Culminating Project
A Fire Protection Life Safety Analysis of Permian Oil Plaza

FPE 596
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Winter 2019
Presentation Overview

- Introduction of Permian Oil Plaza building
- Fire Detection, Alarm & Communication Systems
- Smoke Control
- Flammability
- Fire Suppression System
- Egress
- Performance Analysis
Permian Oil Plaza (POP)

- Office Building
- Midland, TX
- Four Stories
- 500 employees
Permian Oil Plaza (POP)

- North Wing, South Wing and Connector Building
Permian Oil Plaza (POP)

- Constructed of unprotected non-combustible (Type II-B) building materials
- 200,000 ft²
- Completed 2015
Occupancy Classification

- Majority of the building is used for office space and considered Business Group B Occupancy.
- Large conference center “Town Hall Room” is considered Assembly Group A-3.
Fire Resistance Requirements

- No minimum fire resistance rating required for building’s structural elements.
  - Due to Type II-B construction and separation distance.

- Specific portions of the building required to be separated from adjacent areas by fire resistive materials:
  - Stairwells (2-hour rating);
  - Elevator Shafts (2-hour rating);
  - Exit Passageways (2-hour rating); and,
  - Town Hall Room (1-hour rating).
Fire Resistance Requirements
Fire Detection & Alarm Systems

- Primary Objective = Occupant Safety
- “Intelligent System”
  - Capable of communicating with devices and performing processes management tasks such as shutting down the HVAC system, unlocking doors, recalling elevators, etc.
- Monitored by an off premise monitoring company.
Fire Detection & Alarm Systems

- Initiating Devices - signal input devices that supply an incoming signal to the fire alarm control unit.
  - Heat Detectors
    - Elevator Shaft & Elevator Machine Room
    - Sprinkler Heads (via water flow alarm)
  - Smoke Detectors (photoelectric)
  - Duct Detectors
  - Pull Stations
  - Tamper Switches
Fire Detection & Alarm Systems

- Fire Alarm Control Panel (FACP)
  - Receives alarm, supervisory and trouble signals from initiating devices and relays information to alarm monitoring company.
  - Indicates the location of any alarm signal (addressable).
  - Initiates specific responses based on the alarm signal received.

Fike CyberCat 254 FACP
Fire Detection & Alarm Systems

- Notification Devices
  - Audible Notification Devices
    - Most sound pressure levels (SPA) set to 81 dBA.
  - Visual Notification
    - Strobe feature set at various candela (cd) intensities based on room size per NFPA.
Two-way in-building Emergency Communication Systems (ECS)

- POP personnel can use the FACU to initiate pre-recorded voice messages or use the microphone to provide live instructions.
  - Tornado, Active Shooter, etc.
Communication Systems

- To ensure messages are intelligible, audible notification devices with high fidelity speakers and low distortion were selected.
- Carpeted floors, drop down ceiling tiles and walls covered in a felt fabric assist in limiting reverberation.
- Improvement Opportunity
  - Change wall-mounted speakers in corridors to ceiling-mounted
Secondary Power Supply

- **NFPA 72 Requirements**
  - Sufficient capacity to operate the system in standby for 24-hours followed by operating all notification appliances for 5 minutes.
  - Safety margin of 20 percent above the calculated amp-hour capacity.

- Adequate secondary power is provided via two 12 volt 26 amp-hour batteries wired in series located in the FACP.
Smoke Control

- POP building not equipped with smoke exhaust system.
- Photoelectric duct detectors installed throughout HVAC system are connected to individual relays.
- Relay will shutdown associated air handling units upon activation.
Smoke Control

- Upon the activation of a smoke detector, duct detector or heat detector, fire smoke doors are magnetically released and fire smoke dampers close.
Flammability

- Interior Finish Requirements
  - Interior wall and ceiling finish materials must be classified into one of three classes.
  - Permitted materials are based upon the occupancy classification & location.
    - Lower flame spread index may be required for exit stairways.

<table>
<thead>
<tr>
<th>Class</th>
<th>Flame Spread Index</th>
<th>Smoke Development Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>0-25</td>
<td>0-450</td>
</tr>
<tr>
<td>Class B</td>
<td>26-75</td>
<td>0-450</td>
</tr>
<tr>
<td>Class C</td>
<td>76-200</td>
<td>0-450</td>
</tr>
</tbody>
</table>
Flammability

- Interior Finish Requirements for POP
  - Enclosure spaces = Class A, B or C
  - Exit stairways, ramps, passageways = Class A or B
  - Corridors and enclosures for exit access stairways/ramps = Class A or B.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>SPRINKLERED</th>
<th>NONSPRINKLERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1 &amp; A-2</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>A-3, A-4, A-5</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>B, E, M, R-1</td>
<td>B</td>
<td>A</td>
</tr>
</tbody>
</table>

\[\text{\textsuperscript{a,b}}\text{Corridors and enclosure for exit access stairways and exit access ramps}\]

\[\text{\textsuperscript{c}}\text{Rooms and enclosed spaces}\]
Flammability

- Acoustical wall panels in Town Hall Room were tested per ASTM E84 for flame spread and smoke development.
  - Flame Spread Index = 25
  - Smoke Development = 40.
  - Considered Class-A.

- Core of panel is nonflammable fiberglass.
Fire Suppression System

- Fully equipped with a “wet pipe” automatic sprinkler system.
- Intended to control or suppress a fire.
- The most common sprinkler installed is the Tyco concealed pendent sprinkler.
  - Quick Response Extended Coverage Rating
    - Up to coverage area of 324 ft$^2$
  - K-Factor = 11.2
  - Bulb Rating = 160°F
Fire Suppression System

- **Design Criteria**
  - Occupancy Classification = Light Hazard
  - Density = 0.10 gpm/ft²
  - Initial Area of Operation = 1500 ft²
    - Forty percent reduction on account of the following:
      - Quick-Response Sprinklers
      - Light Hazard
      - No unprotected ceiling pockets exceeding 32 ft²
    - **Final Area of Operation = 900 ft²**
Fire Suppression System

- Hydraulic calculations were performed on two remote areas of the fire suppression system.
  - Fourth floor
  - Away from pump
Fire Suppression System

Remote Areas for Hydraulic Calculation. Yellow = Remote Area #1. Pink = Remote Area #2
Fire Suppression System

- AutoSPRINK was used to perform the hydraulic calculations of this looped system.
- Hand calculations were also performed to determine the water demand.

<table>
<thead>
<tr>
<th></th>
<th>Remote Area #1</th>
<th>Remote Area #2</th>
<th>Hand Calculation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupancy</td>
<td>Light Hazard</td>
<td>Light Hazard</td>
<td>Light Hazard</td>
</tr>
<tr>
<td>Classification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>0.100gpm/ft²</td>
<td>0.100gpm/ft²</td>
<td>0.100gpm/ft²</td>
</tr>
<tr>
<td>Sprinkler Type</td>
<td>Extended Coverage</td>
<td>Extended Coverage</td>
<td>Extended Coverage</td>
</tr>
<tr>
<td>K-Factor</td>
<td>11.2</td>
<td>11.2</td>
<td>11.2</td>
</tr>
<tr>
<td>Minimum Sprinkler Flow</td>
<td>33 gpm</td>
<td>33 gpm</td>
<td>33 gpm</td>
</tr>
<tr>
<td>Minimum Sprinkler Pressure</td>
<td>8.7 psi</td>
<td>8.7 psi</td>
<td>8.7 psi</td>
</tr>
<tr>
<td>Number of Sprinklers Calculated</td>
<td>8</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>AutoSPRINK Demand</td>
<td>279.49 gpm @ 113.8 psi</td>
<td>183.37 gpm @ 72.1 psi</td>
<td>217.25 gpm @ 86.3 psi</td>
</tr>
</tbody>
</table>

*Hand calculations were performed as if the system were designed as a branch system. As a result, these calculations should not be used to validate the calculations performed by AutoSPRINK.
Fire Suppression System

- Class I Standpipe System
- Calculated Hydraulic Demand
  - 1250 GPM @ 142 psi
Fire Suppression System

- Electric Fire Pump
  - 1250 GPM @ 115 psi
- In addition, a jockey pump maintains system pressure during static conditions.
Fire Suppression System

Sprinkler System
Fire Suppression System

Standpipe System
Egress Design

- Path occupants may use to safely exit a building.
- An assessment of POP’s egress design was performed to ensure this system was designed and constructed in a manner that meets, or exceeds, the intent of pertinent codes/standards:
  - 2012 International Building Code;
  - 2012 International Fire Code; and,
  - 2012 Texas Accessibility Standards.
Egress Design
## Egress Design

### Occupant Load

<table>
<thead>
<tr>
<th>Level</th>
<th>Function of Space</th>
<th>Area (sf)</th>
<th>Occupant Load Factor (sq. ft./occupant)</th>
<th>Calculated Occupant Load</th>
<th>Total Occupant Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Business</td>
<td>52,386</td>
<td>100 gross</td>
<td>524</td>
<td>524</td>
</tr>
<tr>
<td>2</td>
<td>Business</td>
<td>49,128</td>
<td>100 gross</td>
<td>492</td>
<td>596</td>
</tr>
<tr>
<td></td>
<td>Assembly (unconcentrated)</td>
<td>1,550</td>
<td>15 net</td>
<td>104</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Business</td>
<td>44,735</td>
<td>100 gross</td>
<td>448</td>
<td>1,090</td>
</tr>
<tr>
<td></td>
<td>Assembly (unconcentrated)</td>
<td>4,049</td>
<td>15 net</td>
<td>270</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assembly (concentrated)</td>
<td>2,601</td>
<td>7 net</td>
<td>372</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Business</td>
<td>46,601</td>
<td>100 gross</td>
<td>466</td>
<td>642</td>
</tr>
<tr>
<td></td>
<td>Assembly (unconcentrated)</td>
<td>2,627</td>
<td>15 net</td>
<td>176</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>2,852</strong></td>
</tr>
</tbody>
</table>
Egress Design

1st Floor

Exit Legend

<table>
<thead>
<tr>
<th>Color</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>36”</td>
</tr>
<tr>
<td>Yellow</td>
<td>42”</td>
</tr>
<tr>
<td>Green</td>
<td>72”</td>
</tr>
<tr>
<td>Blue</td>
<td>77”</td>
</tr>
<tr>
<td>Red Cross</td>
<td>Not an Exit</td>
</tr>
</tbody>
</table>
## Egress Design

<table>
<thead>
<tr>
<th>Level</th>
<th>Stair Width</th>
<th>Stair Capacity</th>
<th>Door Width</th>
<th>Door Capacity</th>
<th>Total Capacity</th>
<th>Total Occupant Load</th>
<th>Compliance Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N/A</td>
<td>N/A</td>
<td>42&quot;</td>
<td>210</td>
<td>1,945</td>
<td>524</td>
<td>Compliant</td>
</tr>
<tr>
<td>2</td>
<td>49&quot; 245</td>
<td>36&quot; 180</td>
<td>49&quot;</td>
<td>245</td>
<td>900</td>
<td>596</td>
<td>Compliant</td>
</tr>
<tr>
<td>3</td>
<td>49&quot; 245</td>
<td>42&quot; 210</td>
<td>49&quot;</td>
<td>245</td>
<td>1,050</td>
<td>1,090</td>
<td>Noncompliant</td>
</tr>
<tr>
<td>4</td>
<td>49&quot; 245</td>
<td>36&quot; 180</td>
<td>49&quot;</td>
<td>245</td>
<td>900</td>
<td>642</td>
<td>Compliant</td>
</tr>
</tbody>
</table>
Egress Design

- Third Floor Egress Issues
  - Significantly higher total occupant load due to the presence of multiple assembly areas.
  - Violation is likely the result of modifications made to the third floor layout after the building was approved.
    - A portion of the building originally intended to be used for office cubicles was converted to an assembly room.
    - Changing how this area is used increased the area’s calculated occupant load.

- Important Concepts
  - Management of change program
  - Consider how a space may be used in the future
Egress Design

- Maximum permitted common path of travel:
  - Assembly Occupancy = 75’
  - Business Occupancy = 100’

- Maximum permitted dead end length:
  - Sprinklered Building = 50’
Egress Design

Exit Separation from Floors (left) and Spaces (Right)
Egress Design

- Door Encroachment
  - It is important to consider how opening doors may limit the clear width of an aisle, corridor, exit passageway, landing, etc.
Performance-based Analysis

- **Goal: Life Safety**
  - Assumed that all other goals (e.g. property protection, continuity of operations & limitation of environmental impact) will be satisfied if the more conservative life safety goals are achieved.

- **Objective: Occupant Protection**
  - Protect occupants not intimate with initial fire development for the time needed to evacuate, relocate or defend in place.
Performance-based Analysis

- **ASET > RSET**

- **ASET**
  - Time from ignition until the room/ space/ building becomes untenable.
  - Tenability based on performance criteria

- **RSET**
  - Time required by occupants to evacuate room/ space/ building
Performance-based Analysis

- **Performance Criteria**
  - Any occupant not intimate with ignition shall not be exposed to instantaneous or cumulative untenable conditions.

<table>
<thead>
<tr>
<th>Design Criteria</th>
<th>Tenability Limit</th>
<th>Consequence</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility</td>
<td>10 meters</td>
<td>In a large enclosure, visibility of less than 10 meters could impair an occupant’s ability to escape safely.</td>
<td>SFPE Handbook Pg. 2-180</td>
</tr>
<tr>
<td>Temperature</td>
<td>60°C</td>
<td>Thermal burns to an occupant’s respiratory tract can occur upon the inhalation of air saturated with water above 60°C.</td>
<td>SFPE Handbook Pg. 2-184</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>30,000 ppm*min</td>
<td>Carbon monoxide is the most common toxic gas released in building fires. It can prevent evacuation by causing disorientation and loss of consciousness.</td>
<td>LSC (A.7.2.12.3.2)</td>
</tr>
<tr>
<td></td>
<td>(Integrated dose of 1,000 ppm for 30 minutes)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Performance-based Analysis

- Life Safety Code - Design Fire Scenario #2
  - Ultrafast developing fire (dry Christmas tree) in the primary means of egress (lobby).
  - Interior doors open at the start of the fire.
Evacuation of first floor conference room adjacent to Christmas tree fire.

- Closest gathering area to fire.
- Assume occupants are immediately alerted.
- Radiant heat also evaluated due to proximity to fire.
Evacuate study area on second floor.

- Occupants will be closer to accumulated smoke plume.
- Assume occupants are alerted almost immediately.
Performance Test #3

- Evacuation of entire building.
  - Assume glass door is opened separating lobby from exit discharge.
  - Assume occupants are alerted by smoke alarm.
Performance-based Analysis

- Heat Release Rate Curve
  - Assume very dry Douglas-fir tree (worst case scenario).
  - Fire Code permits cut trees in business occupancies with automatic sprinkler system.
  - Tree should not obstruct means of egress.

Tree Height = ~ 7’
Tree Weight = ~ 25 lbs.
Performance-based Analysis

Sprinkler Activation = 55 seconds
Performance Test #1 - RSET

- Evacuation of
  first floor
  conference
  room adjacent
to Christmas
tree fire.

RSET = Detection Phase ($t_d$) + Notification Phase ($t_n$) + Pre-Evacuation Phase ($t_{p-e}$) + Evacuation Phase ($t_e$)

$$RSET = 5 \text{ seconds} + 5 \text{ seconds} + 30 \text{ seconds} + 48 \text{ seconds}$$

$$RSET = 88 \text{ seconds}$$
Performance Test #1 - ASET

- Visibility
  - 6 feet above first floor
  - Drops below 10m in ~245 seconds
Performance Test #1 - ASET

- Temperature
  - 6 feet above first floor
  - Never exceeds performance criteria of 60°C
  - Max. = ~40°C

Time = 300 seconds
Performance Test #1 - ASET

- Carbon Monoxide
  - 6 feet above first floor
  - Max. = 150 ppm
  - Never exceeds performance criteria of 30,000 ppm*min
Performance Test #1 - ASET

- Heat Flux
  - Never exceeds 2 kW/m²
  - Exposure below 2.5 kW/m² can be tolerated for several minutes (SFPE HB page 2-184).
Performance Test #1 - Conclusion

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Visibility</th>
<th>Temperature</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASET</td>
<td>245 seconds</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>RSET</td>
<td>88 seconds</td>
<td>88 seconds</td>
<td>88 seconds</td>
</tr>
<tr>
<td>Conclusion</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
</tr>
</tbody>
</table>

NOTE: Radiant heat flux not anticipated to adversely affect egress.
Performance Test #2 - RSET

- Evacuation of second floor study area.

\[
\text{RSET} = \text{Detection Phase} (t_d) + \text{Notification Phase} (t_n) + \text{Pre-Evacuation Phase} (t_{p-e}) + \text{Evacuation Phase} (t_e)
\]

\[
\text{RSET} = 10 \text{ seconds} + 5 \text{ seconds} + 30 \text{ seconds} + 65 \text{ seconds} = 110 \text{ seconds}
\]
Performance Test #2 - ASET

- **Visibility**
  - 6 feet above second floor
  - Drops below 10m in ~83 seconds
Performance Test #2 - ASET

- Temperature
  - 6 feet above second floor
  - Exceeds 60°C in ~100 seconds
Performance Test #2 - ASET

- Carbon Monoxide
  - 6 feet above second floor
  - Max. = 200 ppm
  - Never exceeds performance criteria of 30,000 ppm*min

*ppm*min
Performance Test #2 - Conclusion

<table>
<thead>
<tr>
<th></th>
<th>Performance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Visibility</td>
</tr>
<tr>
<td>ASET</td>
<td>83 seconds</td>
</tr>
<tr>
<td>RSET</td>
<td>110 seconds</td>
</tr>
<tr>
<td>Conclusion</td>
<td>FAIL</td>
</tr>
</tbody>
</table>
Performance Test #3 - RSET

- Evacuation of entire building.

\[
\text{RSET} = \text{Detection Phase} \ (t_d) + \text{Notification Phase} \ (t_n) + \text{Pre-Evacuation Phase} \ (t_{p-e}) + \text{Evacuation Phase} \ (t_e)
\]

\[
\text{RSET} = 55 \text{ seconds} + 5 \text{ seconds} + 60 \text{ seconds} + 700 \text{ seconds}
\]

\[
\text{RSET} = 820 \text{ seconds}
\]

2852 ppl.
Performance Test #3 - ASET

- **Visibility**
  - 6 feet above first floor (in exit discharge).
  - Drops below 10m in ~500 seconds
Performance Test #3 - ASET

- **Temperature**
  - 6 feet above first floor (in exit discharge).
  - Max. = ~34°C
  - Never exceeds performance criteria of 60°C
Performance Test #3 - ASET

- Carbon Monoxide
  - 6 feet above first floor (in exit discharge).
  - Max. = 115 ppm
  - Never exceeds performance criteria of 30,000 ppm*min
Performance Test #3 - Conclusion

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Visibility</th>
<th>Temperature</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASET</td>
<td>500 seconds</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>RSET</td>
<td>820 seconds</td>
<td>820 seconds</td>
<td>820 seconds</td>
</tr>
<tr>
<td>Conclusion</td>
<td>FAIL</td>
<td>PASS</td>
<td>PASS</td>
</tr>
</tbody>
</table>
Other Scenarios

- Replace Douglas-fir with artificial tree.
  - Reduced HRR

- Fire in “Town Hall Room”
  - Ability to evacuate to fully occupied
  - Potential for fire (stacked plastic chairs) to grow unnoticed when unoccupied
Conclusions

- The POP complies with the prescriptive requirements evaluated with the following exceptions:
  - Inadequate egress capacity of third floor
  - One location where door encroachment exceeds 7 inches

- The performance-based analysis indicated erecting a cut Christmas tree creates an unacceptable fire risk.
Recommendations

- Convert assembly space on third floor to office cubicles.
  - Converting the smallest conference room (780 ft²) would adequately reduce the floor’s overall occupant load.

- Reconfigure door arrangement to eliminate encroachment issue.

- Prohibit the erection of cut Christmas Trees
  - Revise Fire Safety Management Plan to include the restriction
Questions?
NIST Tests (Tallest)

Height = 10’
NIST Tests (Heaviest)

Weight = 44 lbs.