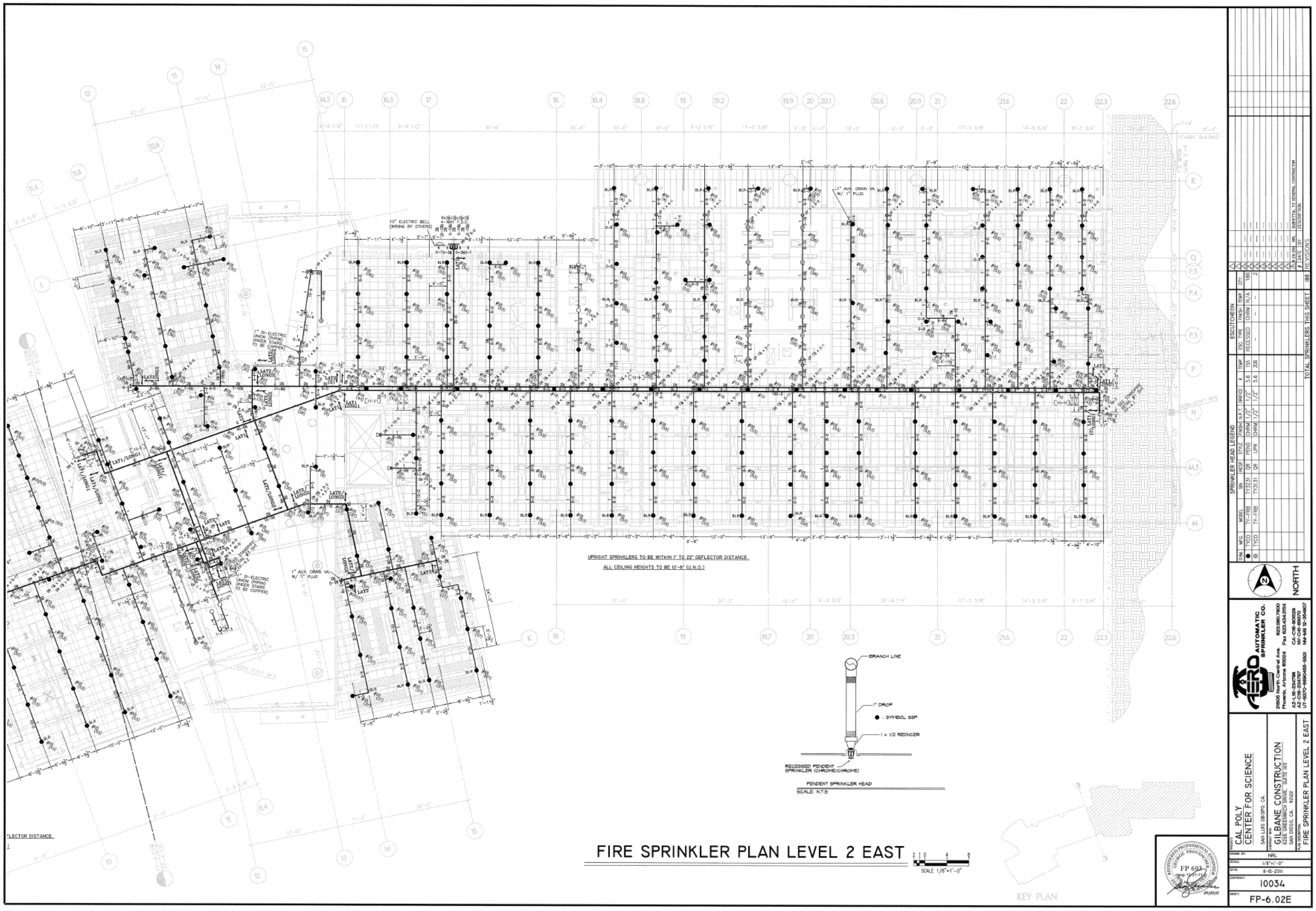
FA 5.0

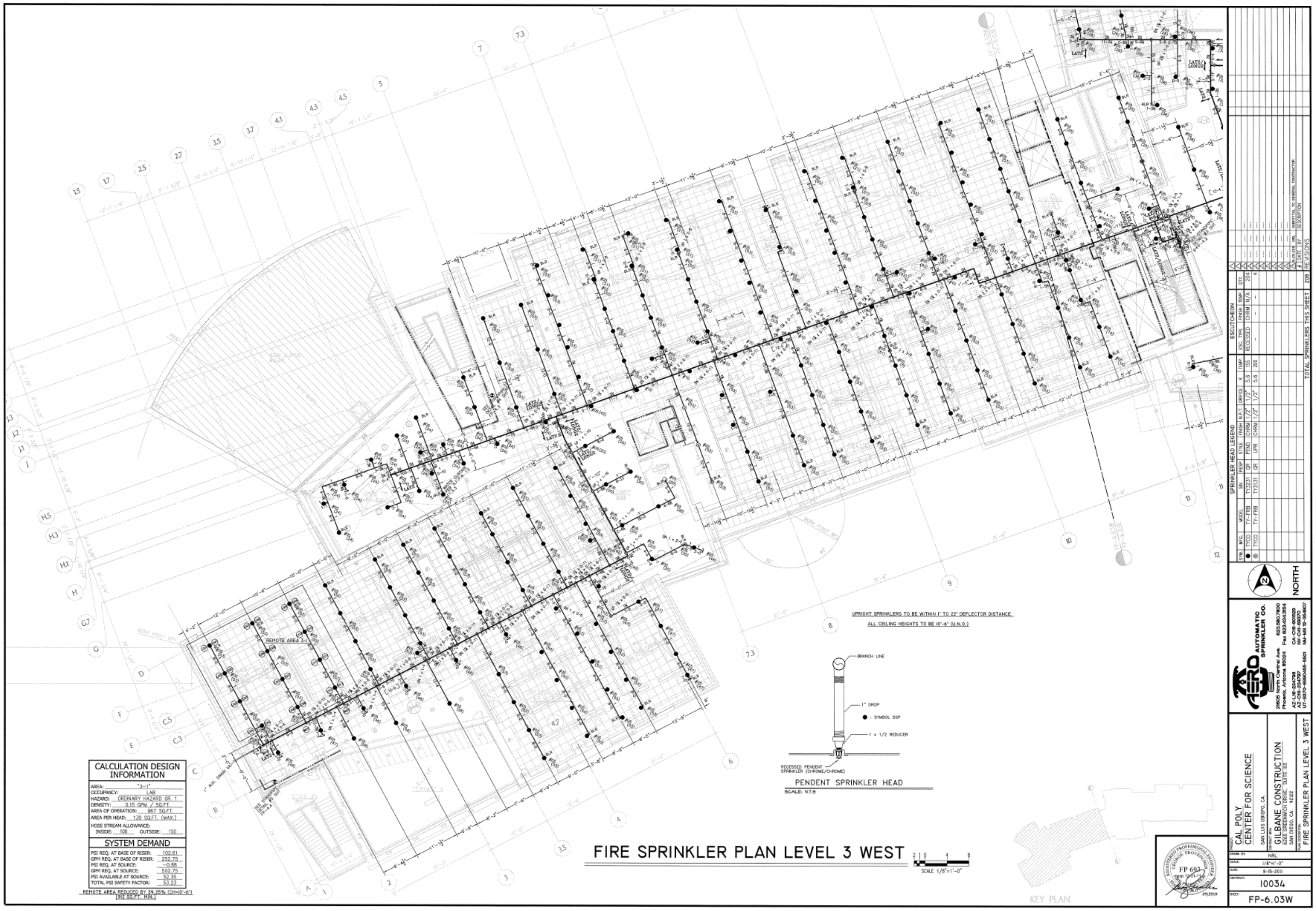
10.2 Wet Pipe Fire Sprinkler System Design

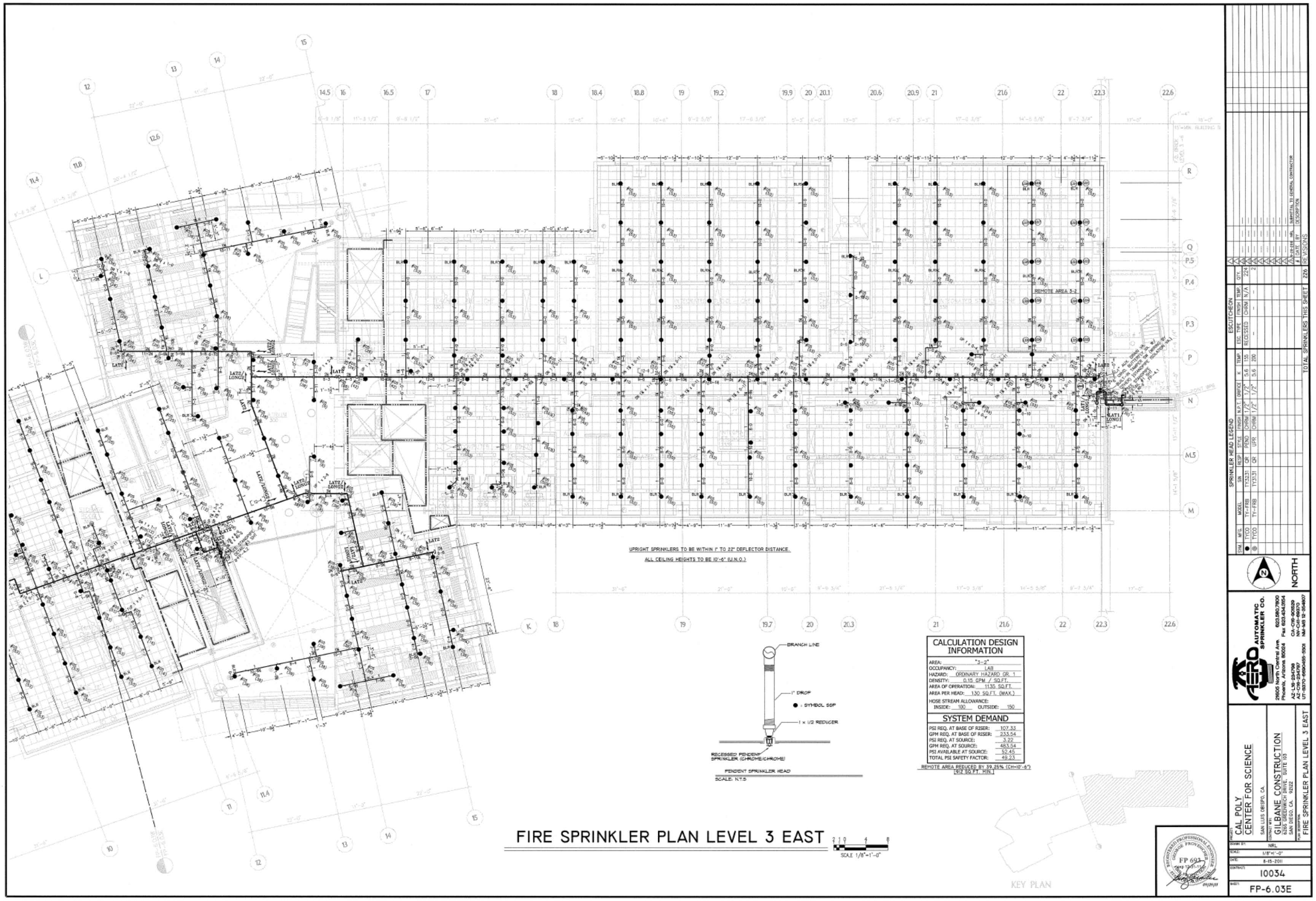



CALCULATION DESIGN INFORMATION
AREA: "1-2"
OCCUPANCY: LECTURE
HAZARD: LIGHT HAZARD
DENSITY: 0.10 GPM / SQ.FT.
AREA OF OPERATION: 1575 SQ. FT.
AREA PER HEAD: 163 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE:
SYSTEM DEMAND
PSI REQ. AT BASE OF RISER: 162.2
GPM REQ. AT BASE OF RISER: 328.4
PSI REQ. AT SOURCE: 45.59
GPM REQ. AT SOURCE: 428.4
PSI AVAILABLE AT SOURCE: 52.76
TOTAL PSI SAFETY FACTOR: 7.17
CALCULATION DESIGN INFORMATION
AREA: "1-1"
OCCUPANCY: LECTURE
HAZARD: LIGHT HAZARD
DENSITY: 0.10 GPM / SQ.FT.
AREA OF OPERATION: 1520 SQ. FT.
AREA PER HEAD: 168 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE:
SYSTEM DEMAND
PSI REQ. AT BASE OF RISER: 126.6
GPM REQ. AT BASE OF RISER: 250.6
PSI REQ. AT SOURCE: 7.27
GPM REQ. AT SOURCE: 350.6
PSI AVAILABLE AT SOURCE: 53.15
TOTAL PSI SAFETY FACTOR: 45.88
FIRE SPRINKLER PLAN LEVEL I WEST
SCALE 1/8"=1'-0"
NORTH
CAL POLY
CENTER FOR SCIENCE
GILBANE CONSTRUCTION
FIRE SPRINKLER PLAN LEVEL I WEST
10034
FP-6.01W

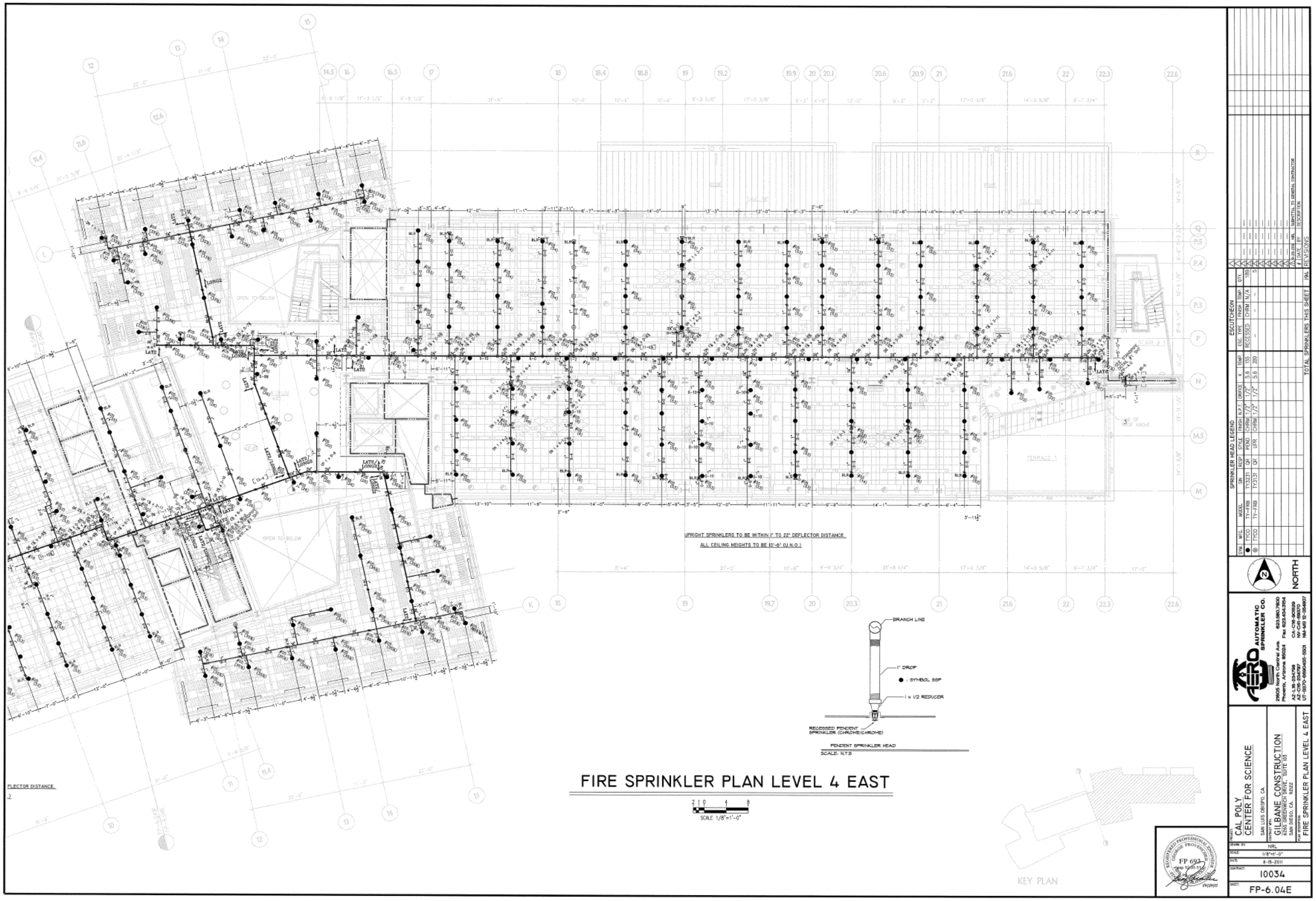

FIRE SPRINKLER PLAN LEVEL 2 WEST
SCALE 1/8"=1'-0"
UPRIGHT SPRINKLERS TO BE WITHIN 1" TO 22" DEFLECTOR DISTANCE.
ALL CEILING HEIGHTS TO BE 10'-6" (U.N.O.)
BRANCH LINE
1" DROP
SYMBOL SSP
1 x 1/2 REDUCER
RECESSED PENDENT SPRINKLER (CHROME/CHROME)
PENDENT SPRINKLER HEAD
SCALE: N.T.S.
KEY PLAN
SPRINKLER HEAD LEGEND
TOTAL SPRINKLERS THIS SHEET 188
REVISIONS
NORTH
AUTOMATIC SPRINKLER CO.
CAL POLY
CENTER FOR SCIENCE
SAN LUIS OBISPO, CA
GILBANE CONSTRUCTION
FIRE SPRINKLER PLAN LEVEL 2 WEST
NRL
1/8"=1'-0"
8-15-2011
10034
FP-6.02W

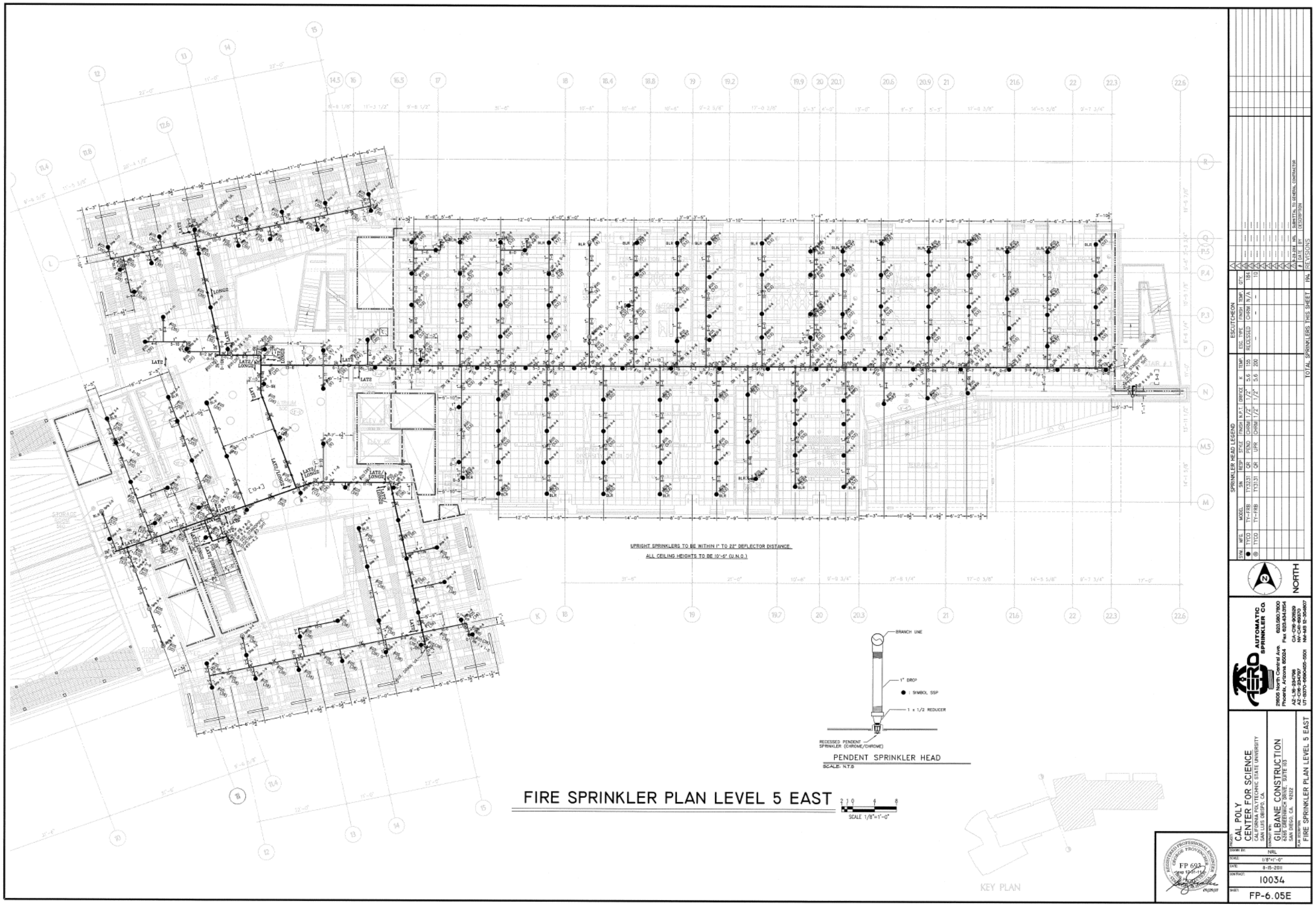

FIRE SPRINKLER PLAN LEVEL 2 EAST
UPRIGHT SPRINKLERS TO BE WITHIN 1" TO 22" DEFLECTOR DISTANCE.
ALL CEILING HEIGHTS TO BE 10'-6" (U.N.O.)
CAL POLY
CENTER FOR SCIENCE
GILBANE CONSTRUCTION
FIRE SPRINKLER PLAN LEVEL 2 EAST
10034
FP-6.02E
NORTH
KEY PLAN

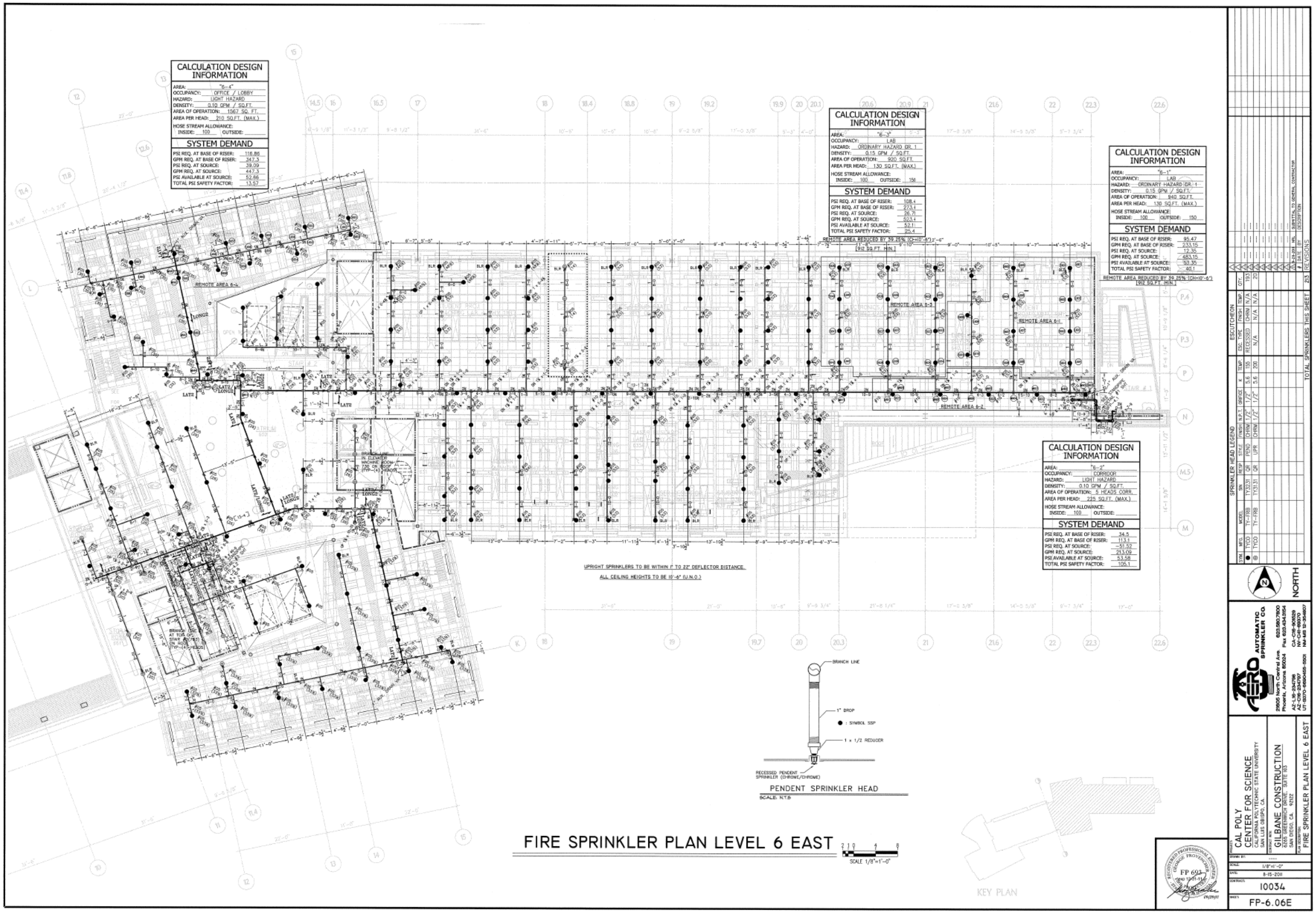

FIRE SPRINKLER PLAN LEVEL 3 WEST
SCALE 1/8"=1'-0"
CALCULATION DESIGN INFORMATION
AREA: "3-1"
OCCUPANCY: LAB
HAZARD: ORDINARY HAZARD GR. 1
DENSITY: 0.15 GPM / SQ.FT.
AREA OF OPERATION: 967 SQ.FT.
AREA PER HEAD: 130 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE: 150
SYSTEM DEMAND
PSI REQ. AT BASE OF RISER: 102.61
GPM REQ. AT BASE OF RISER: 252.75
PSI REQ. AT SOURCE: -0.88
GPM REQ. AT SOURCE: 502.75
PSI AVAILABLE AT SOURCE: 52.35
TOTAL PSI SAFETY FACTOR: 53.23
REMOTE AREA REDUCED BY 39.25% (CH=10'-6")
[912 SQ.FT. MIN.]
REMOTE AREA 3-1
UPRIGHT SPRINKLERS TO BE WITHIN 1" TO 22" DEFLECTOR DISTANCE.
ALL CEILING HEIGHTS TO BE 10'-6" (U.N.O.)
BRANCH LINE
1" DROP
: SYMBOL SSP
1 x 1/2 REDUCER
RECESSED PENDENT SPRINKLER (CHROME/CHROME)
PENDENT SPRINKLER HEAD
SCALE: N.T.S
KEY PLAN
NORTH
SPRINKLER HEAD LEGEND
TOTAL SPRINKLERS THIS SHEET 208
REVISIONS
AERO AUTOMATIC SPRINKLER CO.
21605 North Central Ave.
Phoenix, Arizona 85024
AZ-L16-234798
AZ-C16-234797
UT-5370-6690455-5501
CAL POLY
CENTER FOR SCIENCE
SAN LUIS OBISPO, CA.
GILBANE CONSTRUCTION
6265 GREENWICH DRIVE, SUITE 103
SAN DIEGO, CA. 92122
FIRE SPRINKLER PLAN LEVEL 3 WEST
DRAWN BY: NRL
SCALE: 1/8"=1'-0"
DATE: 8-15-2011
CONTRACT: 10034
SHEET: FP-6.03W

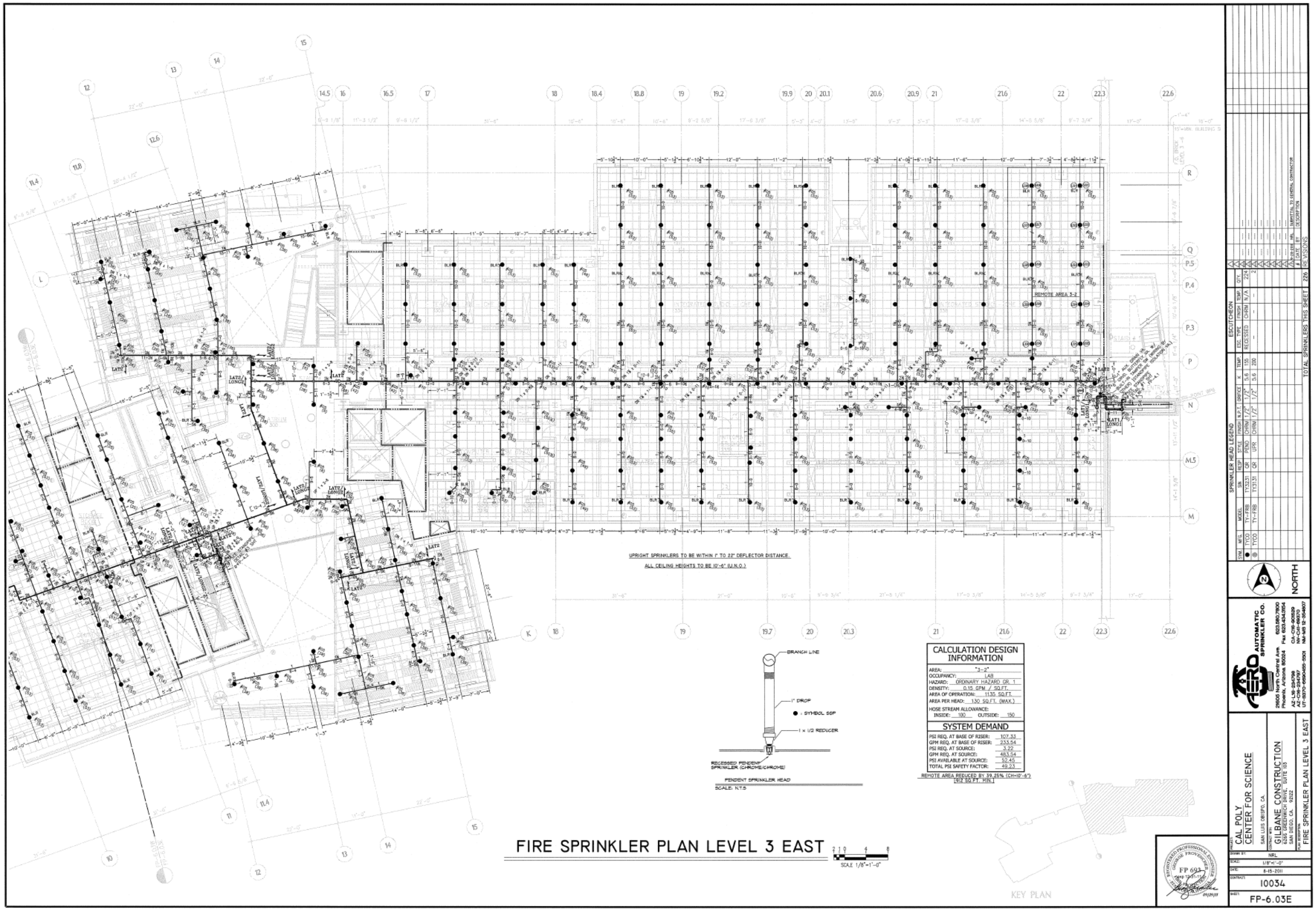

FIRE SPRINKLER PLAN LEVEL 3 EAST
SCALE 1/8"=1'-0"
UPRIGHT SPRINKLERS TO BE WITHIN 1" TO 22" DEFLECTOR DISTANCE.
ALL CEILING HEIGHTS TO BE 10'-6" (U.N.O.)
REMOTE AREA 3-2
BRANCH LINE
1" DROP
SYMBOL SSP
1 x 1/2 REDUCER
RECESSED PENDENT SPRINKLER (CHROME/CHROME)
PENDENT SPRINKLER HEAD
SCALE: N.T.S.
CALCULATION DESIGN INFORMATION
AREA: "3-2"
OCCUPANCY: LAB
HAZARD: ORDINARY HAZARD GR. 1
DENSITY: 0.15 GPM / SQ.FT.
AREA OF OPERATION: 1135 SQ.FT.
AREA PER HEAD: 130 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE: 150
SYSTEM DEMAND
PSI REQ. AT BASE OF RISER: 107.33
GPM REQ. AT BASE OF RISER: 233.54
PSI REQ. AT SOURCE: 3.22
GPM REQ. AT SOURCE: 483.54
PSI AVAILABLE AT SOURCE: 52.45
TOTAL PSI SAFETY FACTOR: 49.23
REMOTE AREA REDUCED BY 39.25% (CH=10'-6")
[912 SQ.FT. MIN.]
KEY PLAN
NORTH
AERO AUTOMATIC SPRINKLER CO.
CAL POLY
CENTER FOR SCIENCE
SAN LUIS OBISPO, CA.
GILBANE CONSTRUCTION
FIRE SPRINKLER PLAN LEVEL 3 EAST
10034
FP-6.03E

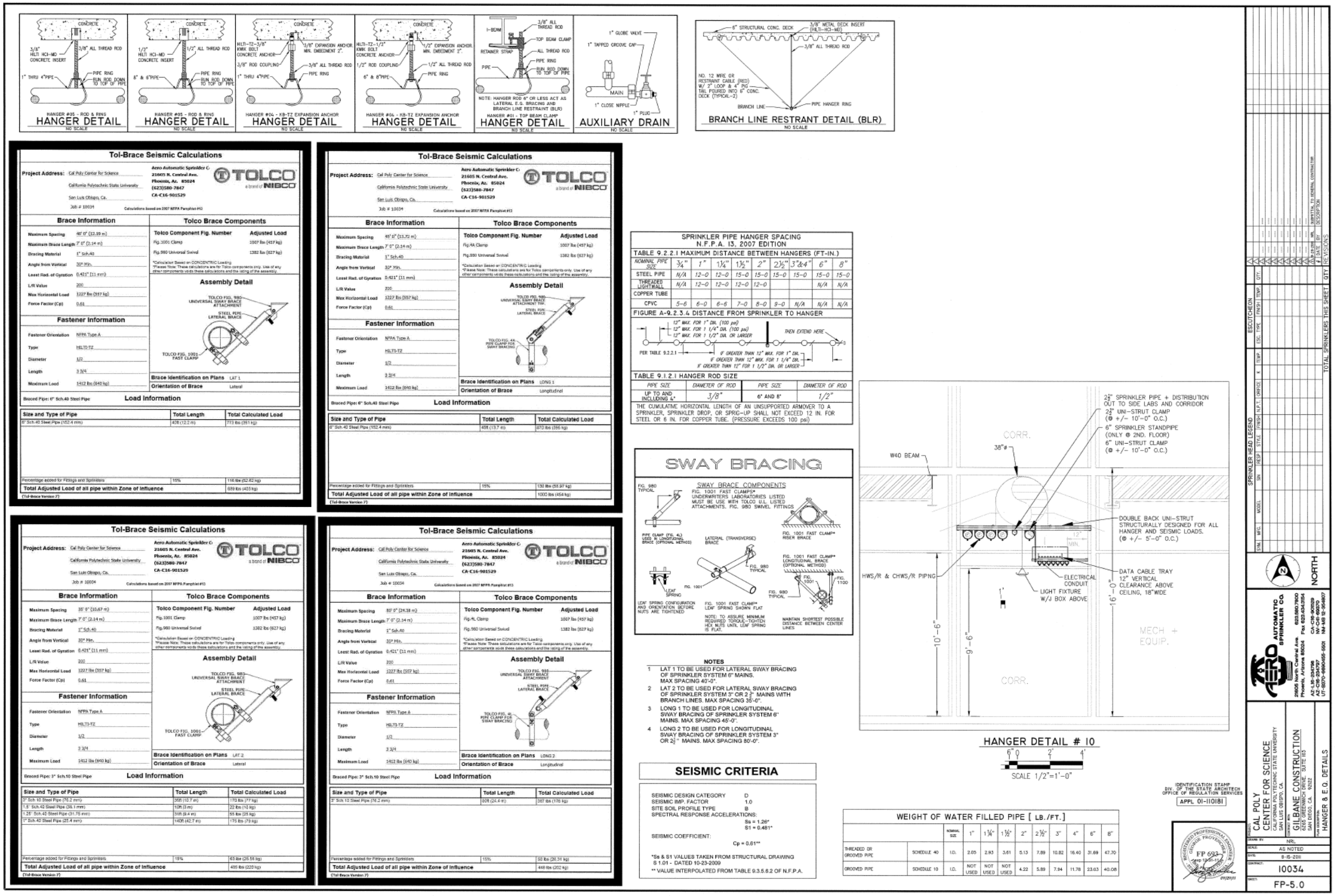

FIRE SPRINKLER PLAN LEVEL 4 WEST
KEY PLAN
UPRIGHT SPRINKLERS TO BE WITHIN 1" TO 22" DEFLECTOR DISTANCE.
ALL CEILING HEIGHTS TO BE 10'-6" (U.N.O.)
PENDENT SPRINKLER HEAD
BRANCH LINE
RECESSED PENDENT SPRINKLER (CHROME/CHROME)
CAL POLY
CENTER FOR SCIENCE
GILBANE CONSTRUCTION
FIRE SPRINKLER PLAN LEVEL 4 WEST
AERO AUTOMATIC SPRINKLER CO.
NORTH
10034
FP-6.04W


FIRE SPRINKLER PLAN LEVEL 4 EAST
SCALE 1/8"=1'-0"
UPRIGHT SPRINKLERS TO BE WITHIN 1" TO 22" DEFLECTOR DISTANCE.
ALL CEILING HEIGHTS TO BE 10'-6" (U.N.O.)
BRANCH LINE
1" DROP
SYMBOL SSP
1 x 1/2 REDUCER
RECESSED PENDENT SPRINKLER (CHROME/CHROME)
PENDENT SPRINKLER HEAD
SCALE: N.T.S
TERRACE 1
KEY PLAN
NORTH
AERO AUTOMATIC SPRINKLER CO.
CAL POLY
CENTER FOR SCIENCE
SAN LUIS OBISPO, CA
GILBANE CONSTRUCTION
FIRE SPRINKLER PLAN LEVEL 4 EAST
NRL
1/8"=1'-0"
8-15-2011
10034
FP-6.04E
SPRINKLER HEAD LEGEND
ESCUTCHEON
TOTAL SPRINKLERS THIS SHEET
REVISIONS


FIRE SPRINKLER PLAN LEVEL 5 EAST
SCALE 1/8"=1'-0"
UPRIGHT SPRINKLERS TO BE WITHIN 1" TO 22" DEFLECTOR DISTANCE
ALL CEILING HEIGHTS TO BE 10'-0" (U.N.O.)
PENDENT SPRINKLER HEAD
KEY PLAN
NORTH
CAL POLY
CENTER FOR SCIENCE
GILBANE CONSTRUCTION
FIRE SPRINKLER PLAN LEVEL 5 EAST
10034
FP-6.05E


CALCULATION DESIGN INFORMATION
SYSTEM DEMAND
PENDENT SPRINKLER HEAD
FIRE SPRINKLER PLAN LEVEL 6 EAST
NORTH
CAL POLY CENTER FOR SCIENCE
GILBANE CONSTRUCTION
FIRE SPRINKLER PLAN LEVEL 6 EAST
KEY PLAN
10034
FP-6.06E


FIRE SPRINKLER PLAN LEVEL 3 EAST
SCALE 1/8"=1'-0"
UPRIGHT SPRINKLERS TO BE WITHIN 1" TO 22" DEFLECTOR DISTANCE.
ALL CEILING HEIGHTS TO BE 10'-6" (U.N.O.)
CALCULATION DESIGN INFORMATION
AREA: "3-2"
OCCUPANCY: LAB
HAZARD: ORDINARY HAZARD GR. 1
DENSITY: 0.15 GPM / SQ.FT.
AREA OF OPERATION: 1135 SQ.FT.
AREA PER HEAD: 130 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:
INSIDE: 100 OUTSIDE: 150
SYSTEM DEMAND
PSI REQ. AT BASE OF RISER: 107.33
GPM REQ. AT BASE OF RISER: 233.54
PSI REQ. AT SOURCE: 3.22
GPM REQ. AT SOURCE: 483.54
PSI AVAILABLE AT SOURCE: 52.45
TOTAL PSI SAFETY FACTOR: 49.23
REMOTE AREA REDUCED BY 39.25% (CH=10'-6")
[912 SQ.FT. MIN.]
BRANCH LINE
1" DROP
1 x 1/2 REDUCER
RECESSED PENDENT SPRINKLER (CHROME/CHROME)
PENDENT SPRINKLER HEAD
SCALE: N.T.S.
REMOTE AREA 3-2
KEY PLAN
NORTH
CAL POLY CENTER FOR SCIENCE
GILBANE CONSTRUCTION
FIRE SPRINKLER PLAN LEVEL 3 EAST
10034
FP-6.03E


HANGER DETAIL
HANGER DETAIL
HANGER DETAIL
HANGER DETAIL
HANGER DETAIL
AUXILIARY DRAIN
BRANCH LINE RESTRANT DETAIL (BLR)
Tol-Brace Seismic Calculations
TOLCO
SPRINKLER PIPE HANGER SPACING
N.F.P.A. 13, 2007 EDITION
SWAY BRACING
SWAY BRACE COMPONENTS
NOTES
SEISMIC CRITERIA
HANGER DETAIL # 10
SCALE 1/2"=1'-0"
WEIGHT OF WATER FILLED PIPE [LB./FT.]
APPL 01-110181
NORTH
CAL POLY
CENTER FOR SCIENCE
GILBANE CONSTRUCTION
HANGER & E.Q. DETAILS
AS NOTED
8-15-2011
10034
FP-5.0