Taylor Place
Arizona State University – Downtown Campus
Phoenix, Arizona

Cal Poly – San Luis Obispo
Fire Protection Engineering
Culminating Project Presentation

Christopher Thomas
March 17, 2016
Summary

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Building Overview

The Arizona State University (ASU) dormitory is a thirteen story high-rise with two towers connected by open air pedestrian bridges. It was completed in 2009 for $116,624,000. This is part of the modern ASU campus in the City of Phoenix.

The first floor provides basic services for students including a cafeteria, community areas, resident administration, security, and street level shops and restaurants. The remaining twelve floors in each tower are residential housing with 1,250 beds for ASU students.

The building is to be provided with an automatic fire sprinkler system, fire alarm, fire emergency/alarm communications systems, 24-hour security guard, and a resident assistants on staff.
Site Plan and Fire Department Access
Photo Tour
Photo Tour
Photo Tour
Photo Tour
Codes of Record

• 2012 Phoenix Building Code (IBC)
• 2012 Phoenix Fire Code (IFC)
• 2012 International Mechanical Code (IMC)
• City of Phoenix Amendments

• 2011 NFPA 13, Standard for the Installation of Sprinkler Systems
• 2010 NFPA 25, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems
• 2011 NFPA-70 / National Electrical Code
• 2010 NFPA 72 National Fire Alarm and Signaling Code
• 2010 ASME A17.1 Safety Standard for Elevators and Escalators

Note: The current City of Phoenix codes were used for the report for educational benefit and to compare with codes used when constructed.
## Occupancy Classifications

<table>
<thead>
<tr>
<th>FLOOR</th>
<th>GROUP</th>
<th>AREA (SF)</th>
<th>OCCUPANCY DESCRIPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASEMENT</td>
<td>S-2</td>
<td>6,700</td>
<td>Mechanical and electrical equipment, maintenance supplies, maintenance shop</td>
</tr>
<tr>
<td>GROUND</td>
<td>A-2</td>
<td>2200</td>
<td>Restaurants on perimeter</td>
</tr>
<tr>
<td></td>
<td>A-2</td>
<td>510</td>
<td>Cafeteria area (standing room)</td>
</tr>
<tr>
<td></td>
<td>A-2</td>
<td>5,369</td>
<td>Open seating and community space on the ground floor is provided with dining Tables which could be relocated to use the space for various functions.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>6,100</td>
<td>Staff, resident assistants, administrative, and building security areas.</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>5,610</td>
<td>Areas can be used for restaurants, businesses, or mercantile.</td>
</tr>
<tr>
<td></td>
<td>R-2</td>
<td>2,150</td>
<td>The dormitories provide sleeping and habitation for students.</td>
</tr>
<tr>
<td></td>
<td>S-2</td>
<td>2,110</td>
<td>Storage, Fire Command, Electrical, Loading Dock</td>
</tr>
<tr>
<td>TWO TO THIRTEEN</td>
<td>R-2</td>
<td>South Tower - 9,250 North Tower - 9,720</td>
<td>The dormitories provide sleeping and habitation for students.</td>
</tr>
<tr>
<td></td>
<td>S-2</td>
<td>South Tower - 580 North Tower - 630</td>
<td>Several areas have been designated for storage of supplies, janitorial equipment, and mechanical equipment.</td>
</tr>
<tr>
<td></td>
<td>A-3</td>
<td>South Tower 330 upper 430 lower</td>
<td>Located on each floor 2-13 are small common areas linking two floors. These areas where students will gather and will not have fixed seating.</td>
</tr>
</tbody>
</table>
Occupancy Classifications - Basement
Occupancy Classifications – Ground Floor
Occupancy Classifications – 13th Floor
## Occupant Characteristics

<table>
<thead>
<tr>
<th>Role</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Janitorial Staff</strong></td>
<td>Onsite 24 hours a day and familiar with building and procedures.</td>
</tr>
<tr>
<td><strong>Students</strong></td>
<td>Familiar with building layout and some procedures. May be impaired, disruptive, or ignore alarms.</td>
</tr>
<tr>
<td><strong>Disabled Students</strong></td>
<td>Designated ADA rooms. Familiar with building and areas of refuge.</td>
</tr>
<tr>
<td><strong>Café/Mercantile Staff</strong></td>
<td>On the lower levels and exit directly out onto the ground level.</td>
</tr>
<tr>
<td><strong>Resident Assistants</strong></td>
<td>Onsite 24 hours a day on assigned shifts. Live on the ground floor. Familiar with the building and procedures.</td>
</tr>
<tr>
<td><strong>Office Staff</strong></td>
<td>Assigned shifts and present during normal business hours. Familiar with the building layout and procedures, and evacuation.</td>
</tr>
<tr>
<td><strong>Security Officers</strong></td>
<td>Assigned shifts and located at security desk on the first floor. Deeply familiar with the building, procedures, and evacuation. Responsible for handling fire protection equipment and starting the fire pump if needed.</td>
</tr>
<tr>
<td><strong>Maintenance Techs</strong></td>
<td>Assigned shifts and will be onsite 24 hours a day. Familiar with the building, procedures, and equipment. Assist with fire protection equipment.</td>
</tr>
</tbody>
</table>
Construction
Construction

- Twelve residential floors on a podium
  - Mixed-use first floor
- Structure
  - Type IB reinforced concrete construction for floors and columns
- Interior
  - Gypsum walls board with metal studs, tile floors, and limited carpeting
- Automatic sprinkler protection throughout
  - Allows for additional story and 160 foot height per IBC Chapter 5.
- Fire Resistance
  - Occupancy separation between A and R occupancy is 1 hour per IBC Table 508.4
  - Residential corridors fire-resistance rating is ½ hour per IBC Table 1017.1.
  - Fire partitions required between dwellings with fire-resistance rating of 1 hour per IBC section 708. Fire blocking and draft stopping not required in sprinklered building.
  - Fire barrier or horizontal assembly rating between A, B, M, and R is 2 hours per IBC 707.3.10
## Construction – Building Elements

### From IBC Table 503 – Allowable Building Heights and Area Limitations

<table>
<thead>
<tr>
<th>FLOOR (SF)</th>
<th>OCC. GROUP</th>
<th>AREA (SF)</th>
<th>Type IB (160 height)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASEMENT (6,700)</td>
<td>S-2</td>
<td>6,700</td>
<td>11 / 79,000</td>
</tr>
<tr>
<td>FIRST (35,500)</td>
<td>A-2</td>
<td>5,170</td>
<td>11 / UL</td>
</tr>
<tr>
<td></td>
<td>A-2/A-3</td>
<td>8,320</td>
<td>11 / UL</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>6,100</td>
<td>11 / UL</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>5,610</td>
<td>11 / UL</td>
</tr>
<tr>
<td></td>
<td>R-2</td>
<td>2,150</td>
<td>11 / UL</td>
</tr>
<tr>
<td></td>
<td>S-2</td>
<td>2,110</td>
<td>11 / UL</td>
</tr>
<tr>
<td>TWO TO THIRTEEN</td>
<td>R-2</td>
<td>Tower 1 - 9,250</td>
<td>11 / UL</td>
</tr>
<tr>
<td>(Tower 1-13,240)</td>
<td></td>
<td>Tower 2 - 9,720</td>
<td>11 / UL</td>
</tr>
<tr>
<td>(Tower 2-12,600)</td>
<td>S-2</td>
<td>Tower 1 - 580</td>
<td>11 / UL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tower 2 – 630</td>
<td>11 / UL</td>
</tr>
<tr>
<td></td>
<td>A-3</td>
<td>Tower 1 - 430</td>
<td>11 / UL</td>
</tr>
</tbody>
</table>

### From IBC Table 601 – Fire-Resistance Requirements for Building Elements (hours)

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Structural frame&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Interior</td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td></td>
</tr>
<tr>
<td>Floor construction</td>
<td></td>
</tr>
<tr>
<td>Including supporting beams and joists</td>
<td>2</td>
</tr>
<tr>
<td>Roof construction</td>
<td></td>
</tr>
<tr>
<td>Including supporting beams and joists</td>
<td>1&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Type of Occupancy</td>
<td>Common Path Limit</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td></td>
<td>Unsprinklered</td>
</tr>
<tr>
<td></td>
<td>ft</td>
</tr>
<tr>
<td>Assembly</td>
<td></td>
</tr>
<tr>
<td>New</td>
<td>20/75</td>
</tr>
<tr>
<td>Existing</td>
<td>20/75</td>
</tr>
<tr>
<td>Residential</td>
<td></td>
</tr>
<tr>
<td>Hotels and dormitories</td>
<td></td>
</tr>
<tr>
<td>New</td>
<td>35</td>
</tr>
<tr>
<td>Existing</td>
<td>35</td>
</tr>
<tr>
<td>Mercantile</td>
<td></td>
</tr>
<tr>
<td>Class A, B, C</td>
<td></td>
</tr>
<tr>
<td>New</td>
<td>75</td>
</tr>
<tr>
<td>Existing</td>
<td>75</td>
</tr>
<tr>
<td>Business</td>
<td></td>
</tr>
<tr>
<td>New</td>
<td>75</td>
</tr>
<tr>
<td>Existing</td>
<td>75</td>
</tr>
</tbody>
</table>

Notes:

- ^a^ Common path limit includes travel distance to a dead end.
- ^b^ Dead-end limit includes travel distance to a dead end.
- ^c^ Travel distance limit includes travel distance to a dead end.
- ^d^ Applies to new construction only.
- ^e^ Applies to existing construction only.
- ^f^ Applies to sprinklered construction only.
- ^g^ Applies to unsprinklered construction only.
- ^h^ Applies to hotels and dormitories.
- ^i^ Applies to adjustments for occupancy density.
- ^j^ Applies to adjustments for building height.

Source: CAL POLY Fire Protection Engineering
Construction – Separation, Common Path, Travel Distance, and Dead End
Construction – Separation, Common Path, Travel Distance, and Dead End
Water Supply

• City Water Supply
  • 16" main under N 2nd St.
  • 8" system supply
  • Flow 1,200gpm
  • Static 60psi
  • Residual 50psi

• Electric Fire Pump
  • Pentair/Fairbanks
  • Horizontal Split Case
  • 1,000gpm @ 100psi
  • 1,770 RPM
Prescriptive Requirements

• Fire Alarm
  • Fire alarm control panel is located in the fire command control room
  • Emergency voice panel is located behind security desk
  • Remote Annunciator Panel (FAAP) located at Security Desk
  • Smoke control panel located in the fire command control room

• Initiating and Supervision Devices
  • Duct detection in return airflows over 2,000 fpm (IMC)
  • Sprinkler water flow switches, tamper switches
  • Elevator lobbies, mechanical room, shaft
  • Fire Alarm Control Panel location
  • Carbon Monoxide detection in commercial kitchens
  • Residential
    • Smoke detection in sleeping areas and path of travel

• Notification
  • 520Hz sounder bases for smoke detectors in sleeping areas
  • Speaker/Strobes for mass notification and general alarms
  • Speaker/Strobes in bathrooms of ADA units
Prescriptive Requirements

- Fire Sprinkler Design
  - Quick response sprinklers
  - Light hazard
    - 0.1 gpm/sqft
    - 50 inside/100 total hose
    - 30-60 minute duration
  - Ordinary hazard
    - 0.15 & 0.2 gpm/sqft
    - 50 inside/250 total hose
    - 60-90 minute duration
  - Residential Towers (9 sprinklers)
    - Room plus 75 feet of Corridor
    - NFPA 13: 11.2.3.3.6

- Special Hazards
  - Commercial Kitchen
    - Type I non-combustible hoods
    - Wet chemical extinguishing system (NFPA 17)

### Table 13. Sprinkler System Design Summary

<table>
<thead>
<tr>
<th>Location of Remote Area</th>
<th>Occupancy Class</th>
<th>Design Area</th>
<th>Demand Pump Discharge (gpm@psi)</th>
<th>Duration (minutes)</th>
<th>Inside/Total Hose (gallons per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>OH2</td>
<td>1500</td>
<td>439 gpm @ 71.6psi</td>
<td>60-90</td>
<td>0/250</td>
</tr>
<tr>
<td>Ground Floor Café</td>
<td>OH1</td>
<td>1080</td>
<td>264.8 gpm @ 47.8psi</td>
<td>60-90</td>
<td>0/250</td>
</tr>
<tr>
<td>North Tower</td>
<td>LH</td>
<td>Room + Corrido r</td>
<td>242.7 gpm @ 103.8</td>
<td>30-60</td>
<td>0/100</td>
</tr>
</tbody>
</table>
Special Requirements – City of Phoenix and High Rise

• **IBC Section 403 – High Rise Buildings**
  - Occupied Floors above 75 feet
  - 403.3 requires an automatic sprinkler system throughout, risers placed in interior exit stairways, standpipe system, and two city connections to supply the fire pump.
  - 403.4 requires fire alarm, emergency voice/alarm communication, emergency responder radio coverage, fire command center, smoke removal, and standby power.
  - 403.5 requires stairway remoteness, stairway communication, smoke proof enclosures, stair pressurization, and luminous egress path markings

• **City of Phoenix Amendments**
  - Fire Fighter Air Systems (FFAS) are required for high rises
  - Fill two standard SCBA cylinders in 2 minutes at same time.
  - Carbon dioxide monitoring for bulk carbon dioxide storage cylinder (more than 100lb). Pre-alarm and alarm concentration levels.
  - Two-way radio communication
Performance Based Validation

• Design Fire Scenario 1
  • NFPA 101, Section 5.5.3.2
  • Loss of two exits due to location of fire.
  • Christmas Tree Fire
  • Douglas Fir used based on availability of test data
    • Quick fire with 3MW peak heat release rate
    • Peak heat release achieved in 50 seconds after ignition
    • Fire burns through branches leaving trunk continuing to burn

• Design Fire Scenario 2
  • NFPA 101, Section 5.5.3.1
  • Fire representative for the occupancy, partial loss of exit
  • Upholstered chair fire in the common area
    • Low ceiling fire with convenience openings to upper floor
    • Foam couch produces a lot of smoke
    • Heat and smoke concentrate on the floor above
    • Self closing doors in hall, but maybe one is left open
Tenability

- Visibility at height of 1.8m above floor\(^1\)
  - Large enclosure OD/m 0.08 (10m visibility)
  - Small enclosure OD/m 0.2 (5m visibility)
  - 30% of people turn back rather than enter at 4m

- Carbon Monoxide at height of 1.8m above floor\(^2\)
  - 1,700 ppm
  - Incapacitation in 30 minutes

- Temperature at height of 1.8m above floor\(^3\)
  - Hyperthermia can occur at lower temperatures
  - 110 °C - 25 min
  - 70 °C – 60 min
  - Temperature elevated, upright egress is goal

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1. SFPE 4\(^{th}\) Ed., Table 2-6.11
2. SFPE 4\(^{th}\) Ed., Table 2-6B1
3. SFPE 4\(^{th}\) Ed., Table 2-6.17/Fig. 2-6.27
Design Fire Scenario 1

- **Douglas Fir Christmas Tree**
  - NFPA 5.5.3.2, Design Fire 2
  - Chemical Formula\(^1\)
    - \(\text{CH}_{1.7}\text{O}_{0.74}\text{N}_{0.002}\)
  - Moisture Content 20% (Arizona)
  - 2.1m tall
- **FDS Model – 500 seconds**
  - 9 meshes
  - Moderate Grid
    - 0.15m x 0.15m x 0.15m
  - Flaming
  - Carbon Monoxide\(^2\)
    - \(y(\text{CO}) = 0.004\) at 21% Oxygen
  - Soot Yield\(^2\)
    - \(y(\text{S}) = 0.010\) at 21% Oxygen

\(^1\) SFPE 4th Ed., Table 3-4.13

\(^2\) Table 1 - The Effects of Oxygen Concentration on CO and Smoke Produced by Flames, Mullholland, et. al., 1991

**Figure 3-1.18.** Typical HRR curves of Douglas fir Christmas trees.
Sprinkler Testing on Christmas Trees

• Unsprinklered dry Fraser Fir Tree No. 3
• HRR from 3.2kW to 4.3kW for 4 trees
• Majority of needles lost in 60 seconds

First Floor Egress
- NFPA Handbook Section 4, Chapter 2
- Fire in assembly area reduces exit capacity
- Egress path
  - South Corridor
    - Two 36 inch door (24” eff.)
    - 4.5 foot corridor (37.5” eff.)
    - Exterior egress door, 48 persons/minute
  - West Exit
    - Two 72 inch doors (48” eff.)
    - 96 persons/minute each
- Occupants evenly divided between egress paths
- West exits visible from South Corridor entry door and occupants could divert if que develops
- Pre-movement time is 45 seconds\(^1\)
- Second sprinkler activation: 47 seconds
- HRR capped: 2MW from 47 to 75 seconds
- Resume HRR curve at 75 seconds

\(^1\)SFPE 4\(^{th}\), Table 4.2.1 – One story dept. store\(^{20,21}\)
Sprinkler Testing on Christmas Trees

- Sprinklered Fraser Fir Tree No. 3
- 155°F, 9.8gpm@8.4psi
- Sprinkler activation at 10 seconds

Figure 18. Post fire photographs (Sprinklered room on the left and non-sprinklered room on the right.)

Figure 14. Heat release rate vs time for the sprinklered compartment

FDS Boundaries and Egress Capacity – First Floor

- Lose two exits during event.
FDS – 3D Smoke and Visibility at 1.8m AFF Sprinkler Activation (t=47 seconds)
FDS – 3D Smoke and Visibility at 1.8m RSET (t=269 seconds)
FDS – 3D Smoke at RSET (t=269 seconds)
FDS – 3D Smoke and Visibility at 1.8m ASET (t=400 seconds)
FDS – CO Concentration (ppm) at z = 1.8m
(t=400 seconds)
FDS – Temperature (°C) at z = 1.8m (t=400 seconds)
# ASET vs. RSET – First Floor Egress

## TABLE 25. DESIGN FIRE SCENARIO ONE – ASET VS. RSET

<table>
<thead>
<tr>
<th></th>
<th>ASET</th>
<th>RSET</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evacuation Time</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre-movement Time</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition Time</td>
<td>400 s</td>
<td>269 s</td>
</tr>
<tr>
<td>Response Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Movement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety Margin</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ignition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t = 0 s</td>
<td>15 s</td>
<td>30 s</td>
</tr>
<tr>
<td>Sprinkler*</td>
<td>15 s</td>
<td>30 s</td>
</tr>
</tbody>
</table>
| *Alternate RSET path based on a fire at night with automatic detection.*
Limitations

• Ceiling features and chain link partitions were not modeled. These could delay smoke travel to the cafeteria/kitchen, and lower the smoke level.
• Model was moderate, but still provided detail.
• Did not use DETACT model, 2\textsuperscript{nd} sprinkler used for activation (per AHJ) due to construction features.
• Capping HRR in ultra-fast fires can lead to higher HRR when using sprinkler activation as trigger.

Comments & Recommendations

• Visibility very low in elevator lobby, Fire Command Center, and Cafeteria
  • Provide a smoke barrier triggered by first floor water flow activation or beam smoke detector for elevator lobby and fire command center
• Reduce the combustible load in the assembly area and cafeteria
  • Building management should prohibit Christmas trees, kiosks, and large combustible objects, or specify furniture tested to CA TB 133
• South corridor combined egress changes.
  • Door size reduced, door removed, access to business from interior of building. Corridor maintains tenability through 400 seconds.
Change Management
Design Fire Scenario 2

- **Foam Sofa (F21)**
  - NFPA 5.5.3.1, Design Fire 1
  - Flexible Polyurethane foam (GM27)
    - \( \text{CH}_1.7\text{O}_{0.003}\text{N}_{0.05} \)
  - Chair Construction
    - Polyurethane Foam Cushions
    - Polyolefin fabric
    - CA TB117 and/or CA TB133

- **FDS Model – 500 seconds**
  - 9 meshes
  - Moderate Grid
    - 0.15m x 0.15m x 0.15m
  - Well ventilated
  - Carbon Monoxide\(^3\)
    - \( y(\text{CO}) = 0.042 \)
  - Soot Yield\(^3\)
    - \( y(\text{S}) = 0.198 \)

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2. SFPE 4th, Table 3-4.15
3. SFPE 4th, Table 3-4-16

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**Figure 3-1.52. Several upholstered furniture items tested by NIST.**

F31 – Loveseat, CA TB 117, polyolefin fabric, 2,560kW (not shown)
F32 – Sofa, CA TB117, polyolefin fabric
F21 – Chair, CA TB117, polyolefin fabric
F24 – Chair, CA TB117, cotton fabric
Tower Egress

- Fire on 12th floor in common area
- Occupants split on fire floor by fire in common area
  - 12th and 13th floor: 57 west and 137 east
  - 10th and 11th floor: 97 west and 97 east
- Stair egress door limits: 48 occupants per minute
- Time to fill each stair 20.8 seconds
- Movement speed is 103 feet per minute
- Detection (smoke) and alarm is 70 seconds
- Pre-movement time is <2 minutes
  - Voice evacuation, trained staff
- Evacuate 12th and 13th Floor: 192 seconds
- Evacuate 10th and 11th Floor: 141 seconds
- Sprinkler activation
  - 106 seconds (3MW)
  - 200 seconds (2MW)
- HRR capped: 250kW shown
- Total evacuate of floors 10 through 13 in 18.8 minute

1SFPE 4th, Table 4.2.1 – High-rise Office, High-rise apartment
Smoke Detector Activation and DETACT

- Fire on 12th floor in common area lower level
- Smoke detection in 10 seconds

**FIGURE 31. DETACT RESULTS – CHAIR FIRE IN COMMON AREA**
FDS Boundaries – Twelfth Floor

Stair 3

ADA

AOR

Stair 4

AOR

Open air bridge not designated as horizontal exit

N

13th Floor

12th Floor

Stair 1

ADA

AOR

Open to 12th Floor

Stair 2
FDS Boundaries – Twelfth Floor
FDS Model and Area Naming

Diagram showing the naming of areas and corridors:
- Upper West Corridor
- Lower West Corridor
- Upper East Corridor
- Lower East Corridor
- Corridor to Elevator
- Dorm Room
- Upper Common Area
- Lower Common Area
- Fire
FDS – 3D Smoke and Visibility at 1.8m
3MW - F32 Sofa (CA TB 117)
Visibility less than 5m (t=211 seconds)
FDS – 3D Smoke
250kW capped HRR – F21 Chair (CA TB 117)
Visibility less than 5m (t=340 seconds)
FDS – 3D Smoke and Visibility at 1.8m
250kW capped HRR – F21 Chair (CA TB 117)
Second Sprinkler Activation (t=200 seconds)

FDS – 3D Smoke and Visibility at 1.8m
250kW capped HRR – F21 Chair (CA TB 117)
Smoke Detector Activation and Alarm (t=70 seconds)
FDS – CO Concentration (ppm) at z = 1.8m
250kW capped HRR – F21 Chair (CA TB 117)
RSET (t=360 seconds)
FDS – Temperature (°C) at z = 1.8m
250kW capped HRR – F21 Chair (CA TB 117)
RSET (t=360 seconds)
FDS – Temperature - Fire and Corridor Slice
250kW capped HRR – F21 Chair (CA TB 117)
RSET (t=360s)
### ASET vs. RSET – Common Area 12th Floor

#### TABLE 28. DESIGN FIRE SCENARIO TWO – ASET VS. RSET

<table>
<thead>
<tr>
<th></th>
<th>ASET</th>
<th>RSET</th>
<th>600 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignition</td>
<td></td>
<td></td>
<td>600 s</td>
</tr>
<tr>
<td>Detection Time</td>
<td></td>
<td></td>
<td>W: 262 s E: 361 s</td>
</tr>
<tr>
<td>Alarm Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evacuation Time</td>
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<td></td>
<td></td>
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<tr>
<td>Pre-movement Time</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Recognition Time</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Response Time</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Movement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety Margin</td>
<td>600 s</td>
<td>W: 262 s E: 361 s</td>
<td>600 s</td>
</tr>
</tbody>
</table>

| Electrical       | Sprinkler | Waterflow | 10 s 
|                 | (DETACT)  | Voice Evac | (Security) |
|                 |           | 30 s       | 90 s       |
| t = 0 s         |           |            |            |
| 200 s¹ (FDS/2nd sprinkler) | 60 s |           |            |

1. Alternate RSET path based on automatic detection method.
2. W = West and E = East
3. 120 Seconds, SFPE Handbook 4th, Table 4.2.1 – High-rise Office¹⁸, High-rise apartment²⁴
Tenability fails based on visibility

- Options
  - Inform occupants over mass notification to shelter in place - Some will still try and evacuate thru the halls
  - Look at fuel source and building construction

- ASU Furniture Guidelines require CA TB133, or CA TB117
  - Furniture for public occupancies

- CA TB 117
  - Effective in 1975, revised for 2014
  - Still component test, increased use of flame retardants
  - Was open flame test, but revised to smoldering ignition

- CA TB 133
  - Effective in 1992
  - Full scale test of assembled furniture, fire barrier
  - Smoldering ignition test using a propane gas burner
  - 13 liters per minute for 80 seconds, remove burner
  - 10’ x12’ x 8’ room
California Technical Bulletin 133 Test Criteria

A. Seating furniture fails to meet the requirements of this test procedure if any of the following criteria are exceeded in a room test using the room instrumentation.
   1. A temperature increase of 200°F or greater at the ceiling thermocouple.
   2. A temperature increase of 50°F or greater at the 4-foot thermocouple.
   3. Greater than 75% opacity at the 4-foot smoke opacity monitor.
   4. Carbon monoxide concentration in the room, as measured in accordance with Section VI, Part C, of 1000 ppm or greater for 5 minutes.
   5. Weight loss due to combustion of 3 pounds or greater in the first 10 minutes of the test.

OR

B. Seating furniture fails to meet the requirements of this test procedure if any of the following criteria are exceeded in a room test using oxygen consumption calorimetry.
   1. A maximum rate of heat release of 80 kW or greater.
   2. A total heat release of 25 MJ or greater in the first 10 minutes of the test.
   3. Greater than 75% opacity at the 4-foot smoke opacity monitor.
   4. Carbon monoxide concentration in the room, as measured in accordance with Section VI, Part C, of 1000 ppm or greater for 5 minutes.
Considerations

• FDS
  • Smoldering fires are difficult to model in FDS
  • Smoke generated in direct proportion to HRR in FDS
  • Require defining a smoke production rate independent of HRR.
  • Limited support for this approach
  • Can’t use FDS to model smoldering without support

• Tenability
  • Tenability based on carbon monoxide and temperature passes at 340 seconds
  • Tenability fails on visibility at 120 seconds for Lower West Corridor

• CA TB133 Test Criteria
  • Tenability requirements built into the test
  • Use test criteria to set ASET to 600 seconds, and accept test criteria tenability as equivalent to design goals
Limitations

• Model uses a moderate grid, not fine
• Used DETACT model and not 2nd sprinkler to activate
• Unable to effectively model a smoldering fire
• If upholstery is damaged, TB 133 test criteria not applicable

Comments & Recommendations

• Require furniture in the common areas pass the test criteria in CA TB 133 and exclude CA TB117, or:
  • Isolate the corridors per PBC 712.1.8 for a Group R Occupancy
  • Provide vertical smoke barriers to isolate the corridors
• Install a permanent sign documenting the furniture requirement
• Although not require in Group R-2 occupancy, provide low level exit signage per the Group R-1 requirements
• Review use of smoke control system if corridor isolation or furniture requirements are excluded as options
Questions?

Recognition

• Dr. Christopher Pascual
• Dr. Fred Mowrer
• Jim Gallup, Aon FPE
• Joe McElvaney, City of Phoenix FPE
• Doug Fisher, Fisher Engineering, Inc.