Final Project

Jacob Ludeman
FPE 596
Cal Poly, SLO
Winter 2018
Applicable Criteria

- California Building Code, 2016 Edition
- California Fire Code, 2016 Edition
- SFPE Handbook, 3rd Edition
- NFPA 14, Standard for the Installation of Standpipe and Hose Systems, 2016 Edition
- NFPA 72, National Fire Alarm and Signaling Code, 2016 Edition
- Handbook of Smoke Control Engineering
## Building Area Summary

<table>
<thead>
<tr>
<th>Level</th>
<th>Area (Square Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service</td>
<td>30,417</td>
</tr>
<tr>
<td>Plaza</td>
<td>34,794</td>
</tr>
<tr>
<td>Second</td>
<td>41,703</td>
</tr>
<tr>
<td>Third</td>
<td>41,703</td>
</tr>
<tr>
<td>Fourth</td>
<td>41,703</td>
</tr>
<tr>
<td>Fifth</td>
<td>41,703</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>232,023</strong></td>
</tr>
</tbody>
</table>
Prescriptive Requirements

Egress Requirements
Fire Alarm Design Requirements
Sprinkler System Requirements
Structural Requirements
Exit Requirements

- Discharge from Exits
  - Stair B discharges 720 of 2,160 occupants (33%)

- Number of Means of Egress
  - All levels require three exits
  - Levels 2 through 5: three provided
  - Level 1: five provided
  - Sub-Level: 4 provided

- Arrangement of Means of Egress
- Travel Distances, Common Path and Dead-Ends
Exit Requirements

- Exit capacity factors are from Table 7.3.3.1 from the 2015 Life Safety Code.
- Only the sub-level and plaza level meet exiting criteria.
- Unavailable exit: Main Entrance – 37%
## Occupancy Classification & Loads

<table>
<thead>
<tr>
<th>Room Type</th>
<th>Occupancy Type</th>
<th>Occupant Load Factor (Persons/square feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labs</td>
<td>Education</td>
<td>1/50</td>
</tr>
<tr>
<td>Office/Admin.</td>
<td>Business</td>
<td>1/100</td>
</tr>
<tr>
<td>Lecture Hall</td>
<td>Assembly</td>
<td>1/20 unless Fixed</td>
</tr>
<tr>
<td>Classroom</td>
<td>Business</td>
<td>1/20</td>
</tr>
<tr>
<td>Storage</td>
<td>Storage</td>
<td>1/300</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Storage</td>
<td>1/300</td>
</tr>
<tr>
<td>Electrical</td>
<td>Storage</td>
<td>1/300</td>
</tr>
</tbody>
</table>

### Fire Protection Engineering

**Room**

<table>
<thead>
<tr>
<th>OCCUPANCY</th>
<th>AREA</th>
<th>OLF</th>
<th># OCCUPANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Sub-Level Life Safety Plan

### Sub-Level Exit Capacity

<table>
<thead>
<tr>
<th></th>
<th>Stair A</th>
<th>Stair B</th>
<th>Stair C</th>
<th>SL Stair</th>
<th>Northeast Exit</th>
<th>South Exit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stairway Width (Inches)</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>-</td>
<td>-</td>
<td>240</td>
</tr>
<tr>
<td>Stair Factor</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stair Exit Capacity</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>-</td>
<td>-</td>
<td>800</td>
</tr>
<tr>
<td>Door Width (Inches)</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>72</td>
<td>72</td>
<td>144</td>
</tr>
<tr>
<td>Door Factor</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Door Exit Capacity</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>360</td>
<td>360</td>
<td>720</td>
</tr>
<tr>
<td>Available Exit Capacity</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>360</td>
<td>360</td>
<td>1440</td>
</tr>
<tr>
<td>Required Exit Capacity</td>
<td>131</td>
<td>131</td>
<td>131</td>
<td>131</td>
<td>131</td>
<td>131</td>
<td>784</td>
</tr>
</tbody>
</table>

### Diagram

- **Classrooms Business**: 988 SF
- **Business**: 370 SF
- **1/20**: 4
- **Office Business**: 370 SF
- **1/100**: 4
- **Electrical Substation**: 1022 SF
- **Mechanical Storage**: 3,395 SF
- **Storage Storage**: 79 SF
- **1/300**: 1

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**Cal Poly Fire Protection Engineering**
# Level 1 Life Safety Plan

## Plaza (First) Level Exit Capacity

<table>
<thead>
<tr>
<th></th>
<th>Main Entrance (South)</th>
<th>Northeast Exit</th>
<th>Northwest Exit</th>
<th>Southeast Exit</th>
<th>Southwest Exit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Door Width (Inches)</td>
<td>144</td>
<td>72</td>
<td>72</td>
<td>36</td>
<td>72</td>
<td>396</td>
</tr>
<tr>
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<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Door Exit Capacity</td>
<td>720</td>
<td>360</td>
<td>360</td>
<td>180</td>
<td>360</td>
<td>1980</td>
</tr>
<tr>
<td>Available Exit Capacity</td>
<td>720</td>
<td>360</td>
<td>360</td>
<td>180</td>
<td>360</td>
<td>1980</td>
</tr>
<tr>
<td>Required Exit Capacity</td>
<td>166</td>
<td>166</td>
<td>166</td>
<td>166</td>
<td>166</td>
<td>828</td>
</tr>
</tbody>
</table>

## Floor Plan

[Diagram of Level 1 showing various rooms and exit capacities]

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Fire Protection Engineering
# Level 2 Life Safety Plan

## Second Level Exit Capacity

<table>
<thead>
<tr>
<th></th>
<th>Stair A</th>
<th>Stair B</th>
<th>Stair C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stairway Width (Inches)</strong></td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>216</td>
</tr>
<tr>
<td><strong>Stair Factor</strong></td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td><strong>Stair Exit Capacity</strong></td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>720</td>
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<tr>
<td><strong>Door Width (Inches)</strong></td>
<td>42</td>
<td>72</td>
<td>42</td>
<td>156</td>
</tr>
<tr>
<td><strong>Door Factor</strong></td>
<td>0.2</td>
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<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td><strong>Door Exit Capacity</strong></td>
<td>210</td>
<td>360</td>
<td>210</td>
<td>780</td>
</tr>
<tr>
<td><strong>Available Exit Capacity</strong></td>
<td>210</td>
<td>240</td>
<td>210</td>
<td>660</td>
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<tr>
<td><strong>Required Exit Capacity</strong></td>
<td>212</td>
<td>212</td>
<td>212</td>
<td>635</td>
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</tbody>
</table>

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**Cal Poly**

Fire Protection Engineering
# Level 3 Life Safety Plan

## Third Level Exit Capacity

<table>
<thead>
<tr>
<th></th>
<th>Stair A</th>
<th>Stair B</th>
<th>Stair C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stairway Width (Inches)</strong></td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>216</td>
</tr>
<tr>
<td><strong>Stair Factor</strong></td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td><strong>Stair Exit Capacity</strong></td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>720</td>
</tr>
<tr>
<td><strong>Door Width (Inches)</strong></td>
<td>72</td>
<td>72</td>
<td>42</td>
<td>186</td>
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<tr>
<td><strong>Door Factor</strong></td>
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<td>0.2</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td><strong>Door Exit Capacity</strong></td>
<td>360</td>
<td>360</td>
<td>210</td>
<td>930</td>
</tr>
<tr>
<td><strong>Available Exit Capacity</strong></td>
<td>240</td>
<td>240</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td><strong>Required Exit Capacity</strong></td>
<td>243</td>
<td>243</td>
<td>243</td>
<td>728</td>
</tr>
</tbody>
</table>

*Note: Calculations based on standard fire safety regulations.*

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Fire Protection Engineering
# Level 4 Life Safety Plan

## Fourth Level Exit Capacity

<table>
<thead>
<tr>
<th></th>
<th>Stair A</th>
<th>Stair B</th>
<th>Stair C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stairway Width (Inches)</strong></td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>216</td>
</tr>
<tr>
<td><strong>Stair Factor</strong></td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td><strong>Stair Exit Capacity</strong></td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>720</td>
</tr>
<tr>
<td><strong>Door Width (Inches)</strong></td>
<td>72</td>
<td>72</td>
<td>42</td>
<td>186</td>
</tr>
<tr>
<td><strong>Door Factor</strong></td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td><strong>Door Exit Capacity</strong></td>
<td>360</td>
<td>360</td>
<td>210</td>
<td>930</td>
</tr>
<tr>
<td><strong>Available Exit Capacity</strong></td>
<td>240</td>
<td>240</td>
<td>210</td>
<td>690</td>
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<tr>
<td><strong>Required Exit Capacity</strong></td>
<td>247</td>
<td>247</td>
<td>247</td>
<td>740</td>
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**Cal Poly**

Fire Protection Engineering
Level 5 Life Safety Plan

<table>
<thead>
<tr>
<th></th>
<th>Stair A</th>
<th>Stair B</th>
<th>Stair C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stairway Width (Inches)</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>216</td>
</tr>
<tr>
<td>Stair Factor</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>Stair Exit Capacity</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>720</td>
</tr>
<tr>
<td>Door Width (Inches)</td>
<td>72</td>
<td>72</td>
<td>42</td>
<td>186</td>
</tr>
<tr>
<td>Door Factor</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Door Exit Capacity</td>
<td>360</td>
<td>360</td>
<td>210</td>
<td>930</td>
</tr>
<tr>
<td>Available Exit Capacity</td>
<td>240</td>
<td>240</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Required Exit Capacity</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>749</td>
</tr>
</tbody>
</table>

### Floor Plan Diagram

- OFFICE BUSINESS: 1,959 SF, 1/20, 26
- CLASSROOM BUSINESS: 2,376 SF, 1/20, 119
- CONFERENCE ASSEMBLY: 966 SF, 1/15, 66
- STORAGE: 150 SF, 1/20, 1 EACH
- CLASSROOM BUSINESS: 555 SF, 1/20, 26
- OFFICE BUSINESS: 2,172 SF, 1/100, 23

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CAL POLY
Fire Protection Engineering
Prescriptive Requirements

Egress Requirements
Fire Alarm Design Requirements
Sprinkler System Requirements
Structural Requirements
Fire Alarm Devices

Simplex Manual Pull Station

Simplex Heat Detector

Simplex True Alarm Photoelectric Analog Sensor

Simplex Duct Detector
Level One Fire Alarm Devices
Notification Appliances

Simplex Visual Unit

Wheelock MT-12/24 Audible Horn Appliance

Simplex Audio Visual Unit
Battery Calculations

- Two 50 amp-hour batteries
- 44.357 amp-hours required including 20% increase

<table>
<thead>
<tr>
<th>TOTAL STANDBY X # OF HOURS</th>
<th>36.660 AH (24 Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL ALARM X # OF MINUTES/60</td>
<td>0.304 AH (5 Minutes)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>36.964 AH</td>
</tr>
<tr>
<td>AH REQUIRED W/20% DERATING FACTOR</td>
<td>44.357 AH</td>
</tr>
<tr>
<td>ACTUAL BATTERIES BEING SUPPLIED</td>
<td>QTY. 2 50.0 AH BATTERIES</td>
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<td></td>
<td>2081-9296</td>
</tr>
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</table>
Fire Alarm Design Requirements

- Sequence of Operations

<table>
<thead>
<tr>
<th>Sequence of Operations</th>
<th>Fire Sprinkler Waterflow</th>
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</thead>
<tbody>
<tr>
<td>ANNUNCIATE AT FIRE CONTROL PANEL</td>
<td>YES</td>
</tr>
<tr>
<td>ANNUNCIATE AT 24 HR ATTENDED LOCATION</td>
<td>YES</td>
</tr>
<tr>
<td>ACTIVATE SPRINKLER BELL</td>
<td>YES</td>
</tr>
<tr>
<td>ACTIVATE AUDIO/VISUAL DEVICES THROUGHOUT BLDG</td>
<td>YES</td>
</tr>
<tr>
<td>RECALL ELEVATORS TO FIRST FLOOR</td>
<td>NO</td>
</tr>
<tr>
<td>RECALL ELEVATORS TO ALTERNATE FLOOR</td>
<td>NO</td>
</tr>
<tr>
<td>SHUT DOWN AHU 1, 2, &amp; 3</td>
<td>NO</td>
</tr>
<tr>
<td>SHUT DOWN EXHAUST FANS 1, 2, 3, 4, 5, 6, 7, 8</td>
<td>NO</td>
</tr>
<tr>
<td>CLOSE DAMPERS SERVING LAB VENTILATION AREAS</td>
<td>NO</td>
</tr>
<tr>
<td>CLOSE DAMPERS IN COMMON AREAS</td>
<td>NO</td>
</tr>
<tr>
<td>SHUT DOWN AHU 4 &amp; 5</td>
<td>NO</td>
</tr>
<tr>
<td>SHUNT TRIP ELEVATOR POWER</td>
<td>NO</td>
</tr>
<tr>
<td>RELEASE ELECTRO-MAG DOORS</td>
<td>YES</td>
</tr>
<tr>
<td>RAISE AUDITORIUM LIGHTS/MUTE AUDITORIUM</td>
<td>YES</td>
</tr>
<tr>
<td>RELEASE MONITORED SMOKE GUARD</td>
<td>NO</td>
</tr>
</tbody>
</table>

Cal Poly
Fire Protection Engineering
Prescriptive Requirements

Egress Requirements
Fire Alarm Design Requirements
Sprinkler System Requirements
Structural Requirements
Existing Standpipe System

- Class I manual dry standpipe system
- 4-way fire department inlet
- Existing 6” dry standpipe riser in each of the 3 main stairwells with 2 ½” hose valves on floor landings levels 1 through 5
- Two 2 ½” test hose valves on the roof above each riser
- Water supply is from a 12” main circulating around the perimeter of the building and adjacent building with 6” fire water supply to the existing sprinkler system in the building.
Water Flow Tests

- Static Pressure: 87 psi
- Residual Pressure: 67 psi
- Observed Flow: 1,117 gpm
- Flow at 20 psi: 2,147 gpm
Fire Sprinkler Demands

- Light Hazard
  - 0.10 gpm/sf over 1,500 sf
- Ordinary Hazard Group 2
  - 0.20 gpm/sf over 3,000 sf
- Extra Hazard Group 1 (High Hazard)
  - 0.30 gpm/sf over 2,500 sf
Hydraulic Calculations

- Extra Hazard Group 1
- HSA = 500 gpm for 120 min. per Table 11.2.3.1.2
- Standard response sprinklers with k-factor of 5.6 and activation temperature of 212°F
- Steel Pipe
  - C=120
Hydraulic Calculations

Sprinkler #1, Branch Line #11
- \( Q = 100 \text{ sf} \times 0.30 \text{ gpm/sf} = 30 \text{ gpm} \)
- \( P = (30 \text{ gpm} / 5.6)^2 = 28.7 \text{ psi} \)
- Required flow and pressure at POC
  - \( Q=598 \text{ gpm} \)
  - \( P=142.3 \text{ psi} \)
- The city water pressure does not meet the requirements and a fire pump will need to be installed.
- Hose Stream Allowance: 500 gpm for 90 minutes
Hydraulic Graph
Pump Graph
Hydraulic Graph

- **Combined Supply Curve**
  - $Q = 1,100$ gpm
  - $P = 170$ psi

- **1000 GPM Fire Pump**
  - $Q = 1,100$ gpm
  - $P = 142$ psi

- **City Water Supply**

- **Sprinkler Demand**
Prescriptive Requirements

- Egress Requirements
- Fire Alarm Design Requirements
- Sprinkler System Requirements
- Structural Requirements
Elements of Construction

- **Columns**: Concrete, Steel Wide Flange
- **Beams**: Concrete, Steel Wide Flange
- **Floor Assemblies**: Concrete mat foundation, concrete footings, 2 hour rated concrete floor assembly
- **Roof Assemblies**: Concrete roof structure with insulation and built up roof membrane
- **Exterior Walls**: Concrete
- **Interior Walls**: Steel C Studs with rating wallboard protection on both sides of wall
  - 45 min = 1 layer ½” thick
  - 1 hour = 1 layer ⅝” thick
  - 1-½ hour = 2 layers ½” thick
  - 2 hour = 2 layers ⅝” thick
- **Joints**: Continuous min. 1” depth Hiliti FS-One Intumescent Firestop Sealant
- **Penetrations**: Sealant and 2 hour firestopping at penetration
- **Bracing**: HSS Steel Braces, Steel WF Moment Frames
# Structural Elements Requirements

<table>
<thead>
<tr>
<th>Building Element</th>
<th>Requirement</th>
<th>Existing Construction</th>
</tr>
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<tbody>
<tr>
<td>Primary Structural Framing</td>
<td>3 hours</td>
<td>3</td>
</tr>
<tr>
<td>Exterior Bearing Walls</td>
<td>3 hours</td>
<td>3</td>
</tr>
<tr>
<td>Interior Bearing Walls</td>
<td>3 hours</td>
<td>3</td>
</tr>
<tr>
<td>Interior Nonbearing Walls and Partitions</td>
<td>0 hours</td>
<td>1</td>
</tr>
<tr>
<td>Floor Construction and Members</td>
<td>2 hours</td>
<td>2</td>
</tr>
<tr>
<td>Roof Construction and Members</td>
<td>1.5 hours</td>
<td>2</td>
</tr>
<tr>
<td>Exterior Nonbearing Walls and Partitions</td>
<td>Table 602 of 2016 CBC</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Performance-Based Analysis

Goals
ASET vs. RSET
Design Fires
Tenability Criteria
Scenario Evaluation
Structural
Performance-Based Goals

- Create realistic worst-case scenario design fires
- Determine a realistic yet conservative egress time
- Utilize smoke control to assist in saving occupants not intimate with the ignition source
- Determine smoke layer height relative to occupant egress time
Performance-Based Analysis

Goals
- ASET vs. RSET
- Design Fires
- Tenability Criteria
- Scenario Evaluation
- Structural
ASET vs. RSET

- The available safe egress time must be more than the required safe egress time. The RSET value will include a factor of safety.
- ASET will be provided from a performance-based analysis on a design fire using FDS
- RSET will be measured from fire ignition and account for detection time, alarm notification time, pre-movement time and movement time.
Pre-Movement Time

- Occupancy Characteristics
  - Assume primarily college students and professors
- Pre-movement time: includes time to notification, reaction time, and pre-evacuation activity time
- Time to notification: 72 seconds
- Pre-Evacuation Activity Time: 48 seconds
- Total Pre-Movement Time: 2 minutes
Fire Detection Time

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>CALC. PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling height (H)</td>
<td>R/H</td>
</tr>
<tr>
<td>3.048 m</td>
<td>1.473</td>
</tr>
<tr>
<td>Radial distance (R)</td>
<td>dT(cj)/dT(pl)</td>
</tr>
<tr>
<td>4.5 m</td>
<td>0.232</td>
</tr>
<tr>
<td>Ambient temperature (To)</td>
<td>u(cj)/u(pl)</td>
</tr>
<tr>
<td>20 C</td>
<td>0.145</td>
</tr>
<tr>
<td>Actuation temperature (Td)</td>
<td>Rep. t2 coeff.</td>
</tr>
<tr>
<td>41.1 C</td>
<td>k</td>
</tr>
<tr>
<td>Response time index (RTI)</td>
<td>Slow</td>
</tr>
<tr>
<td>5 (m-s)1/2</td>
<td>0.003</td>
</tr>
<tr>
<td>Fire growth power (n)</td>
<td>Medium</td>
</tr>
<tr>
<td>2</td>
<td>0.012</td>
</tr>
<tr>
<td>Fire growth coefficient (k)</td>
<td>Fast</td>
</tr>
<tr>
<td>0.047 kW/s^2•n</td>
<td>0.047</td>
</tr>
<tr>
<td>Time step (dt)</td>
<td>Ultrafast</td>
</tr>
<tr>
<td>2 s</td>
<td>0.400</td>
</tr>
</tbody>
</table>
DETACT Model Results

DETACT

- Gas temp
- Det temp
- HRR

<table>
<thead>
<tr>
<th>Calculation time (s)</th>
<th>HRR</th>
<th>Gas temp</th>
<th>Gas velocity</th>
<th>Det temp</th>
<th>dT/dt</th>
</tr>
</thead>
<tbody>
<tr>
<td>72</td>
<td>243.6</td>
<td>43.8</td>
<td>0.62</td>
<td>41.03</td>
<td>0.4437</td>
</tr>
<tr>
<td>74</td>
<td>257.4</td>
<td>44.7</td>
<td>0.64</td>
<td>41.92</td>
<td>0.4478</td>
</tr>
</tbody>
</table>
Performance-Based Analysis

Goals
ASET vs. RSET
Design Fires
Tenability Criteria
Scenario Evaluation
Structural
Fire Scenarios

Diagram showing heat release rate (HRR) over time for different fire scenarios:

- **Sprinkler Activation**
  - Growth (HRR) decreases after activation.
  - **Constant HRR**
    - HRR remains constant after activation.
  - **Sprinklers overpowered by fire**
    - Continued growth with sprinkler activation.

Graph illustrating heat release rate (KW) vs. time from ignition (s):
- **Ultra-Fast**
- **Fast**
- **Medium**
- **Slow**

Fire scenarios:
- Thin Plywood Wardrobe
- Methyl Alcohol Pool
- Corrugated Cardboard Cartons 4.6 m (15 ft) High Various Contents
- Wood Pallets 1.5 m (5 ft) High
- Full Mail Bags 1 m (3 ft) High Pallet Stack
- Upholstered Furniture
- Cotton/Polyester Interspring Mattress
- Solid wood cabinetry
Design Fires

- Design Fire 1
  - Large lecture hall fire
  - Fast growth rate
- Design Fire 2
  - Upper level lab fire
  - Ultra-fast growth rate
- Design Fire 3
  - Reactor Fire
  - Ultra-Fast growth rate
- Design Fire 4
  - Wing classroom fire
  - Fast growth rate

Sources:
Design Fire #1

- Fast fire growth
  - Paper and cardboard
- First level
  - Greatest impact on structural
- Sprinkler Activation
  - $t = 185$ seconds
  - $HRR = 1605$ kW
Design Fire #2

- Ultra-fast fire growth
  - Flammable liquids
- Upper level laboratory
  - Steel construction
  - Smoke travel
- Sprinkler Activation
  - $t = 102$ seconds
  - $HRR = 1952$ kW
Design Fire #3

- Ultra-fast fire growth
  - 250 kW Nuclear Reactor
- Sub-Level
  - Smoke effect potential
  - Eliminate egress from Stair A
- Safe operating characteristics
  - Moderated
Design Fire #4

- Fast fire growth
  - Wastebasket or desks
- New wing classroom
  - Concrete construction
- Sprinkler Activation
  - $t = 185$ seconds
  - $HRR = 1355$ kW
Performance-Based Analysis

Goals
ASET vs. RSET
Design Fires
Tenability Criteria
Scenario Evaluation
Structural
Tenability Criteria

- Smoke Density of 0.5 [1/m]
- Visibility of 4m
- Temperature of 60 C
- Determine smoke layer height
  - More than 6 feet above floor
    - Method 3 (SFPE Handbook)
  - Less than 6 feet in any space
    - Method 2 (SFPE Handbook)
Performance-Based Analysis

Goals
ASET vs. RSET
Design Fires
Tenability Criteria
Scenario Evaluation
Structural
Design Fire #1

1.8 Minutes

7.1 Minutes
Level 1 Egress

- RSET = 2 minutes + 3 minutes = 5 minutes
- ASET = 7.1 minutes
Design Fire #2 - Temperature

8.8 Minutes
Design Fire #2 - Visibility

1.8 Minutes
Design Fire #2 - Visibility

3.1 Minutes
Design Fire #2 - Visibility

5.1 Minutes
Level 5 Egress

- For full building simultaneous evacuation, level 5 will have entered the protected stairway after 15.2 minutes.
- For staged evacuation, level 5 will have entered the protected stairway after 7.1 minutes.

<table>
<thead>
<tr>
<th>Event</th>
<th>Time [s]</th>
<th>Time [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>all persons have evacuated the Plaza (First) Level</td>
<td>139.3</td>
<td>2.3</td>
</tr>
<tr>
<td>All persons have evacuated the Sub-Level</td>
<td>181.3</td>
<td>3.0</td>
</tr>
<tr>
<td>All persons have evacuated the Fifth Level</td>
<td>425.3</td>
<td>7.1</td>
</tr>
<tr>
<td>End of Flow reaches the Fourth Level</td>
<td>438.3</td>
<td>7.3</td>
</tr>
<tr>
<td>All persons have evacuated the Fourth Level</td>
<td>852.5</td>
<td>14.2</td>
</tr>
<tr>
<td>End of Flow reaches the Third Level</td>
<td>865.5</td>
<td>14.4</td>
</tr>
<tr>
<td>All persons have evacuated the Third Level</td>
<td>1285.4</td>
<td>21.4</td>
</tr>
<tr>
<td>End of Flow reaches the Second Level</td>
<td>1299.4</td>
<td>21.7</td>
</tr>
<tr>
<td>All persons have evacuated the Second Level</td>
<td>1702.9</td>
<td>28.4</td>
</tr>
<tr>
<td>All persons have evacuated the building</td>
<td>1716.9</td>
<td>28.6</td>
</tr>
</tbody>
</table>
## ASET vs. RSET Summary

<table>
<thead>
<tr>
<th>Design Fire</th>
<th>Level</th>
<th>RSET</th>
<th>ASET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Local (room only) [min]</td>
<td>Overall (entire floor) [min]</td>
</tr>
<tr>
<td>Lecture Hall</td>
<td>1</td>
<td>1.2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1.2</td>
<td>9.1 or 17.2</td>
</tr>
</tbody>
</table>

[Cal Poly Fire Protection Engineering]
Solutions – Smoke Control

- Section 909.6 of the California Building Code, 2016
- Pressurization Method
  - Minimum 0.05 water gauge
  - Maximum 30 pound door-force

Full Building Egress

- $RSET = 2\text{ minutes} + 18.3\text{ minutes} = 20.3\text{ minutes}$
- $ASET = TBD$
Performance-Based Analysis

ASET vs. RSET
Design Fires
Tenability Criteria
Scenario Evaluation
Structural
Design Fire 2 - Beam Temperatures

- Unprotected W21 x 62
- Protected W21 x 62
Design Fire 4 - Concrete Beam Temperature vs. Depth

Temperature (°C)

Time (minutes)

0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00

0 100 200 300 400 500 600 700 800 900

CAL POLY
Fire Protection Engineering
Conclusion and Recommendations

- **Prescriptive Analysis**
  - Fire alarm system compliant with CBC requirements
  - Egress systems not compliant with CBC requirements
    - Change occupant load through redesignating spaces
    - Additional width for stairs and upper floor exits
  - Sprinkler system water demand exceeds the city water supply
    - Fire pump added to address issue
  - Structural fire protection complies with CBC requirements for Type I-A construction

- **Performance Based Analysis**
  - EVACS system and trained staff will decrease egress time
  - Smoke control system
Questions or comments?

Acknowledgements
- Dr. Richard Emberley
- Dr. Fred Mowrer
- Dr. Christopher Pascual