Fire Protection Analysis

Warren J. Baker Center for Science and Mathematics (CSM) Building 180, Cal Poly San Luis Obispo, CA.

Neal Larsen
June 14th, 2018
Safety Topic

• Our company also always starts a presentation with a safety moment

Hotel & Motel Safety

Vacations and business travel make hotels and motels our home away from home. It is just as important to be prepared and know what you would do in a hotel/motel emergency as it is in your own home.

BE SAFE WHEN TRAVELING!

• Choose a hotel/motel that is protected by both smoke alarms and a fire sprinkler system.
• When you check in, ask the front desk what the fire alarm sounds like.
• When you enter your room, review the escape plan posted in your room.
• Take the time to find the exits and count the number of doors between your room and the exit. Make sure the exits are unlocked. If they are locked, report it to management right away.
• Keep your room key by your bed and take it with you if there is a fire.
• If the alarm sounds, leave right away, closing all doors behind you. Use the stairs — never use elevators during a fire.
• If you must escape through smoke, get low and go under the smoke to your exit.

If You Can’t Escape...

SHUT off fans and air conditioners.
STUFF wet towels in the crack around the doors.
CALL the fire department and let them know your location.
WAIT at the window and signal with a flashlight or light colored cloth.

FACTS

1. On average, one of every 13 hotels or motels reported a structure fire each year.
2. The majority of hotel fire deaths result from fires that started in the bedroom.
3. Cooking equipment is the leading cause of hotel/motel fires.

Name of Organization Here
Contact Information Here
Presentation Overview

• Project Building Information

• Prescriptive Approach
  – Egress Analysis
  – Structural Fire Protection
  – Fire Suppression System
  – Fire Alarm and Detection System
  – Smoke Management System

• Performance-Based Approach
  – RSET vs ASET
  – Design Fire Scenario Selection
  – Tenability Conditions Assessment
Project Building Information

- Warren J. Baker Center for Science and Mathematics
- Building 180 on Cal Poly SLO Campus
- 6-Story, ~190,000 Sq.Ft. Area, with Classrooms, Lecture Halls, Labs, Offices, Storage and Study Spaces
- Building Calculated Occupancy Load of 2,996
Project Building Information

• Construction – Type 1-B
• Occupancy – Mainly Group B, with mixed-use of Groups A, H, and S
• Fully Sprinklered Building
• Addressable Fire Alarm System with EVACS
• 5-Story Atrium between the East and West Wings
Project Building Information

- Explanation of 80 foot High Building Classified as Non-High Rise
- Building is Located on a Hill – Main Entry (Lowest Floor Fire Department Access) is on the Second Floor to Highest Occupied Floor is 64 feet (This Interpretation of the IBC Value of 75-ft for a High Rise Building was acceptable to the AHJ)
Prescriptive Approach

Codes & Standards (Report Analysis):

• International Building Code (IBC) 2015
• International Fire Code (IFC) 2015
  - NFPA 13 – 2015
  - NFPA 14 – 2013
  - NFPA 25 – 2011
  - NFPA 101 - 2015
  - NFPA 92B - 2009
• SFPE Handbook of Fire Protection Engineering, 4th edition

(Existing CSM Building Designed and Constructed to 2007 Codes)
• Egress Analysis:

**Occupant Load Factor**

<table>
<thead>
<tr>
<th>Use</th>
<th>(sq.ft. per occupant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly Use (Less concentrated use,</td>
<td>15 net</td>
</tr>
<tr>
<td>without fixed seating)</td>
<td>(or # of fixed Seats)</td>
</tr>
<tr>
<td>Business Use (Lecture)</td>
<td>15 net</td>
</tr>
<tr>
<td>Business Use (Laboratories)</td>
<td>50 net</td>
</tr>
<tr>
<td>Business Use (Admin-Office)</td>
<td>100 gross</td>
</tr>
<tr>
<td>Storage Use (In other than storage</td>
<td>300 gross</td>
</tr>
<tr>
<td>occupancies)</td>
<td></td>
</tr>
</tbody>
</table>

Reference: CBC (2016) Table 1004.1.2

**Building Square Footage per Floor**

<table>
<thead>
<tr>
<th>Building Level</th>
<th>Square Footage (SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>23,146</td>
</tr>
<tr>
<td>Level 2</td>
<td>43,458</td>
</tr>
<tr>
<td>Level 3</td>
<td>43,209</td>
</tr>
<tr>
<td>Level 4</td>
<td>33,307</td>
</tr>
<tr>
<td>Level 5</td>
<td>25,294</td>
</tr>
<tr>
<td>Level 6</td>
<td>19,958</td>
</tr>
<tr>
<td>Level 7</td>
<td>250</td>
</tr>
<tr>
<td>TOTAL</td>
<td>190,182</td>
</tr>
</tbody>
</table>

Building SF are from ACAD Drawings

**Occupant Load per Floor**

<table>
<thead>
<tr>
<th>Level</th>
<th>Occupant Loads (Persons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>West</td>
</tr>
<tr>
<td>1</td>
<td>712</td>
</tr>
<tr>
<td>2</td>
<td>322</td>
</tr>
<tr>
<td>3</td>
<td>314</td>
</tr>
<tr>
<td>4</td>
<td>212</td>
</tr>
<tr>
<td>5</td>
<td>121</td>
</tr>
<tr>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>1560</td>
</tr>
</tbody>
</table>

**Required Exits per Occupant Load**

<table>
<thead>
<tr>
<th>Occupant Load Per Story</th>
<th>Minimum Number of Exits from Story</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-500</td>
<td>2</td>
</tr>
<tr>
<td>501-1000</td>
<td>3</td>
</tr>
</tbody>
</table>

**Cal Poly Fire Protection Engineering**
<table>
<thead>
<tr>
<th>Building Level</th>
<th>Required # of Exits</th>
<th>Actual # of Exits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

CBC Table 1021.1

Occupant Load: 712

Warren J. Baker Center for Science and Mathematics Building 180 Floor-1
<table>
<thead>
<tr>
<th>Building Level</th>
<th>Required # of Exits</th>
<th>Actual # Exits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 2</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>

CBC Table 1021.1

Occupant Load: 582

TWO (2) H-3 STORAGE ROOMS
- MEETS TABLE 414.2.5(2)
FOR MAQ AMOUNTS

MAXIMUM TRAVEL DISTANCE IS 300 FT (LSC 92015) SECTION 38.2.6.3
LONGEST TRAVEL DISTANCE = 185 FT

LEGEND

- BUSINESS
- ASSEMBLY
- RATED EXIT CORRIDORS
- S, S–1, S–2 (STORAGE, MECH., ELECT., TELECOM, ELEV MACH., FIRE PUMP -- ROOMS)
- RESTROOMS
- EXTERIOR EXITS
- VERTICAL EXITS
- LOCATION OF MAIN EXITS

Warren J. Baker Center for Science and Mathematics Building 180 Floor-2
<table>
<thead>
<tr>
<th>Building Level</th>
<th>Required # of Exits</th>
<th>Actual # Exits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 3</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

CBC Table 1021.1
Occupant Load: 660

LEGEND
- **BUSINESS**
- **ASSEMBLY**
- **RATED EXIT CORRIDORS**
- **5,S-1,S-2 (STORAGE, MECH., ELECT., TELECOM, ELEV MACH, FIRE PUMP Rooms)**
- **RESTROOMS**
- **EXTERIOR EXITS**
- **VERTICAL EXITS**
- **LOCATION OF MAIN EXITS**

Warren J, Baker Center for Science and Mathematics Building 180 Floor-3
<table>
<thead>
<tr>
<th>Building Level</th>
<th>Required # of Exits</th>
<th>Actual # of Exits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 4</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

CBC Table 1021.1

Occupant Load: 494
<table>
<thead>
<tr>
<th>Building Level</th>
<th>Required # of Exits</th>
<th>Actual # of Exits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 5</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

CBC Table 1021.1
Occupant Load: 273

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Maximun Travel Distance is 300 FT (LSC 92015) Section 38.2.6.3

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LEGEND

- BUSINESS
- ASSEMBLY
- Rated Exit Corridors
- S.S-1.5-2 (Storage, Mech, Elect, Telecom, Elev Mach.
- Fire Pump Rooms)
- Restrooms
- Exterior Exits
- Vertical Exits
- Exit Location of Main Exits

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Warren J. Baker Center for Science and Mathematics Building 180 Floor-5

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CAL POLY
Fire Protection Engineering
CBC Table 1021.1

Building Level | Required # of Exits | Actual # of Exits
--- | --- | ---
Level 6 | 2 | 3

Occupant Load: 254

Warren J. Baker Center for Science and Mathematics Building 180 Floor-6

CAL Poly
Fire Protection Engineering
<table>
<thead>
<tr>
<th>Building Level</th>
<th>Required # of Exits</th>
<th>Actual # of Exits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 7</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

CBC Table 1021.1

Occupant Load: 1

Natural Atrium Roof Dampers (Typical -2)

Warren J. Baker Center for Science and Mathematics Building 180 Floor-7
• Occupant Behavior:

- The CSM is mainly used by students and professors for classes and laboratory experiments.
- The center open atrium area is set up for people to congregate or study on floors two through six.
- In the case of an alarm, most occupants would react quickly, therefore we would have very little pre-movement time.
- There is also an Emergency Voice/Alarm Communication System (EVACS) alarm system with pre-recorded messages for evacuation.
- From the SFPE Handbook, Table 3-12.2 for our type of building and occupants we would get a Pre-Movement time of 36 seconds.

• Egress Capacity:

- Egress capacities for Doors and Stairs based on LSC Table 7.3.3.1, (0.3) for stairs and (0.2) for doors is summarized in the next table.
All existing width components exceed the required occupancy load for all floors.
• **Structural Fire Protection:**

  • Construction Type & Fire Resistance Rating

  - The CSM building is a Type 1-B per IBC Section 602 (2015), fully sprinklered

  - Steel I-Beams with Spray on Fire Proofing (SFRM) and Steel Columns with SFRM or Encased in Concrete

  - Light Weight Concrete on Metal Decking (6” Slab Thickness)

  - The Existing Building is in compliance with CBC Section 506.2 for Allowable Area per Floor based on mixed occupancy

  - The Fire Resistance Rating for Building Elements for Type 1-B Construction & Occupancy Separation are shown in the next two tables
## Fire-resistance rating for building elements – Type 1-B

<table>
<thead>
<tr>
<th>Building Element</th>
<th>Fire resistance rating (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Structural Frame</td>
<td>2*</td>
</tr>
<tr>
<td>Bearing Walls (Exterior)</td>
<td>2</td>
</tr>
<tr>
<td>Bearing Walls (Interior)</td>
<td>2*</td>
</tr>
<tr>
<td>No Bearing Walls (Interior)</td>
<td>0</td>
</tr>
<tr>
<td>Floor Construction and Associated Secondary Members</td>
<td>2</td>
</tr>
<tr>
<td>Roof Construction and Associated Secondary Members</td>
<td>1</td>
</tr>
</tbody>
</table>

*Ref. CBC- 2007 Table 601  (*1 hour permitted where only supporting a roof.)*

## Fire-resistance rating specified in CSM project

- 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*
Table 6- Fire-resistance rating for occupancies separation

<table>
<thead>
<tr>
<th>Building Element</th>
<th>Fire resistance rating (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B to A-3</td>
<td>1</td>
</tr>
<tr>
<td>B to H-3</td>
<td>1</td>
</tr>
<tr>
<td>B to S-1</td>
<td>No separation required</td>
</tr>
<tr>
<td>B to S-2</td>
<td>1</td>
</tr>
<tr>
<td>S-1 to H-3</td>
<td>1</td>
</tr>
<tr>
<td>S-1 to S-2</td>
<td>1</td>
</tr>
</tbody>
</table>

Ref. CBC- 2007 Table 508.3.3
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.

All Fire / Smoke Barriers and Penetrations - Fire Stopped per NFPA 101 (2015) Section 8.5.3
Open Atrium PyroSim Section
Open Atrium Pictures
Flame Spread and Smoke Development

As defined by NFPA 101 – 2015, Section 3.3.92.3 Interior Finish are the exposed surfaces of walls, ceilings, and floors within buildings.

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

<table>
<thead>
<tr>
<th>Classification (Class)</th>
<th>Flame Spread</th>
<th>Smoke Development</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0-25</td>
<td>0-450</td>
<td>No continued propagation of fire in any element thereof when tested</td>
</tr>
<tr>
<td>B</td>
<td>26-70</td>
<td>0-450</td>
<td>-</td>
</tr>
<tr>
<td>C</td>
<td>76-200</td>
<td>0-450</td>
<td>-</td>
</tr>
</tbody>
</table>

Ref. NFPA 101-2015, Section 10.2.3.4
Flame spread classifications required for interior finishes in the CSM, according to 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>
<thead>
<tr>
<th>Group</th>
<th>Exit enclosures and exit passageways*</th>
<th>Corridors*</th>
<th>Rooms and enclosed spaces*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-3</td>
<td>B</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>S-1</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>S-2</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>

Ref. CBC-2007, Table 803.5 *Sprinklered

Flame Spread Classification specified for the CSM

<table>
<thead>
<tr>
<th>GROUP</th>
<th>EXIT ENCLOSURES AND EXIT PASSAGeways SPRINKLER</th>
<th>CORRIDORS SPRINKLED</th>
<th>ROOMS AND ENCLOSED SPACES SPRINKLED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-3</td>
<td>B</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>S-1</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>S-2</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>

Ref. ZGF, 2009
• Fire Suppression System:

- Wet Pipe Sprinkler Systems (Zoned per Floor, Levels 1 thru 6)
- Public Water Supply
- In-Line Electric Fire Pump (Connected to Emergency Generator per CBC Section 404.7)
- Class 1 Standpipes located in all Required Egress Stairs
- Design Criteria Light Hazard and Ordinary Hazard Group 1
- Design Criteria Class 1 Standpipe
- Quick Response Upright and Pendent Sprinklers
- Fire Sprinkler Piping is Schedule 10 for Mains and Schedule 40 for Branch Lines
• Fire Suppression Public Water Supply:

FLOW TEST SUMMARY

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>STATIC PSI</td>
<td>60</td>
</tr>
<tr>
<td>RESIDUAL PSI</td>
<td>55</td>
</tr>
<tr>
<td>PITOT PSI</td>
<td>35</td>
</tr>
<tr>
<td>ORIFICE DIAMETER</td>
<td>2 1/2</td>
</tr>
<tr>
<td>COEFFICIENT OF DISCHARGE</td>
<td>0.9</td>
</tr>
<tr>
<td>GPM</td>
<td>914</td>
</tr>
<tr>
<td>DATE</td>
<td>8-19-2011</td>
</tr>
<tr>
<td>LOCATION</td>
<td>N. POLY VIEW DRIVE</td>
</tr>
<tr>
<td>BY WHO</td>
<td>FLUID RESOURCE MANAGEMENT, INC.</td>
</tr>
<tr>
<td>ADJUSTED FLOW 10% REDUCTION</td>
<td></td>
</tr>
<tr>
<td>STATIC PSI</td>
<td>54</td>
</tr>
<tr>
<td>RESIDUAL PSI</td>
<td>49</td>
</tr>
<tr>
<td>GPM</td>
<td>914</td>
</tr>
</tbody>
</table>

STATIC & RESIDUAL TAKEN FROM HYD. # 63
FLOW TAKEN FROM HYD. # 64

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• In-Line Electric Fire Pump:

### Performance Curve

- **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 shut off: 156.2 psi
- 65% Head at 150% flow: 73.4 psi
- Flow at 150%: 1125 US gpm
- Head at 150: 89 psi
- Power Req. at 150%: 66.3 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 included.

### Table

<table>
<thead>
<tr>
<th>Flow (US gpm)</th>
<th>Head (psi)</th>
<th>Pump Efficiency (%)</th>
<th>Power Required (hp)</th>
<th>NPSH Required (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>125.2</td>
<td>0.0</td>
<td>34.7</td>
<td></td>
</tr>
<tr>
<td>197.6</td>
<td>125.2</td>
<td>36.6</td>
<td>39.5</td>
<td></td>
</tr>
<tr>
<td>356.1</td>
<td>124.2</td>
<td>62.6</td>
<td>45.7</td>
<td></td>
</tr>
<tr>
<td>592.7</td>
<td>119.6</td>
<td>78.8</td>
<td>52.6</td>
<td></td>
</tr>
<tr>
<td>790.2</td>
<td>110.9</td>
<td>86.2</td>
<td>59.5</td>
<td></td>
</tr>
<tr>
<td>967.8</td>
<td>98.9</td>
<td>97.0</td>
<td>65.7</td>
<td></td>
</tr>
<tr>
<td>1185.3</td>
<td>84.4</td>
<td>82.8</td>
<td>70.7</td>
<td></td>
</tr>
<tr>
<td>1382.9</td>
<td>67.9</td>
<td>74.2</td>
<td>74.0</td>
<td></td>
</tr>
<tr>
<td>1560.4</td>
<td>48.2</td>
<td>59.1</td>
<td>75.4</td>
<td></td>
</tr>
</tbody>
</table>
2 ½” Fire Hose & Zone Control Valves on Level 1 are Pressure Reducing (175 psi Max.)

Standpipe 3 is a Combination of Fire Hose and Sprinkler Control Valves

In-Line Electric Fire Pump Rated for 113 psi @ 750 gpm

8” Backflow Preventer

Public Water Main

Standpipe Stair 4

Standpipe Stair 5

Standpipe Stair 3

Standpipe Stair 1

Standpipe - Overall Isometric

4-Way FDC

24”x24” Recessed Fire Hose Va. Cabinet Crocker Fig. 1700 W/ Full wired glass (FW)

2½” Fire Hose Va. Croker Fig. 5035 Polish Brass W/ 2½” Adapter W/ 37° Cap & Chain W/ Pressure Gages (1st. Floor Only)

2½” Pressure Reducing Fire Hose Valve Elkhart Model #BFR-25-2.5

Setting ‘E’ Polish Brass W/ 3½” Adapter W/ ½” Cap & Chain W/ Pressure Gages (1st. Floor Only)
• Building Standpipe Locations:

- Stair 1
- Stair 2 (No Standpipe Required)
- Stair 3
- Stair 4
- Stair 5
• Design Criteria Sprinkler Systems:

<table>
<thead>
<tr>
<th>Description</th>
<th>Hazard Classification</th>
<th>NFPA 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classrooms, auditoriums, corridors, offices, conference rooms</td>
<td>Light Hazard</td>
<td>5.2</td>
</tr>
<tr>
<td>Laboratories, storage, mechanical, electrical</td>
<td>Ordinary Hazard Group 1</td>
<td>5.3.1</td>
</tr>
</tbody>
</table>

**Design Criteria: Occupancy Classification**

\[
\text{Percent reduction to design area} = -\frac{3x}{2} + 55
\]

Ceiling Height = 10.5 feet  
Area Reduction = 39.25%  
Design Area = \((0.6075) \times (1500 \text{ ft}^2) = 911.25 \text{ ft}^2\)
### Design Criteria & Hydraulic Calculation for Standpipe Systems:

**Water Supply Curve (C)**

#### Pressure at most remote outlet
- **100 psi**

#### Flow at most remote outlet
- **500 gpm**

#### Flow for each additional SP
- **250 gpm**

#### Max Flow
- **1000 gpm** (fully sprinklered building)

#### Duration
- **30 minutes**

### Note

- **2 ½” Fire Hose & Zone Control Valves located on Level 1 are Pressure Reducing (175 psi Max.)**

---

<table>
<thead>
<tr>
<th>Pressure at most remote outlet</th>
<th>100 psi</th>
<th>7.8.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow at most remote outlet</td>
<td>500 gpm</td>
<td>7.10.1.1.1</td>
</tr>
<tr>
<td>Flow for each additional SP</td>
<td>250 gpm</td>
<td>7.10.1.1.3</td>
</tr>
<tr>
<td>Max Flow</td>
<td>1000 gpm</td>
<td>7.10.1.1.5</td>
</tr>
</tbody>
</table>

### Table of Design Criteria & Hydraulic Calculation

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Requirement</th>
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</thead>
<tbody>
<tr>
<td>Pressure at most remote outlet</td>
<td>100 psi</td>
</tr>
<tr>
<td>Flow at most remote outlet</td>
<td>500 gpm</td>
</tr>
<tr>
<td>Flow for each additional SP</td>
<td>250 gpm</td>
</tr>
<tr>
<td>Max Flow</td>
<td>1000 gpm (fully sprinklered building)</td>
</tr>
<tr>
<td>Duration</td>
<td>30 minutes</td>
</tr>
</tbody>
</table>

### Diagram

- **City Water Supply Curve**
- **Pump Data**
- **Demand**
  - **D1 - Elevation**: 24.254
  - **D2 - System Flow**: 144.081
  - **Hose (Adj City)**: 1000
  - **Hose (Demand)**: 1000
  - **Safety Margin**: 6.911

---

**Combined City & Fire Pump Curve**

**Fire Pump Curve**

**City Supply Curve**

---

**Cal Poly**

**Fire Protection Engineering**
Fire Sprinkler System Hydraulic Calculations:

Water Supply Curve (C)

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

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

City Water Adjusted to Pump Inlet for PI - 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

<table>
<thead>
<tr>
<th>PSI Req. at BOR6</th>
<th>Hand Calculation</th>
<th>Computer Based Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSI Req. at Source (SRC)</td>
<td>316.3</td>
<td>347.3</td>
</tr>
<tr>
<td>PSI Available at Source (SRC)</td>
<td>32.65</td>
<td>52.66</td>
</tr>
<tr>
<td>PSI Safety Factor</td>
<td>8.52</td>
<td>13.57</td>
</tr>
</tbody>
</table>
• Typical Fire Sprinkler System Lay-out:
Fire Alarm and Detection System:

- CSM is a PROTECTED BUILDING:
  - Signals are sent to the University Police Department’s Communications Center which is staffed 24/7 (Supervising Station)

- Addressable Supervising Station Alarm System

- Emergency Communication System:
  - One-Way Fire Emergency Voice/Alarm Communications System (EVACS)
  - Two-Way Emergency Communication System (Telephone System)

- Fire Alarm Control Panel (FACP)

- Detection / Notification Devices

- Sequence of Operation
• Alarm System - Class B: (Addressable & Manual Detection)

- NFPA 72, 6.4.2.1.1 (2)
  Class B circuits 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 NAC.
• Fire Alarm Control Panel - FACP

- FACP Located in Room 122 on First Level
• Initiating / Supervisory Devices

➢ Initiating devices:
  • Sprinkler Water Flow Switch
  • Spot Type Smoke Detectors
  • Duct Smoke Detectors
  • Beam Smoke Detectors
  • Fire Pump Controller - Pump Run

➢ Supervisory Signal Devices:
  • Fire Pump Controller - Trouble Signal
  • Tamper Switches – Sprinkler System Control Valves

➢ Manual Initiating Devices:
  • Manual Fire Alarm Pull Stations
• Notification Devices
  • Speakers
  • Speaker / Strobe
  • Bells
  • Annunciators
• Atrium Smoke Beam Detection

2 PER FLOOR – TOTAL OF 10

12’ AFF

12’ AFF

SYMBOL LEGEND

<table>
<thead>
<tr>
<th>COUNT</th>
<th>FIRE ALARM SYMBOLS</th>
<th>MODEL #</th>
<th>OPEN LISTING #</th>
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<tbody>
<tr>
<td>31</td>
<td>MANUAL PULL STATION</td>
<td>N93-12LX</td>
<td>7150-0028:0116</td>
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<tr>
<td>73</td>
<td>STROBE ONLY</td>
<td>SW</td>
<td>7305-1653-001</td>
</tr>
<tr>
<td>165</td>
<td>SPEAKER/STROBE</td>
<td>SWPS</td>
<td>7305-1653-001</td>
</tr>
<tr>
<td>8</td>
<td>SPEAKER ONLY</td>
<td>SWP</td>
<td>7305-1653-001</td>
</tr>
<tr>
<td>7</td>
<td>SPEAKER - WEATHER PROOF</td>
<td>SPF-WK</td>
<td>7305-1653-001</td>
</tr>
<tr>
<td>1</td>
<td>HEAT DETECTOR</td>
<td>PST-J81</td>
<td>7270-0028:196</td>
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<td>18</td>
<td>SMOKE DETECTOR</td>
<td>FSR-611</td>
<td>7272-0028:206</td>
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<tr>
<td>64</td>
<td>SMOKE DETECTOR - DUCT</td>
<td>UNR</td>
<td>5243-1653-990</td>
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<tr>
<td>25</td>
<td>BEAM SMOKE DETECTOR - TRANSMITTER</td>
<td>OSI-SPW</td>
<td>7200-1728:0121</td>
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<tr>
<td>15</td>
<td>BEAM SMOKE DETECTOR - RECEIVER</td>
<td>OSI-04</td>
<td>7200-1728:0121</td>
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<tr>
<td>1</td>
<td>FIRE ALARM CONTROL PANEL</td>
<td>NFS0.840</td>
<td>7160-0028:0043</td>
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<td>6</td>
<td>REMOTE NOTIFICATION POWER SUPPLY</td>
<td>ACPFD010</td>
<td>7315-0028:246</td>
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<td>4</td>
<td>FIRE ALARM TERMINAL CABINET</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>32</td>
<td>END OF LINE RESISTOR</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>2</td>
<td>REMOTE ANNUNCIATOR</td>
<td>FD4-80</td>
<td>7160-0028:0069</td>
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<tr>
<td>8</td>
<td>MAGNETIC DOOR HOLDER</td>
<td>N/A</td>
<td>BY OTHERS</td>
</tr>
<tr>
<td>21</td>
<td>ADDRESSABLE MODULE</td>
<td>FMM-1</td>
<td>7200-0028:0219</td>
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<tr>
<td>12</td>
<td>RELAY MODULE</td>
<td>FMM-1</td>
<td>7300-0028:219</td>
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<tr>
<td>15</td>
<td>WATERFLOW SWITCH</td>
<td>N/A</td>
<td>BY OTHERS</td>
</tr>
<tr>
<td>10</td>
<td>VALVE TAMPER SWITCH</td>
<td>N/A</td>
<td>BY OTHERS</td>
</tr>
<tr>
<td>21</td>
<td>DUAL MONITOR MODULE</td>
<td>PDM-1</td>
<td>7300-0028:0219</td>
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<tr>
<td>64</td>
<td>DUAL RELAY / MONITOR MODULE</td>
<td>PDRM-1</td>
<td>7300-0028:0219</td>
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<tr>
<td>12</td>
<td>FIRE FIGHTERS PHONE JACKS</td>
<td>FJM-1</td>
<td>7305-1653-0152</td>
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<tr>
<td>4</td>
<td>DIGITAL AUDIO AMPLIFIERS</td>
<td>DA2</td>
<td>7110-0028:023</td>
</tr>
<tr>
<td>1</td>
<td>SIX RELAY CONTROL MODULE</td>
<td>XP6-H</td>
<td>7300-0028:0219</td>
</tr>
<tr>
<td>1</td>
<td>TEN-INPUT MONITOR MODULE</td>
<td>XP10-M</td>
<td>7300-0028:0219</td>
</tr>
</tbody>
</table>

CAL POLY
Fire Protection Engineering
## Sequence of Operations (Atrium Detection & Activation)

Second Floor Flow Switch Covers Entire Floor. Not just the Atrium.
• **Smoke Management System (SMS)**

• **Building SMS:** When Duct Detectors activated Alarm System goes off, Air Handler Units are shut down, and Smoke Dampers are closed, this compartmentalizes the Heat & Smoke into the fire area of origin per NFPA 92A

• **Atrium SMS:** The five story Atrium is the major concern for Smoke Management. As indicated in the Sequence of Operations many devices have to operate for this Naturally Ventilated System to operate correctly per NFPA 92B
Performance-Based Approach

- Any occupant who is not intimate with ignition shall not be exposed to instantaneous or cumulative **untenable** conditions. (NFPA 101 -2015 - 5.2.2)

- **RSET vs ASET**

\[
\text{RSET} = t(\text{detection}) + t(\text{pre-movement}) + t(\text{movement})
\]

- \( t(\text{detection}) = \text{Time from ignition to detection and notification} \) [ 60 sec* ]
- \( t(\text{pre-movement}) = \text{Time from notification to start of egress} \) [ 36 sec** ]
- \( t(\text{movement}) = \text{Time to completely evacuate} \) [ Pathfinder ]

* Visual Awareness, Smoke / Beam Detectors, Sprinklers, or Manual Pull

** Prerecorded voice message with trained staff (SFPE Handbook Table 3.12.2)
Design Fire Scenario Selection

- Selection of a design fire for performance-based design is the most important first step
- The process used to develop my scenarios are as follows:

  Qualitative Hazard Analysis - Potential fuel / ignition sources were reviewed based upon representative materials and equipment within various areas.

  Heat Release Rate Curves - The fire scenarios were quantified by assuming a fast $t^2$ fire ($\propto = 0.047$ (NFPA 204)). This assumption is a reasonable estimate for the types of hazards that are likely in the building.

  Maximum Heat Release Rate - The maximum heat release rate was estimated by determining the maximum fire size of a given fuel package.
Relative Fire Size
Design Fire # 1 (DF-1)

- Level 2 in atrium center area, under balcony
- All Furniture is TB 133 compliant (Max HRR is 80 kW per piece of furniture)
- Sprinkler Controlled
- With the furniture and picture arrangement shown we will get a HRRPUA of 340 kW/m² (0.24 m²) to get a Max HRR of +/- 80 kW
- Fast $t^2$ fire ($\alpha = 0.047$)
Design Fire # 2 (DF-2)

• Level 2 in atrium open area, 80 ft. ceiling height

• All Furniture is TB 133 compliant (Max HRR is 80 kW per piece of furniture)

• Sprinklers not Expected to Activate

• With the furniture arrangement shown we will get a HRRPUA of 340 kW/m² (0.24 m²) to get a Max HRR +/- 80 kW

• Fast $t^2$ fire ($\alpha = 0.047$)
Tenability Condition Assessment

Tenability Criteria:

- Visibility - 13 m
- Temperature - 60°C
- Radiant Flux – 1.7 kW/m²
- Carbon Monoxide – 30000 ppm*min (X_CO - 1.07e-4 mol/mol maximum level after 10 min)
- Measured at 1.8 m Above Finish Floor (AFF)
RSET - Pathfinder

- Pathfinder model with the building fully occupied (2996) and Stair 2 closed (Atrium Exposed Stair)

- Pathfinder model with the building fully occupied (2996) and Stair 2 open (Atrium Exposed Stair)
RSET - Pathfinder

- Pathfinder model with the last occupant exiting (1229.0 sec.) and Stair 2 closed (Atrium Exposed Stair)

- Pathfinder model with the last occupant exiting (650.3 sec.) and Stair 2 open (Atrium Exposed Stair)
RSET - Pathfinder

- Pathfinder model with Center Atrium Loaded and Stair 2 open (Atrium Exposed Stair)

- Pathfinder model with the last occupant exiting Center Atrium (274.8 sec.) and Stair 2 open (Atrium Exposed Stair)
## RSET - Pathfinder

<table>
<thead>
<tr>
<th>Level</th>
<th>t(detection) [sec]</th>
<th>t(pre-movement) [sec]</th>
<th>t(movement) [sec] (Pathfinder)</th>
<th>RSET Total Time [sec]</th>
<th>1.5 times RSET [sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>60</td>
<td>36</td>
<td>55.0</td>
<td>151.0</td>
<td>226.2</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>36</td>
<td>27.5</td>
<td>123.5</td>
<td>185.3</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
<td>36</td>
<td>54.9</td>
<td>150.9</td>
<td>226.4</td>
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<tr>
<td>5</td>
<td>60</td>
<td>36</td>
<td>55.0</td>
<td>151.0</td>
<td>226.2</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>36</td>
<td>82.4</td>
<td>178.4</td>
<td>267.6</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>36</td>
<td>274.8</td>
<td>370.8</td>
<td>556.2</td>
</tr>
</tbody>
</table>

RSET = t(detection) + t(pre-movement) + t(movement)
ASET – PyroSim / FDS

PyroSim Model Section

Roof Dampers – Air Exhaust

DF-1

Second Level Main North Doors – Air Inlet

DF-2

Second Level Main South Doors – Air Inlet
Analyzing Furniture Arrangement Using PyroSim

- Ran first PyroSim model to determine that fire would spread to other furniture within the room for standard Couch with a HRR of 1000 kW

- Furniture Arrangement Showing Fire Spread @ 396 Seconds for 1000 kW Fire
• Using the same parameters in the model the simulation was run keeping the HRR to 80 kW per TB 133 @ 270 and 600 seconds (Time to egress each floor and entire Atrium area respectively per Pathfinder)

Furniture Arrangement HRR – 80 kW @ 270 Seconds
We can see from the model results that the fire does not spread to the other pieces of furniture with a limited HRR of 80 kW per TB 133.
For a HRR of approximately 80 kW the maximum ceiling temperature is 52 °C at 550 seconds, with the TB 133 compliant furniture the sprinkler heads will not activate (activation @ 68 °C)
ASET – PyroSim / FDS – Design Fire 1 (DF-1)

- Figures below show the model simulation Fire/Smoke @ 270 & 600 second for DF-1

PyroSim Model DF-1 @ 270 Seconds    PyroSim Model DF-1 @ 600 Seconds
• Figures below show Visibility results @ 270 & 600 second for DF-1

• I am only showing Figures for Visibility because this was the only Tenable Condition that Failed for ASET vs RSET

PyroSim Model DF-1 @ 270 Seconds

PyroSim Model DF-1 @ 600 Seconds
ASET – PyroSim / FDS – Design Fire 2 (DF-2)

- Figures below show the model simulation Fire/Smoke @ 270 & 600 second for DF-2
• Figures below show Visibility results @ 270 & 600 second for DF-2

• I am only showing Figures for Visibility because this was the only Tenable Condition that Failed for ASET vs RSET
Conclusions

• The CSM building meets or exceeds all the prescriptive base code requirements for building design, egress analysis, structural fire protection, fire sprinkler systems and fire alarm systems design and installation.

• The performance base analysis was interesting in that, all the tenability criteria were met for the values set when comparing ASET being greater than RSET except for visibility of 13 meters.

• The second floor at 600 seconds (Figures Above) shows the area where egress Stair 3 exits out onto the second level Atrium area having visibility tenable criteria impaired.
Conclusions

- The Smoke Management Study used in the design and construction of the CSM building used a K value of 8 for light emitting signs and I used a k value of 3 for light reflective signs. This would account for the visibility criteria of 13 meters being acceptable in their report.

- The furniture within the atrium area must be compliant with TB 133 standards or the analysis would have to be re-evaluated for much higher HRR values.
Recommendations

• The first would be to put in place a voice evacuation system with live directives in conjunction with well-trained, staff that can be heard by all occupants in the building. The building is already designed with 2-hour rated separations for the East Wing, Center Area (Atrium) and West Wing. With the addressable fire alarm system and the EVACS system trained personal could direct occupant to the closest egress path away from the fire, this would reduce queuing and reduce the overall time to safely egress the building.

• Add a mechanical ventilated smoke exhaust system in accordance with NFPA 92B to the existing naturally ventilated smoke exhaust system. The mechanical ventilated smoke exhaust system would bring the second-floor visibility criteria of 13 meters back into compliance.

• Move the corridor doors to the East and West wings in the atrium area to align with the walls so no smoke can propagate into these areas. The would also allow Stair 3 to exit into the corridor and not directly into the atrium area.

Questions?

Thank You for Your Time