Fire & Life Safety Analysis of Cal Poly Engineering IV, Business in Amarillo, TX & Costco

Culminating project presentation

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FPE 596
Buildings Used

- Egress Analysis and Design
  - California Polytechnic State University's Engineering IV building

- Fire Detection, Alarm and Communication Systems
  - A warehouse in Amarillo, TX

- Water-based Fire Suppression Systems
  - Costco

- Structural Fire Protection
  - California Polytechnic State University's Engineering IV building
Engineering IV

- A-3 occupancy of Type II-A (Table 503 of IBC)
  - Maximum floor area
    - 15,500 ft² per floor and three stories in height for a total of 46,000 ft².
  - Actual
    - 17,441 ft² total and three stories.

- B occupancy of Type II-A (Table 503 of IBC)
  - Maximum floor area
    - 37,500 ft² per floor and five stories in height for a total of 187,500 ft².
  - Actual
    - 87,190 ft² total and three stories.
Egress Analysis and Design


- Occupancies:
  - Business (B)
  - Storage (S-2)
  - Assembly (A-3)
  - Industrial (U)
Exit limits (per NFPA 101 Table A.7.6)

- **Assembly**
  - **Common Path minimums**
    - Code: serving >50 persons, 20 ft.; <=50 persons, 75 ft.
    - Actual: 51.67 ft. (Room 223C has 11 people)
  - **Dead-End minimums**
    - Code: 20 ft.
    - Actual: 0 ft.
  - **Travel Distance**
    - Code: 250 ft.
    - Actual: 58.63 ft.
Stairways Capacities
  ◦ 0.3 in/person
    • First floor: 218.4 in.
    • Second floor: 144.6 in.
    • Third floor: 100.2 in

Level Components and Ramps
  ◦ 0.2 in/person
    • First floor: 145.6 in.
    • Second floor: 96.4 in.
    • Third floor: 66.8 in.
Calculated Egress Time

- Stair #1 is 10.30 min
  - Serves the third and second floor
- Stair #2 is 10.43 min
  - Serves the second floor
- Stair #3 is 12.93 min
  - Serves the third and second floor
- Stair #4 is 9.48 min
  - Serves the third and second floor
Egress Time

![Bar chart showing egress time for Stairwell #1, Stairwell #2, Stairwell #3, and Stairwell #4. Stairwell #3 has the highest egress time, followed by Stairwell #2, Stairwell #1, and Stairwell #4.](calpoly.png)
Structural Fire Protection

- 2000 International Building Code (IBC)
- 2001 California Fire Code (CFC)
- Type II-A (fire resistant) construction with automatic fire suppression throughout.
  - Bearing walls, structural frame, shaft enclosures and floor separation – 2-hour fire resistant.
  - Exterior non-bearing walls and permanent partitions – 1-hour fire resistant.
Structural Fire Protection

- 1-hour fire resistant structural steel and decking are covered with lightweight concrete with a thickness to meet 1-hour fire resistant construction.

- 2-hour fire resistant structural steel and decking are covered with lightweight concrete with a thickness to meet a 2-hour fire resistant construction.
  - Thickness of a minimum of 1" to a maximum of 2 1/2" of concrete to achieve a 2-hour fire resistant rating per Table 719.1(1) of the IBC.
Calculated Resistance Time

- $R = [C_1 \ (W/D) + C_2] \ h$
  - Table 4-11.3 of Section 4 Chapter 11 from the 4th edition of the SFPE Handbook of Fire Protection Engineering.

- $h = R / [C_1 \ (W/D) + C_2]$
  - $D = 4a + 2b - 2c$
    - From Figure 4-11.10 of Section 4 Chapter 11 from the 4th edition of the SFPE Handbook of Fire Protection Engineering.
  - $D = 3b_f + 2d – 2t_w$
    - From Figure 4-11.11 of Section 4 Chapter 11 from the 4th edition of the SFPE Handbook of Fire Protection Engineering.

- Columns are W14x68 I-beams
- Beams are W24x55 and W24x62
Calculated Resistance Time

- \( h = \frac{R}{[C_1 \frac{W}{D} + C_2]} \)
  - \( R = 2 \text{ hr} \)
  - \( W_{14\times68} \text{ column} \)
  - \( W = 68 \text{ lbs/ft} \)
  - \( D = 4a + 2b - 2c \)
    - \( a = 10 \text{ in} \)
    - \( b = 14 \text{ in} \)
    - \( c = 1/4 \text{ in} \)
    - \( D = 4(10 \text{ in}) + 2(14 \text{ in}) - 2(1/4 \text{ in}) \)
    - \( D = 67.5 \text{ in} \)
  - \( \frac{W}{D} = \frac{68 \text{ lbs/ft}}{67.5 \text{ in}} \)
  - \( \frac{W}{D} = 1.007 \text{ lbs/ft} * \text{ in} \)
Calculated Resistance Time

- \( h = \frac{R}{[C_1 \times (W / D) + C_2]} \)
  - \( C_1 = 1.05 \)
  - \( C_2 = 0.6 \)
    - These are the example factors from the SFPE Handbook. The C-factors vary depending on the material used.
  - \( h = \frac{2 \text{ hr}}{[1.05 \times (1.007 \text{ lbs/ft} \times \text{ in}) + 0.6]} \)
  - \( h = 1.21 \text{ in} \) of spray-applied cementitious materials at a minimum for W14x68 columns
Calculated Resistance Time

- The thickness calculated of spray-applied cementitious materials for the 1-hr resistant rating was less than 1 in. and the 2-hr resistant rating was less than 2.5 in.
- The hourly resistant was calculated using the equations from Section 4 Chapter 11 Table 4-11.3 from the 4th edition of the SFPE Handbook of Fire Protection Engineering.
Fire Detection, Alarm and Communication Systems

- Warehouse in Amarillo, TX
- Proprietary system that communicates to a supervising location constantly attended and the signals are automatically recorded and is under control of the building owner
- The system monitors the fire suppression system, shuts off the air handling units and notifies the occupants.
Fire Detection, Alarm and Communication Systems
Fire Detection, Alarm and Communication Equipment

- Fire Alarm Control Panel
  - Notifier FireWarden-50(E)

- Initiation Devices
  - System Sensor and Notifier products and Sprinklers

- Notification Devices
  - Notifier SpectraAlert Advance Horn/Strobe
Prescribed code requirements

- The location, spacing and placement of the sprinklers, supervisory switches, manual pull stations and smoke detectors meet the prescribed requirements of NFPA 72, NFPA 90A and NFPA 101.

- The location, spacing and placement of all the notification devices meet the prescribed requirements of NFPA 72, except for in the Outbound Staging area, the Receiving Area and the Corridor in the General Office area.
Warehouse fire

- Sprinklers are Tyco ESFR-17, RTI of 100 m²·sec², activation temperature of 212°F (100°C)
- Per DETACH model activation time of 304 seconds and heat release rate of 4,344 kW.
Performance-based audible and visible notification devices

- Audible Requirements
  - $L_w = L + 20 \log_{10} r +11 \, \text{dB}$
  - $L_w = L_{P1} - (C_3 + C_4 + C_5)$
    - $C_3 = \text{Table 4-1.19}$
    - $C_4 = \text{Table 4-1.20}$
    - $C_5 = \text{Table 4-1.21}$
  - $L_w = L_{P2} - (C_1 + C_2)$
    - $C_1 = \text{Table 4-1.17}$
    - $C_2 = \text{Table 4-1.18}$
  - Tables from the fourth edition of the SFPE Handbook of Fire Protection Engineering
Performance-based audible and visible notification devices

- **Audible Requirements**
  - Storage areas:
    - $L_{P1}$ and $L_{P2} = 95$ dB at a minimum
  - All other areas:
    - $L_{P1}$ and $L_{P2} = 90$ dB at a minimum

- **Visible Requirements**
  - $I = E \cdot d^2$
  - Minimum of 0.0375 lumens/ft$^2$
Chemical Storage Corridor

- South End
  - $L_w = (95 \text{ dB}) - [(-3 \text{ dB}) + (-8 \text{ dB}) + (-11 \text{ dB})]$
    - $L_w = 117 \text{ dB}$
    - A sound power level of 117 dB for a maximum of 40 ft from the device would be required for a two-directional and medium finish.

- North End
  - $L_w = (95 \text{ dB}) - [(-0 \text{ dB}) + (-8 \text{ dB}) + (-11 \text{ dB})]$
    - $L_w = 114 \text{ dB}$
    - A sound power level of 114 dB for a maximum of 40 ft from the device would be required for a single-directional and medium finish.
Chemical Storage Corridor

- \((0.0375\ \text{lumens/ft}^2) \times (15\ \text{ft} \times 89\ \text{ft}) = 50.06\ \text{candela}\)
- Two horn/strobe devices at 30 cd for a total of 60 cd meeting the 50.06 cd required to meet the 0.0375 lumens/ft\(^2\) minimum.
Water-Based Fire Suppression Systems

- Costco
  - 2013 NFPA 13 (Standard for the Installation of Sprinkler Systems).
  - General "box store" construction with 130,227 ft² of sales floor and a roof height of 25 ft 4 in.
  - Assumptions:
    - Class IV Commodities
    - Flat ceiling with no skylights and an elevation of 24 ft 6 in.
    - Storage up to 20 ft with racks up to 15 ft.
  - ESFR 25.2 K-factor being used, requiring a minimum of 15 psi operating pressure per Table 12.8.6.1.
  - The design area "shall consist of the most hydraulically demanding area of 12 sprinklers, consisting of four sprinklers on each of the three branchlines" per Section 16.2.3.5.
  - ESFR sprinklers at ceiling level only
General Sprinkler System Info.

- Water Supply Info
  - Static pressure of 80 psi
  - Residual pressure of 60 psi
  - Flow of 1,000 gpm

- The pump is a Peerless Horizontal Fire Pump rated flow of 1,250 gpm at 90 psi.

- All waterflow alarm switches and tamper switches are Potter Electric Signal Company.
General Sprinkler System Info.
System D

- Flow required at the Base of the Riser (BOR) is 1,681.7 gpm.
- Pressure required at the BOR is 20.0 psi.
- Flow required at the pump is 1,181.8 gpm.
- Pressure required at the pump is 71.35 psi.
- Safety factor of 7.7 psi (28%).
- Total hose stream 500 gpm.
- Minimum flow is 97.6 gpm.
- Minimum pressure is 15 psi.
- Operating density is 0.75 gpm/ft².
System D continued

- Coverage area per sprinkler is 132 ft\(^2\).
- Spacing between branchlines is 11 ft.
- Spacing between sprinklers is 12 ft.
- Area of application is 1,584 ft\(^2\).
- Located farthest to the riser.
  - Calculated using Hydraulic Analyzer of Sprinkler Systems (HASS).
System D continued
Modeling Assumptions

- Fire size
  - 28,900 kW/m² Peak HRR
    - Polyethylene trash barrels in cardboard cartons
  - 578 seconds to Peak
    - Table 3-1.9
  - From the fourth edition of the SFPE Handbook Table 3-1.9

- Used solid blocks due to limited amount of modeling time

- Burner is 1 m²
Egress time

- Calculations use worst case scenario for egress times (minimum widths required at the farthest distance to travel).
- Approximate egress time from the sales floor:
  - 8 minutes
- Approximate egress time from the storage area:
  - 9.5 minutes
Per Table 3-12.2 of the fourth edition of the SFPE Handbook, there is a delay time to start evacuation after the notification is initiated. This value per the table for one-story department store is 0.9 minutes as the worst case scenario.

The total approximate egress times after ignition would be 10.9 minutes from the sales floor and 12.4 minutes from the stock room.

- Know events were people were shopping until they personally saw the flames or smoke.
Fire in Stock Room
Fire on Stock Room

- Only calculated to ten minutes.
- The first sprinkler activates at 186 sec. (3.1 minutes) and that would activate the water flow switch and initiate the notification system.
- Smoke starts to obscure the main entrance at approximately the 6 minute mark.
- All occupants that didn’t make it out of the main entrance from the Sales floor by the 6 minutes after ignition would have to find alternate exits.
- Egress form the Stock Room would be greater than 10 minutes before the smoke would reach head level (6 ft 6 in).
Fire on Sales floor
Fire on Sales Floor

- Only calculated to ten minutes.
- The first sprinkler activates at 161 sec. (2.68 minutes) and that would activate the water flow switch and initiate the notification system.
- Smoke starts to obscure the front exits at approximately the 5.8 minute mark.
- All occupants that didn’t make it out of the front exits from the Sales floor and the Stock Room by the 5.8 minutes after ignition would have to find alternate exits.
Arson Fire
Arson Fire

- Only calculated to ten minutes.
- The first sprinkler activates at 160 sec. (2.68 minutes) and that would activate the water flow switch and initiate the notification system.
- Smoke starts to obscure the back exits at approximately the 2 minute mark.
- Smoke starts to obscure the front exits at approximately the 4.5 minute mark.
- There are still some exits possible after the 4.5 minute mark but most areas will be completely engulfed in smoke 4.5 minutes after ignition.
Questions