Building Description:

• Designed in 2008
• Constructed in 2009
• Located south of Denver, CO
• Four floors
• Total floor area of 92,000 sf
• Government building with special security requirements
• Group B occupancy with incidental Group A, I-3, and S-1 occupancies
• Parking garage not evaluated
Building Construction:

- Type II-B Construction
- Steel columns, beams, and girders
- Two concrete elevator shafts
- Two concrete stairways
- Height – 4 stories
  - Acceptable per IBC Table 503 (4 stories maximum)
- Maximum area per floor – 23,456
  - Acceptable per IBC Table 503 (80,167 maximum with sprinkler system and frontage)
Applicable Codes and Standards:

First Floor Uses:

- Main entrance with lobby in atrium
- Miscellaneous storage
- Evidence processing
- Vehicle parking
- Technical garage
- Technical workshop
- Sprinkler riser room
- Elevator machine room
- Secure interview rooms
- Holding cells

LEGEND

- BUSINESS
- ELECTRICAL
- INSTITUTIONAL
- MECHANICAL
- PARKING GARAGE
- STORAGE
- 2-HOUR EGRESS CORRIDOR
- CORRIDOR/LOBBY
- EXIT STAIR/ELEVATOR
- ACCESSORY/RESTROOM
Second through Fourth Floor Uses:

- Press room (second floor only)
- Training room (second floor only)
- Fitness area (second floor only)
- Open office
- Work rooms
- Electrical rooms
- Server rooms
- Conference rooms
- Break rooms
Second Floor Plan:
Fourth Floor Plan:
Egress Analysis:

- Door widths
- Stairway widths
- Travel distance
- Common path of travel
- Dead end length
- Number of exits
- Occupant load
- Chapter 10 of the IBC
Occupant Load (IBC Table 1004.1.1):

- Room Use Defined
  - Business
  - Storage
  - Training
  - Fitness
  - Open Office
  - Conference Room

- Area of the Space

- Occupant Load Factor

- Occupancy – Area divided by OLF

<table>
<thead>
<tr>
<th>ROOM USE</th>
<th>OCCUPANCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>AREA</td>
<td>OLF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Floor</th>
<th>Occupant Load (persons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>103</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
</tr>
<tr>
<td>3</td>
<td>230</td>
</tr>
<tr>
<td>4</td>
<td>261</td>
</tr>
</tbody>
</table>

Building Total: 844
Egress Width (IBC Table 1005.1):

- Width of component (door or stairway)
- Required width (number of occupants multiplied by width factor)
  - Stairway width factor – 0.2
  - Door width factor – 0.15
- Actual Occupant Capacity (based on occupant load)
- Maximum capacity (width divided by width factor)
Exit Access Travel Distance (IBC Table 1016.1):

- Maximum Travel Distance – 231 feet on the second floor
- Maximum Common Path of Travel – 115 feet on the third floor
Minimum Number of Exits:

- Minimum Number of Exits per Floor – 2. Number Provided: 2
- Minimum Number of Exits per Room (Table 1015.1):

<table>
<thead>
<tr>
<th>OCCUPANCY</th>
<th>MAXIMUM OCCUPANT LOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, E', F, M, U</td>
<td>49</td>
</tr>
<tr>
<td>H-1, H-2, H-3</td>
<td>3</td>
</tr>
<tr>
<td>H-4, H-5, I-1, I-3, I-4, R</td>
<td>10</td>
</tr>
<tr>
<td>S</td>
<td>29</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OCCUPANT LOAD (persons per story)</th>
<th>MINIMUM NUMBER OF EXITS (per story)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-500</td>
<td>2</td>
</tr>
<tr>
<td>501-1,000</td>
<td>3</td>
</tr>
<tr>
<td>More than 1,000</td>
<td>4</td>
</tr>
</tbody>
</table>
Vertical Exit Passageway:

- Interior exit stairs
- At least 50% of exits are to lead to the exterior per IBC 1020.1
- Exit access corridor provided
- Stairway 1 discharges to the lobby
- Exit access stairways to have 2-hour rating per IBC 1020.1
Max Path of Travel = 179 feet

Max Path of Travel = 203 feet
Third Floor:

Max Path of Travel = 144 feet

Common Path of Travel = 80 feet

Common Path of Travel = 91 feet

Common Path of Travel = 115 feet
Detection and Alarm (prescriptive based):

• Manual fire alarm system required per Section 907.2.2 of the IBC
  • Can be eliminated when fully sprinklered
• Sprinkler system required to be monitored by a fire alarm system per 903.4.1 of the IBC
• Notification shall activate upon water flow in accordance with Section 903.4.2 of the IBC
• Will activate the smoke control system
• Will activate elevator recall
• Installed per NFPA 72
Detection:

• Smoke detection at the following locations:
  • Above the FACP
  • Above remote power supplies
  • In elevator lobby
  • In elevator machine room (two machine rooms)
  • Beam smoke detection to protect the atrium
  • Duct smoke detection in supply and return shafts
• Manual detection is provided at an approved location
• Heat detection in elevator machine room
• Monitor sprinkler system for water flow
• Monitor tamper switches
Ancillary Functions:

• AHU Shutdown
• Door closure
• Damper closure
• Initiate smoke exhaust
• Primary elevator recall
• Secondary elevator recall
Notification:

• Audible throughout
  • 15 dBA above ambient
  • 55 dBA ambient in an office
  • Via temporal 3 horns

• Visible notification
  • Located in areas normally occupied by multiple occupants
  • Via strobes
  • Candela ratings per NFPA 72
Sequence of Operations:

### Input Signals

<table>
<thead>
<tr>
<th>General Fire Detection Initiating Devices</th>
<th>Elevator Control Initiating Devices</th>
<th>Trouble Conditions</th>
<th>Notification Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual pull station</td>
<td>Primary floor elevator lobby smoke detector</td>
<td>Ground fault</td>
<td>Silence feature on fire alarm panel</td>
</tr>
<tr>
<td>Smoke detector</td>
<td>Alternate floor elevator lobby smoke detector</td>
<td>Notification appliance short circuit</td>
<td></td>
</tr>
<tr>
<td>Spot heat detector</td>
<td>Smoke detector in elevator equipment room</td>
<td>Open circuit</td>
<td></td>
</tr>
<tr>
<td>Beam smoke detector</td>
<td>Heat detector in elevator equipment room</td>
<td>Low battery</td>
<td></td>
</tr>
<tr>
<td>Waterflow</td>
<td></td>
<td>AC power failure</td>
<td></td>
</tr>
<tr>
<td>Waterproof pressure switch</td>
<td></td>
<td>Telephone line fault</td>
<td></td>
</tr>
<tr>
<td>Low/High air pressure switch</td>
<td></td>
<td>Remote power supply trouble condition</td>
<td></td>
</tr>
<tr>
<td>Tamper switch</td>
<td></td>
<td>Notification functions</td>
<td></td>
</tr>
<tr>
<td>Duct smoke detector</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Output Signals

<table>
<thead>
<tr>
<th>Fire Alarm Panel Indication</th>
<th>Notification</th>
<th>Safety Control / Interlocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actuate fire alarm visual signal on fire alarm control panel</td>
<td>Transmit fire alarm signal to monitoring station</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Actuate fire alarm audible signal on fire alarm control panel</td>
<td>Transmit supervisory signal to monitoring station</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Actuate supervisory audible signal on fire alarm control panel</td>
<td>Transmit trouble signal to monitoring station</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Activate fire alarm visual and audible notification appliances</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Activate fire alarm visual signal from microphone through all speaker circuits</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Broadcast fire alarm signal to monitoring station</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Turn off any security doors that are exit paths</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Release magnetically held open doors in fire rated partitions or walls installed</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Actuate trouble audible signal at fire alarm control panel</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Activate speaker strobes with pre-recorded evacuation message</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Silence the audible notification appliances</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Activate exterior alarm bell by fire riser with waterflow</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Actuate trouble visual signal on fire alarm control panel</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Transmit fire alarm signal to monitoring station</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Transmit supervisory signal to monitoring station</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
<tr>
<td>Transmit trouble signal to monitoring station</td>
<td>Elevator Control Functions</td>
<td>Fire alarm control panel</td>
</tr>
</tbody>
</table>

### General Fire Detection Initiating Devices
- Manual pull station
- Smoke detector
- Spot heat detector
- Beam smoke detector
- Waterflow
- Waterproof pressure switch
- Low/High air pressure switch
- Tamper switch
- Duct smoke detector

### Elevator Control Initiating Devices
- Primary floor elevator lobby smoke detector
- Alternate floor elevator lobby smoke detector
- Smoke detector in elevator equipment room
- Heat detector in elevator equipment room

### Trouble Conditions
- Ground fault
- Notification appliance short circuit
- Open circuit
- Low battery
- AC power failure
- Telephone line fault
- Remote power supply trouble condition
- Notification functions
- Silence feature on fire alarm panel
Suppression System (prescriptive based):

• Not required by the IBC
• Required to be monitored by IBC Section 903.4
• Two independent systems
• Dry-pipe system protecting the garages
• Wet-pipe system protecting all heated spaces of the building
• Installed in accordance with NFPA 13
Water Supply:

- Municipal supply from Centennial Water District
- 12-inch circulating main
- Main runs east to west along Easter Avenue
- Sprinkler will be supplied by 4-inch underground on the north side of the building
- 8.6 psi loss through the 4-inch underground flowing 352 gpm
Water Supply:

- Flow test results:
  - Static pressure – 80 psi
  - Residual pressure – 65 psi
  - Pitot – 27
  - Flow – 872 gpm
  - Flow @ 20 psi – 1843 gpm
First Floor System Layout:
Dry-Pipe Sprinkler System Hydraulic Calculation:

<table>
<thead>
<tr>
<th>Design Area Name</th>
<th>Calc. Mode (Model)</th>
<th>Occupancy</th>
<th>Area of Application</th>
<th>Total Water Pressure @ Source</th>
<th>Min. Density</th>
<th>Min. Pressure</th>
<th>Min. Flow</th>
<th>Calculated Heads</th>
<th>Hose Streams</th>
<th>Margin To Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(ft³)</td>
<td>(gpm)</td>
<td>(psi)</td>
<td>(gpm/ft²)</td>
<td>(psi)</td>
<td>#</td>
<td>(gpm)</td>
</tr>
<tr>
<td>2</td>
<td>Demand (MW)</td>
<td>OH1</td>
<td>1950</td>
<td>602.4</td>
<td>0.15</td>
<td>12.1</td>
<td>19.5</td>
<td>17</td>
<td>250</td>
<td>10.4</td>
</tr>
</tbody>
</table>

![Graph showing hydraulic calculation data](image-url)
Dry-Pipe Sprinkler System Hydraulic Calculation:
Fourth Floor Layout:
Wet-Pipe Sprinkler System Hydraulic Calculation:

Design Areas

<table>
<thead>
<tr>
<th>Design Area Name</th>
<th>Calc. Mode (Model)</th>
<th>Occupancy</th>
<th>Area of Application</th>
<th>Total Water Source</th>
<th>Pressure @ Source</th>
<th>Min. Density</th>
<th>Min. Pressure</th>
<th>Min. Flow</th>
<th>Calculated Heads</th>
<th>Hose Streams</th>
<th>Margin To Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Demand (HW)</td>
<td>Light Hazard</td>
<td>1035</td>
<td>282</td>
<td>Required 51.4</td>
<td>0.1</td>
<td>16.1</td>
<td>22.5</td>
<td>0</td>
<td>100</td>
<td>18.7</td>
</tr>
</tbody>
</table>
Wet-Pipe Sprinkler System Hydraulic Calculation:
Smoke Control System (performance based):

• Section 404.1 of the IBC defines an atrium as a vertical opening connecting three or more stories
• Smoke exhaust system required for atriums in accordance with Section 404.9 of the IBC
• Smoke exhaust system must meet the requirements of Section 909 of the IBC and NFPA 92B
• Smoke exhaust system must keep the smoke layer height 6 feet above the highest walking surface per Section 909.8
• Technically not required because of the glass wall and sprinkler protection not separated by more than 6 feet
NFPA 92B Chapter 6 Smoke Exhaust Rate Calculation:

• Limiting elevation:
  \[ z_l = 0.166Q_c^{2/5} \]

• Mass production rate:
  \[ m = (0.071Q_c^{1/3}z^{5/3}) + 0.018Q_c \]

• Convective Fraction
  \[ \chi_c = 0.7 \]

• Design fire 1 HRR = 3300 kW
• Design fire 2 HRR = 950 kW

<table>
<thead>
<tr>
<th>Atrium Exhaust Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q = 3300 ( \text{kW} )</td>
</tr>
<tr>
<td>( \chi_c = 0.7 ) -</td>
</tr>
<tr>
<td>( Q_c = 2310 \text{ kW} )</td>
</tr>
<tr>
<td>( z_l = 3.7 \text{ m} )</td>
</tr>
<tr>
<td>( z = 9.1 \text{ m} )</td>
</tr>
<tr>
<td>( m = 41.4 \text{ kg/s} )</td>
</tr>
<tr>
<td>( \rho = 1.2 \text{ kg/m}^3 )</td>
</tr>
<tr>
<td>( V = 34.5 \text{ m}^3/\text{s} )</td>
</tr>
<tr>
<td>( V = 73076 \text{ cfm} )</td>
</tr>
</tbody>
</table>
FDS Simulation for Smoke Control System:

• FDS Simulation modeled to verify NFPA 92B calculation
• Two exhaust vents each exhausting 36,500 cfm
• Eight make-up air vents each supplying 7,700 cfm
• Beam smoke detector activating smoke exhaust
• Sprinkler protection modeled, HRR evaluated without suppression for design fire 1 but with suppression for design fire 2
Tenability Criteria:

• Maximum Temperature: 248°F for sustained heat exposure to dry air per SFPE Handbook Table 2-6.16

• Minimum Visibility: 13 feet for occupants familiar with the building per SFPE Handbook 2-4.2

• CO concentration: 1,400 ppm for 20 minutes using Haber’s rule
Atrium Design Fire 1:

- Wood desk in the lobby as shown on the architectural plans
Atrium Design Fire 1:

- Old style wood furniture work station fire as shown for Line A SFPE Handbook Figure 3-1.59
- Maximum heat release rate of 3,300 kW at 500 seconds
- Fire growth rate constant $\alpha = 0.0132$ kW/sec$^2$
- Medium growth fire
Atrium Design Fire 1:

• 865 kW/m²
• Area = 39.6 ft² (3.7m²)
• Soot Yield = 0.015 per SFPE Handbook Table 3-4.14
• CO Yield = 0.004 per SFPE Handbook Table 3-4.14
Design Fire 1 ASET FDS Simulation Results (Second Floor):

- Detection time: 30 seconds
- Maximum Temperature: 90°F
- Minimum Visibility: 48 feet
- Maximum CO concentration: $7 \times 10^{-9}$
- Tenable conditions maintained on the first and second floors
Design Fire 1 ASET FDS Simulation Results (CO):

- Maximum CO on the second floor approximately 7 parts per billion
- Much lower than tenable limit for minimal exposure time
Design Fire 1 ASET FDS Simulation Results (Temperature):

- Highest temperature on the second floor is 90 degrees F
- Much lower than tenable limit for minimal exposure time
Atrium Design Fire 2:

- Polyurethane chair in the elevator lobby
Atrium Design Fire 2:

- Chair made with flexible PU cushions and PU frame from NFPA 72 Table B.2.3.2.6(e)
- Maximum heat release rate of 950 kW at 60 seconds
- T-square growth
- Ultra-fast growth fire
Atrium Design Fire 2:

- HRR = 950 kW/m²
- Area = 10.8 ft² (1 m²)
- Soot Yield = 0.198 per SFPE Handbook Table 3-4.14
- CO Yield = 0.042 per SFPE Handbook Table 3-4.14
Design Fire 2 ASET FDS Simulation Results (Second Floor):

- Sprinkler Activation Time: 70 seconds
- Detection time: 52 seconds
- Maximum Temperature: 70°F
- Minimum Visibility: 69 feet
- Maximum CO concentration: $1 \times 10^{-9}$
- Tenable conditions maintained on the first and second floors
Design Fire 2 ASET FDS Simulation Results (CO):

- Maximum CO on the second floor approximately 1 parts per billion
- Much lower than tenable limit for minimal exposure time
Design Fire 2 ASET FDS Simulation Results (Temperature):

- Highest temperature on the second floor is 70 degrees F
- Much lower than tenable limit for minimal exposure time
ASET:

• Design fires 1 and 2 determined that the smoke control system maintained tenable conditions on the first floor of the lobby and the second floor balcony

• The mechanical system could be optimized based on reducing the smoke exhaust and allowing more smoke to fill the room
Required Safe Egress Time:

• Occupant load modeled as calculated per room
  • 103 Persons on 1st Floor
  • 250 Persons on 2nd Floor
  • 230 Persons on 3rd Floor
  • 261 Persons on 4th Floor
• Egress component widths
  • 36 inch doorway
  • 44 inch stairway
• Modeled without egress through the atrium/lobby
• Monitoring of occupants of the holding cells is expected
Required Safe Egress Time:

• Time to detection: 0.5 minutes (from the FDS Simulation)
• Pre-movement time: 1 minutes (per PF 7974-6:2004 for alert occupants familiar with the building)
• Calculated movement time: 14.75 minutes (per Pathfinder Simulation)
• Total RSET: 16.25 minutes
ASET vs. RSET Summary:

- Building Required Safe Egress Time – 16.25 minutes
- The smoke control system maintained tenable conditions in the lobby
- Without allowing egress through the main lobby the RSET is acceptable
Fire Protection Analysis Summary:

• Building use and construction type was typical of a building this height and for business use

• The egress analysis showed that egress from the building meets most code requirements with the exception of maximum path of travel, this could be remedied by adding egress though an office or breakroom

• The fire alarm system provided is code compliant as shown

• The sprinkler system provided exceeds code requirements to take advantages associated with fully sprinklered buildings

• The smoke control system modeled using NFPA 92B exhaust calculations maintained tenable conditions on the first floor and second floor balcony, this system could be optimized to reduce the exhaust and make-up air rates
Questions?