Fire and Life Safety Analysis
Agricultural Sciences Building – Building 11
California Polytechnic State University

Jonathan Schram  June 12, 2014
INTRODUCTION

Building Overview
Building Construction
Fire & Life Safety Features
Prescriptive Analysis
Performance Analysis
Recommendations
CODES DURING CONSTRUCTION

- Uniform Building Code (UBC)
- National Electric Code (NEC)
- NFPA 13
- NFPA 72
CURRENT CODES

- International Building Code (IBC), 2009 Edition
- NFPA 13, 2013 Edition
- NFPA 72, 2010 Edition
- The SFPE Handbook of Fire Protection Engineering, 4th Edition
**Building Overview**

**Overview**
- Three Story
- Open Mall
- Business Occupancy
- Unprotected Ordinary Construction (Type III-B)
- Fully Sprinklered

**Use and Occupancy**
- Lecture Halls, Labs, Office/Administration, Greenhouses and Storage
Open Mall Building –

Several structures housing a number of tenants, such as retail stores, drinking and dining establishments, entertainment and amusement facilities, offices, and other similar uses, wherein two or more tenants have a main entrance into one or more open malls.
### BUILDING CONSTRUCTION

<table>
<thead>
<tr>
<th>Construction Component</th>
<th>Description</th>
<th>Fire Resistance Rating (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Frame</td>
<td>Unprotected steel wide-flange beams/girders/Joists/columns</td>
<td>0</td>
</tr>
<tr>
<td>Bearing Walls</td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Corridors</td>
<td>5/8” gypsum bd, metal stud, R-11/R-19 insulation, 1/2” gypsum bd sheathing, cement plaster</td>
<td>1</td>
</tr>
<tr>
<td>Nonbearing Int./Ext. Walls</td>
<td>5/8” gypsum bd. Both sides, metal stud, R-11/R-19 insulation</td>
<td>0</td>
</tr>
<tr>
<td>Deck/Roof</td>
<td>Composite metal decking, lightweight concrete with welded wired fabric reinforcement</td>
<td>0</td>
</tr>
</tbody>
</table>

**Construction Type III-B?**

- Wood Trim
- Acoustical and Thermal insulating panels
  - Flame spread index greater than 25
# FIRE RESISTANCE REQUIREMENTS

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A&lt;sup&gt;d&lt;/sup&gt;</td>
<td>B</td>
<td>A&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Primary structural frame&lt;sup&gt;g&lt;/sup&gt; (see Section 202)</td>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Bearing walls</td>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Exterior&lt;sup&gt;f.g&lt;/sup&gt;</td>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Interior</td>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>See Table 602</td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Floor construction and secondary members (see Section 202)</td>
<td>2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Roof construction and secondary members (see Section 202)</td>
<td>1&lt;sup&gt;1/2&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b,c&lt;/sup&gt;</td>
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</tbody>
</table>
# Fire Resistance Requirements

## Table 602

<table>
<thead>
<tr>
<th>Fire Separation Distance = X (feet)</th>
<th>Type of Construction</th>
<th>Occupancy Group H</th>
<th>Occupancy Group F-1, M, S-1</th>
<th>Occupancy Group A, B, E, F-2, I, R, S-2</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td>X &lt; 5c</td>
<td>All</td>
<td>3</td>
<td>2</td>
<td></td>
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<tr>
<td>5 ≤ X &lt; 10</td>
<td>IA</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
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<tr>
<td></td>
<td>Others</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
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<tr>
<td>10 ≤ X &lt; 30</td>
<td>IA, IB</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td></td>
<td>IIB, VB</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
<td></td>
<td>Others</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>X ≥ 30</td>
<td>All</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>
### ALLOWABLE HEIGHT AND AREA

**Type III-B, B Occupancy - 3 Stories, 57 feet, 19,277 S.F.**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>TYPE OF CONSTRUCTION</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
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<tbody>
<tr>
<td>UL</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>HT</td>
<td>A</td>
</tr>
<tr>
<td>A-1</td>
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<td>S</td>
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<td></td>
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<td>A</td>
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<td>15,500</td>
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<td></td>
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</tr>
<tr>
<td>A-2</td>
<td>S</td>
<td>UT</td>
<td>S</td>
<td>UL</td>
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<td>A</td>
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<td>UT</td>
<td>A</td>
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<td>A</td>
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<td></td>
</tr>
</tbody>
</table>

**Table 503**

**ALLOWABLE BUILDING HEIGHTS AND AREAS**

Building height limitations shown in feet above grade plane. Story limitations shown as stories above grade plane. Building area limitations shown in square feet, as determined by the definition of “Area, building,” per story.
**Requirement Modifications**

Automatic Sprinkler System Increase (IBC 504.2)
- Building Height: 55 feet ~ 75 feet
  3 Stories ~ 4 Stories

& Frontage Increase (IBC 506.1, 506.2, 506.3)
- Building Area: 19,000 Sq ft ~ 61,750 Sq ft
HAZARDOUS MATERIALS

Compressed Hydrogen
HAZARDOUS MATERIALS

Maximum Allowable Quantity:
*Flammable Gases - 2000 ft³

❖ Quantity: 5
❖ Size 300 cylinders
❖ 261 ft³ per cylinder

Actual Quantity:
Hydrogen
1,305 ft³

*From IBC Table 307.1(1) (w/ a automatic fire sprinkler system)
Shaft/Exit Enclosures – 1-hour separation (IBC 707.4)
Assisted Rescue Areas – 1-hour separation (IBC 1007.7)
Service Areas Fronting Exit Passageway – 1-hour separation (IBC 402.4.6)
EXIT REMOTENESS

Diagonal = 234 ft

Travel Distance = 149 ft
## Means of Egress

<table>
<thead>
<tr>
<th></th>
<th>Required</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exit Access Corridors Fire Rating</td>
<td>1 hour</td>
<td>1 hour</td>
</tr>
<tr>
<td>Stair/Elevator Enclosure Fire Rating</td>
<td>1 hour</td>
<td>1 hour</td>
</tr>
<tr>
<td>Number of Means of Egress</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Maximum Common Path Distance</td>
<td>*100 ft</td>
<td>50 ft</td>
</tr>
<tr>
<td>Maximum Exit Travel Distance</td>
<td>*300 ft</td>
<td>150 ft</td>
</tr>
</tbody>
</table>

*With a Automatic Fire Sprinkler System*
### Occupancy Use

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Use</th>
<th>Occupant load (sq ft/person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business</td>
<td>Office</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Lecture Hall</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Lab</td>
<td>50</td>
</tr>
<tr>
<td>Storage, S-2</td>
<td>Mech./Elect. Room, Janitorial</td>
<td>300</td>
</tr>
<tr>
<td>Utility</td>
<td>Greenhouse</td>
<td>500</td>
</tr>
</tbody>
</table>

Note: From Table 1004.1.1 in IBC 2009
## Floor Summary

<table>
<thead>
<tr>
<th>Floor</th>
<th>Ground (+Second &amp; Third)</th>
<th>Second (+Third)</th>
<th>Third</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Floor Area</td>
<td>13,579 SF</td>
<td>9,868 SF</td>
<td>7,899 SF</td>
</tr>
<tr>
<td>Occupant Load</td>
<td>279 (622) persons</td>
<td>149 (264) persons</td>
<td>118 persons</td>
</tr>
<tr>
<td>Total Exit Width</td>
<td>784 in.</td>
<td>108 in.</td>
<td>108 in.</td>
</tr>
<tr>
<td>Exit Capacity</td>
<td>2613 persons</td>
<td>472 persons</td>
<td>472 persons</td>
</tr>
</tbody>
</table>
AUTOMATIC FIRE SUPPRESSION SYSTEM

Type: Wet Pipe System
Occupancy Classification: Light Hazard
**WATER SUPPLY**

Static Pressure: 85 psi

Residual Pressure: 65 psi at 1045 gpm

**Test date: 1/31/2002**

---

**Hydraulic Requirements (Light Hazard)**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of Sprinkler Operation</td>
<td>1500 S.F.</td>
<td>NFPA 13 Figure 11.2.3.2</td>
</tr>
<tr>
<td>Density</td>
<td>0.1 gpm/S.F.</td>
<td>NFPA 13 Figure 11.2.3.2</td>
</tr>
<tr>
<td>Hose Stream Allowance</td>
<td>250 gpm</td>
<td>IBC 905.3.3</td>
</tr>
<tr>
<td>Duration</td>
<td>30 minutes</td>
<td>NFPA 13 Table 11.2.3.1.2</td>
</tr>
</tbody>
</table>

---

[Map showing the location of Hydrant #29]
First Remote Area

- Third Floor, West Side
- 82 sq ft per sprinkler
SECOND REMOTE AREA

- Second Floor, North Side
- 148 sq ft per sprinkler
SYSTEM DEMAND/SUPPLY CURVE

Design Area 2 Demand:
- Pressure: 77.5 psi
- Flow (w/ HSA): 570.3 gpm

Design Area 1 Demand:
- Pressure: 49.9 psi
- Flow (w/ HSA): 536.7 gpm

City Supply:
- Static: 85 psi
- Residual: 65 psi @ 1000 gpm

Safety Factor (10% Reduction):
- Static: 76.5 psi
- Residual: 56.5 psi @ 1000 gpm
AUTOMATIC ALARM SYSTEM

• Required by NFPA 101 38.3.4.1 and IBC 907.2.2

• Components
  • Controls
    ● FACP – Mechanical Room
    ● Remote Annunciator – Main Entrance
  • Initiating Devices
    ● Manual Pull Station – at each common exit
    ● Tamper & Flow Switch – at Base of Riser
    ● Smoke Detectors – at Elect. Room and Elevator Lobbies
    ● Duct Detectors
  • Notification Devices
    ● Horn/Strobe Devices – in Corridors
  • Monitored
    ● Connected to Central Monitoring – at Campus PD
DEVICE LOCATIONS

*Visual Devices – within 15 ft of corridor end

*NFPA 72  18.5.4.4.5
RECOMMENDATION
## Power Demand

<table>
<thead>
<tr>
<th>Item</th>
<th>Desc.</th>
<th>Standby Current per Unit (Amps)</th>
<th>QTY</th>
<th>Total Standby Current per Unit (Amps)</th>
<th>QTY</th>
<th>Total System Standby Current (Amps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>FACU</td>
<td>0.13</td>
<td>1</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Duct Det</td>
<td>0.0001</td>
<td>6</td>
<td>0.0006</td>
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<td></td>
</tr>
<tr>
<td>C</td>
<td>Smoke Det</td>
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<td>3</td>
<td>0.0003</td>
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<td></td>
</tr>
<tr>
<td>D</td>
<td>Horn</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Horn/Strobe</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td></td>
<td></td>
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<tr>
<td>F</td>
<td>Annunciator</td>
<td>0.065</td>
<td>1</td>
<td>0.065</td>
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<td></td>
</tr>
</tbody>
</table>

### Standby Current

- **Total System Standby Current (Amps):** 0.1959

### Alarm Current

- **Total System Alarm Current (Amps):** 4.393

### Required Standby Capacity

- **Total System Standby Capacity (Amp-Hours):** 4.7016

### Required Alarm Capacity

- **Total System Alarm Capacity (Amp-Hours):** 0.366

### Required Battery Capacity

- **Total Required Capacity (Amp-Hours):** 5.068

- **Required Battery Capacity (Amp-Hours):** 6.081
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 1
Time: After-hours (unoccupied)
Cause: Electrical Failure
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 1 - Fire Dynamics Simulator (FDS)

Performance Criteria

Pressure Relief Valve
  Temperature < 184 °C

Cylinder
  (Aluminum 6061-T6)
  Height – 60 inches
  *Wall Thickness – 1 inch
    for Operating Pressure – 2400 psi

*CFR Title 49 Vol. 3 Section 178.46
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 1

Fire - Work Station
Peak HRR: 1870 kW
\( \tau Q: - 400 \text{ s} \)  
\((t^2 \text{ fire})\)

Sprinklers -
Type: Upright
Temperature: 100 °C
**RTI:** 100 \((\text{m} \cdot \text{s}^{0.5})\)

**Response Time Index**

From the SFPE Handbook

*Figure 3-1.62. HRR of one unit workstations tested at NRIFD.*
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 1 - Hydrogen

Constant Specific Volume – 0.081 m³/kg
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 1 – 200.0 s

40 °C
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 1 – 238.0 s

50 °C
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 1 – 255.5 s

Performance Criteria Met

55.6 °C
Performance Design Analysis

Hazard Scenario 2

Time: Middle of Day
Cause: Arson

Tenability Criteria

Visibility > 10 m
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 2

Fire - Recycling Cans
Peak HRR: 4280 kW
Polyethylene (PE) -
*Soot Yield: 0.102 g/g

Sprinklers -
Type: Pendant
Temperature: 74 °C
**RTI: 100 (m*s)^{0.5}

*SFPE Handbook Table 3-4.16
**Response Time Index

From the SFPE Handbook

Figure 3-1.6. HRR of single-pallet loads of packaged fruit/berry baskets.
Performance Design Analysis

At Sprinkler Activation – 1412 kW
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 2 - 50 s
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 2 - 100 s
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 2 - 150 s
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 2 - 240 s

6 feet above 2nd floor
PERFORMANCE DESIGN ANALYSIS

Hazard Scenario 2 - 240 s

6 feet above 3rd floor
Available Safe Egress Time

ASET = 4:00
Egress Analysis

**Occupyant Behavior**

- **Occupants:**
  - Students
  - Professors
  - Administrative Personnel

- **Characteristics:**
  - Students
    - Familiar
    - Cognitively Developed
    - Sense of Invincibility
  - Professors and Admin. Personnel
    - Familiar
    - Cognitively Developed
    - Mature
    - Authoritative
TRAVEL TIME

PathFinder - 0 seconds
TRAVEL TIME

PathFinder - 5 seconds
TRAVEL TIME

PathFinder - 25 seconds
TRAVEL TIME

PathFinder - 40 seconds
TRAVEL TIME
PathFinder - 48.8 seconds total

Number of Occupants in Selected Rooms

Time in Seconds

Number of Occupants
# Egress Analysis

Required Safe Egress Time (RSET)

<table>
<thead>
<tr>
<th>RSET</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection Time</td>
<td>98.4 s</td>
</tr>
<tr>
<td>Alarm</td>
<td>30.0 s</td>
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<tr>
<td>Pre-Movement Time</td>
<td>45.0 s</td>
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<tr>
<td>Evacuation Time</td>
<td>48.8 s</td>
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</tbody>
</table>
**Egress Analysis**

Required Safe Egress Time (RSET)

- Fire start/development       - 0:00
- Sprinkler Activation        - 1:38.4
- Alarm                        - 2:08.4
- Delay/Reaction              - 2:53.4
- Evacuation                  - 3:42.2

\[
\text{RSET} = 3:42.2 \text{ s}
\]
QUESTIONS?