Fire and Life Safety Analysis of The “Production Facility” - 870

By Nolan J. Baker, P.E., CET
ABQ/Sandia Location Maps
Outline

- Building Overview
- Prescriptive-Based Design
  - Occupancy Types
  - Fire Barriers and Egress
  - Structural Analysis
  - Water Supply System
  - Fire Sprinkler System
  - Fire Alarm System
- Performance-Based Design
  - Evacuation Approach and Tenability Criteria
  - Egress Analysis
  - Design Fire Scenarios
  - Other Fire Scenarios
- Results and Recommendations
Building Satellite Views

Main Entrance – South View

Top View

Source: Google Earth
Overview

- Code of Record: 1991 UBC (Occupancy Classification B-2) and 2015 IBC (Current Occupancy Classifications are B and A-3), Type II-N (UBC) and **Type II-B Construction** (IBC)
- Total building gross area is approximately **97,000-sq.ft.**
- Height **45 ft.** (75 ft. allowable per IBC Table 503) – Non high-rise
- Two-story Communicating Space – Not classified an Atrium per code-of-record (1991 UBC), therefore NO smoke-control requirements
- Fire and Life Safety Design Features
  - Code compliant Fire Detection and Alarm System
  - Fully sprinklered wet-pipe: **Ordinary Hazard - Group 2** (DOE Requirement)
  - Numerous building exits that are well-separated with compliant travel distances and no dead-ends
DOE Orders, Codes and Standards

- 29 CFR Part 1910, Occupational Safety and Health Standard
- 29 CFR Part 1926, Safety & Health Regulations for Construction
- DOE Standard 1066-2012: Fire Protection Design Criteria
- **DOE Order 420.1.C: Facility Safety**
- Sandia National Labs Site Specific Specifications
- 2015 International Building (IBC®) and Fire Code (IFC®)
- **2015 - NFPA 45, Standard on Fire Protection for Labs Using Chemicals**
- 2015 - NFPA 72, National Fire Alarm and Signaling Code
- 2017 – NFPA 80A, Recommended Practice for Protection of Buildings from Exterior Fire Exposures
- SFPE Handbook of Fire Protection Engineering (4th & 5th Editions)
- **Sandia National Labs Fire Protection and other Specifications**
PRESCRIPTIVE-BASED DESIGN
Building Interior Space Types - Basement

Approx. 19K sqft
Building Interior Space Types – 1st Floor

Legend

- Offices/Rooms
- Conference Rooms
- Restrooms
- Elevator/Stairs
- Hallway

Building Entrances

Buildings

Gates
- Base Gate
- Gate/Turnstile
- Turnstile
- Vehicle Gate

Fence

Limited/Property Protection Area

Fire Hydrants

Parking

Approx. 50K sqft
Building Interior Space Types – 2nd Floor

Approx. 28K sqft
## Occupancy Classifications and Loads

### Occupancy Classification - Comparisons

<table>
<thead>
<tr>
<th>Room</th>
<th>LSC (Ch. 6)</th>
<th>IBC (Ch. 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>Business</td>
<td>B</td>
</tr>
<tr>
<td>Laboratory</td>
<td>Industrial</td>
<td>B</td>
</tr>
<tr>
<td>Conference</td>
<td>Assembly</td>
<td>A-3</td>
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<tr>
<td>Mechanical</td>
<td>Industrial - General</td>
<td>B</td>
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<tr>
<td>Storage</td>
<td>Storage</td>
<td>B</td>
</tr>
<tr>
<td>Cleanroom</td>
<td>Business</td>
<td>B</td>
</tr>
</tbody>
</table>

*On average, there are approx. 140 people working in the building. Ten-percent (10%) are visiting Scientists.*

### Occupancy Loads - Comparisons

<table>
<thead>
<tr>
<th>Use</th>
<th>LSC Load Factor (ft² per person)</th>
<th>IBC Load Factor (ft² per person)</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>15 net</td>
<td>15 net</td>
<td>28</td>
</tr>
<tr>
<td>Business</td>
<td>100</td>
<td>100</td>
<td>782</td>
</tr>
<tr>
<td>Industrial</td>
<td>100</td>
<td>-</td>
<td>27</td>
</tr>
<tr>
<td>Storage</td>
<td>500</td>
<td>300</td>
<td>2</td>
</tr>
<tr>
<td>Mechanical</td>
<td>-</td>
<td>300</td>
<td>18</td>
</tr>
<tr>
<td>TOTAL</td>
<td>*857</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Maximum Travel Distances

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>LSC</th>
<th>IBC</th>
<th>**Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business/B</td>
<td>300</td>
<td>300</td>
<td>163</td>
</tr>
<tr>
<td>Assembly/A-3</td>
<td>250</td>
<td>250</td>
<td>132</td>
</tr>
<tr>
<td>Storage – Low Hazard</td>
<td>NR</td>
<td>NR</td>
<td>-</td>
</tr>
</tbody>
</table>

NR – No requirement

*Table values shown are increased due to the installation of an approved sprinkler system

**Longest walking distance for occupancy type
Means of Egress – Basement

- Calculated Occupant Load = **130 people**
- Basement is located approx. 19'-0" below grade.
- 2 vertical exits provided, therefore **65** people allowed per exit.
- West stair is dedicated to the basement and the North stair has access to all the floors.
- Basement exits (279 people cap. –STW most limiting) are able to support the occupant load.
Means of Egress – 1st Floor

- Calculated Occupant Load = 412 people
- 23 exits go directly to the outside, however 13 of them are in areas not accessible by all of the bldg. occupants.
- 1st floor exit capacity (5,580 people cap.) is more than able to support the occupant load.
Means of Egress – 2\textsuperscript{nd} Floor

- Calculated Occupant Load = 315 people
- 3 vertical exits provided.
- 2 separate entrances into the North and South stairs.
- 2nd floor exiting (492 people cap. – STW limited) is able to support the occupant load.
Fire Barriers – Basement

- Fire barriers shall have a fire-resistance rating in accordance with ASTM E 119 (IBC 703.2)
- Fire barriers are permitted to separate the building into control areas to meet maximum allowable quantities for hazardous materials (IBC 414.2.1)
- 2-hour barriers designed as spill control areas
Fire Barriers (cont.) – 1st & 2nd Floors
Structural Analysis

- Type IIB Construction
  - Slab on grade foundation
  - Steel decks
  - Steel bar joists
  - Steel wide-flange beams
  - Steel columns
  - Spray-applied material not required, but applied in random areas.
  - Exterior nonbearing walls (no fire resistance requirement per IBC – Tables 601 and 602)
Water Supply, Distribution Lines, Riser Locations

- Primary water supply from the USAF Water Tanks.
- City of Albuquerque, NM water supply serves as a backup.
Sprinkler System Analysis

- Fully Sprinklered building: Wet-pipe Ordinary Hazard Group 2 – **DOE Requirement**
  - Two wet-pipe sprinkler risers
  - System includes alarm check valve, OS&Y valve, reduced pressure back flow prevention
  - Risers are located in dedicated rooms on the south and southwest sides of the building
  - Risers supplied by 6 and 8-in. underground lead-ins
- Class I “manual” standpipes located in stairs
- Fire Department Connections located on the North and South sides
- Verified ITM performed in accordance with NFPA 25 and manuf. requirements 🔄
Water Supply Test Results and Three Largest Sprinkler Demands

| Building: | Bldg. 870, Production Facility |
| Location: | M Avenue |
| Area: | I |

<table>
<thead>
<tr>
<th>Area Protected</th>
<th>Density (gpm/ft²) or No. of Heads</th>
<th>Area (ft²)</th>
<th>Flow - gpm (no hose)</th>
<th>B.O.R. Pressure - psi</th>
<th>Hose Stream Flow - gpm (w/hose)</th>
<th>B.O.R. Pressure - psi</th>
<th>Allowance (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Wing, 1st Floor West</td>
<td>0.20</td>
<td>3,000</td>
<td>988</td>
<td>50.02</td>
<td>1488</td>
<td>50.02</td>
<td>500</td>
</tr>
<tr>
<td>Cleanroom</td>
<td>0.20</td>
<td>1,977</td>
<td>499</td>
<td>56.04</td>
<td>999</td>
<td>56.04</td>
<td>500</td>
</tr>
<tr>
<td>West Wing</td>
<td>0.20</td>
<td>2,200</td>
<td>785</td>
<td>55.8</td>
<td>1285</td>
<td>55.8</td>
<td>500</td>
</tr>
</tbody>
</table>

Supply > Demand

85% Water Supply

Flow Test Results:
- Date: 1/26/07
- Static: 85 psi
- Residual: 75 psi
- Flow: 1,513 gpm

Flow Test Results minus 15 percent:
- Date: 1/26/07
- Static: 72 psi
- Residual: 66 psi
- Flow: 1,313 gpm

West Wing: AS plus hose demand, 1,285 gpm at 55.8 psi

North Wing, 1st floor West: AS plus hose demand, 1,488 gpm at 50.2 psi
Fire Alarm System Analysis

- FACP Addressable (EST-QuickStart 4)
- Initiating Devices:
  - Smoke and Heat Detectors – Partial detection (IBC 907.2)
    - Fire Alarm Safety Functions (IBC 907.3)
    - Control door release, HVAC Shutdown (*smoke-control*), and toxic gas shutdown
  - Protect FACP (IBC 907.4.1)
  - Manual Pull Stations – Exits; every 400 feet; every 150 feet along the chemical transport route (IBC 415.10.2)
  - High Sensitivity Smoke Detection (HSSD) – Clean Rooms
  - Toxic Gas Monitoring System
  - Monitoring of Sprinkler Water Flow and Tamper Switches
- Notification Devices: Horn/Strobe (Wheelock) – General alarm throughout bldg.
- Class A Circuits: Redundant path; operates past single open; path integrity results in trouble signal (NFPA 72, 12.3.1)
- Signals report back to a Proprietary Supervising Station
Prescriptive-Based Analysis Summary

- The “Production Facility’s” construction and fire and life safety systems comply with the applicable codes, standards, and orders. ✔
PERFORMANCE-BASED DESIGN
Performance-Based Evacuation Approach

- Assume occupants are:
  - Familiar with their work area/space
  - Trained on evacuation procedures – Fire Drills
  - Physical condition at or above average
  - Awake/alert
  - Office employees typically work better as a group than lab people

- Pre-movement times are based on:
  - Saving computer data
  - Shutting down experiments
  - Safety storing chemicals
  - Notifying others

Selected Pre-movement time = 36 s *

* Ref: NFPA Handbook --- 20th Edition, Table 4.2.1
Performance-Based Objectives & Tenability Criteria

NFPA 72 - 2016, Table B.2.2.4.1 (a) – Goals and Objectives:
- **Fire Protection Goal** – Provide life safety
- **Stakeholder’s Objective** – No loss of life within compartment of origin
- **Design Objective** – Maintain tenable conditions within compartment of origin

<table>
<thead>
<tr>
<th>Fire Protection Goal</th>
<th>Stakeholder Objective</th>
<th>Design Objective</th>
<th>Performance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize fire-related injuries</td>
<td>Allow safe egress for all occupants outside the room of origin</td>
<td>Maintain tenable conditions</td>
<td>Visibility &gt; 4 m (^1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Smoke Layer Height &gt; 1.83 m (6ft.) (IBC 909.8.1) (^2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CO &lt; 1000 ppm (^2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Room Temperature &lt; 60 C (^3)</td>
</tr>
<tr>
<td>Minimize fire-related damage to the buildings and its contents</td>
<td>Prevent thermal damage</td>
<td>Prevent Flashover</td>
<td>Upper Layer Temperature &lt; 500 C (^4)</td>
</tr>
<tr>
<td>Minimize undue loss of operations</td>
<td>Minimize smoke spread</td>
<td>Prevent fire and smoke from spreading outside the room of origin</td>
<td>Upper Layer Temperature &lt; 500 C (^4)</td>
</tr>
</tbody>
</table>

\(^1\) SFPE Table 61.3 – Familiar occupants
\(^2\) NFPA 101
\(^3\) SFPE HB, 4th Edition, Table 2-6.20
\(^4\) Thomas
Pathfinder RSET – Steering Model (1st Floor): **109 s (1.82 min.) for 412 occupants**

- \[ RSET = t_d + t_{p-e} + t_e \]
- \[ t_d = 31 \text{ s}^{*} \]
- \[ t_{p-e} = 36 \text{ s} \text{ (Pre-Movement time previously stated)} \]
- \[ t_e = 109 \text{ s} \text{ (movement time to exits)} \]

\[ RSET \text{ (1st Detector Activation)} = 31 + 36 + 109 = 176 \text{ s (approx. 3 min)} \]

Where:
- \( t_d \) = Time from fire ignition to detection
- \( t_{p-e} \) = Pre-evacuation (aka Pre-movement time)
- \( t_e \) = Time form start of purposive evacuation movement until safety is reached

* Detector activation time from FDS Model (not hand calc.). Includes 2 second lag time. Detector located outside of kitchenette
Performance-Based Fire Scenario Considerations

- NFPA 101, Section 5.5 Design Fire Scenarios
  1. Occupancy Specific/activity related
  2. Ultrafast-developing fire in primary means of egress
  3. Normally unoccupied room
  4. Concealed space next to large unoccupied room
  5. Slowly developing fire, shielded from fire protection
  6. Most severe Fire/Largest fuel load
  7. Outside Exposure Fire
  8. Ordinary combustibles/ineffective-unreliable fire protection

- Fire Scenario 1A - Kitchen Appliance Fire (statistically most significant) * – Design Fire 1, 8. (Sprinklers impaired)
- Fire Scenario 1B - Kitchen Appliance Fire (statistically most significant) * – Design Fire 1. (Sprinklers active)

Kitchen Appliance Fire – SC1A and 1B

- Kitchenette located on the 1st floor near main entrance
- Appliances:
  - Microwave oven (primary ignition source)
  - Coffee maker
  - Wood table
- Based upon most recent fire drill data, most occupants will use the South and West doors to exit the area
- Sprinklers will be impaired due to maintenance work for Fire Scenario 1A only
Fire Scenario 1A: Pyrosim Model Overview

1st Floor View Showing Area Modeled in Pyrosim
**Fuel Characteristics**

- **Microwave Oven** properties:
  - Plastic casing and electronic components
  - Growth & Decay Rates: Slow ($\alpha = 0.00293\text{ kW/s}^2$)
  - Burning Duration: 300 s (5 min.)
  - Peak Heat Release Rate (HRR): **250 kW**
  - CO Yield: 0.024 g/g *
  - Soot Yield: 0.060 g/g *

- **Wood Table** properties: *
  - Pine material
  - Growth Rate: Fast ($\alpha = 0.047\text{ kW/s}^2$)
  - Decay Rate: Slow ($\alpha = 0.00293\text{ kW/s}^2$)
  - Burning Duration: 400 s (6.7 min.)
  - Peak Heat Release Rate (HRR): **500 kW**
  - CO Yield: 0.005 g/g *
  - Soot Yield: 0.015 g/g *

- **Coffee Maker** properties:**
  - Plastic casing and electronic components
  - Growth & Decay Rates: Slow ($\alpha = 0.00293\text{ kW/s}^2$)
  - Burning Duration: 300 s (5 min.)
  - Peak Heat Release Rate (HRR): **23 kW**
  - CO Yield: 0.003 g/g
  - Soot Yield: 0.014 g/g

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* SFPE Handbook – 5th, Table A.39, Babrauskas, HRR
** University of Maryland – Burning Item Database (NIST links)  
http://www.firebid.umd.edu/burning-item-database.php

Source: International Journal on Engineering Performance-Based Fire Codes, Chow
Heat Release Rate – Modeled Fire

- **700 kW Peak HRR for 400 s**
### SC1A/B: FDS Smoke Det. Activation Times

<table>
<thead>
<tr>
<th>DEVICE Activation Times</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  SD</td>
</tr>
<tr>
<td>2  SD01</td>
</tr>
<tr>
<td>3  SD02</td>
</tr>
<tr>
<td>4  SD03</td>
</tr>
<tr>
<td>5  SD04</td>
</tr>
<tr>
<td>6  SD05</td>
</tr>
<tr>
<td>7  SD06</td>
</tr>
<tr>
<td>8  SD07</td>
</tr>
<tr>
<td>9  SD08</td>
</tr>
<tr>
<td>10 SD09</td>
</tr>
</tbody>
</table>

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<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28.6 s *</td>
</tr>
<tr>
<td></td>
<td>86.3 s</td>
</tr>
<tr>
<td></td>
<td>77.3 s</td>
</tr>
<tr>
<td></td>
<td>78.0 s</td>
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<tr>
<td></td>
<td>78.1 s</td>
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<tr>
<td></td>
<td>135.9 s</td>
</tr>
<tr>
<td></td>
<td>109.6 s</td>
</tr>
<tr>
<td></td>
<td>103.7 s</td>
</tr>
<tr>
<td></td>
<td>129.5 s</td>
</tr>
<tr>
<td></td>
<td>138.0 s</td>
</tr>
</tbody>
</table>

*1st Smoke Detector activates at approximately 29 s and horns and strobes are activated 2s later due to inherent system propagation and processing delay (aka lag time); therefore actual smoke detector alarm time is 31 s.
Smoke conditions @ 1st Smoke Detector activation (31 s) and at RSET (176 s) does not meet tenability criterion.
Visibility at RSET - 176 s << 4 m @ 1.83 m (6-ft) AFF in corridor and near main exit. Scale maxed out @ 30 m. Does **not** meet criterion. ✗
Temperature of Corridor @ 60 s and 176 s (6-ft walking surface). At 176 s temp. approx. $48^\circ C < 60^\circ C < < 500^\circ C$ – Never exceeds $105^\circ C < 500^\circ C$ - No Flashover ✅
Fire Scenario 1A: FDS CO Conditions

CO at 1.83 m (6-ft) at 31 s and **RSET - 176 s**; maximum scale = 300 ppm <1000 ppm

Exit

N
Fire Scenario 1A: FDS Smoke Viewpoints

@ 29 s

@ 60 s
Fire Scenario 1A: Viewpoint Video
Fire Scenario 1A: Smoke Layer Height

Layer Height Over Time

1.83 m (6ft) AFF
Fire Scenario 1A: Results Summary – Recommendations

If occupants are NOT initially alerted by the presence of smoke, then:
- Smoke Detector alarm will occur at 31 s
- 176 s for last person to evacuate 1st floor safely

ASET = 66 s – (SLIDE 35) **Visibility is the most limiting condition**
RSET = 176 s
Overall Assessment: **FAIL**

**Recommendations:**
- Ensure sprinklers are operational and if not, then a fire watch needs to be in place
- Keep exits clear of obstructions and potential combustibles
- Limit amount of secondary combustibles in kitchenette
- Replace suspect, old, or malfunctioning appliances
SC1B: FDS Sprinkler Activation Times & HRR

### DEVICE Activation Times

<table>
<thead>
<tr>
<th>Device</th>
<th>Activation Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD</td>
<td>28.1 s</td>
</tr>
<tr>
<td>SD01</td>
<td>93.7 s</td>
</tr>
<tr>
<td>SD02</td>
<td>83.9 s</td>
</tr>
<tr>
<td>SD03</td>
<td>80.2 s</td>
</tr>
<tr>
<td>SD04</td>
<td>90.1 s</td>
</tr>
<tr>
<td>SD05</td>
<td>166.7 s</td>
</tr>
<tr>
<td>SD06</td>
<td>129.2 s</td>
</tr>
<tr>
<td>SD07</td>
<td>122.2 s</td>
</tr>
<tr>
<td>SD08</td>
<td>160.9 s</td>
</tr>
<tr>
<td>SD09</td>
<td>177.2 s</td>
</tr>
<tr>
<td>SPRK01</td>
<td>No Activation</td>
</tr>
<tr>
<td>SPRK02</td>
<td>No Activation</td>
</tr>
<tr>
<td>SPRK03</td>
<td>No Activation</td>
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<tr>
<td>SPRK04</td>
<td>No Activation</td>
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<tr>
<td>SPRK05</td>
<td>No Activation</td>
</tr>
<tr>
<td>SPRK06</td>
<td>No Activation</td>
</tr>
<tr>
<td>SPRK07</td>
<td>75.5 s</td>
</tr>
<tr>
<td>SPRK08</td>
<td>No Activation</td>
</tr>
<tr>
<td>SPRK09</td>
<td>No Activation</td>
</tr>
<tr>
<td>SPRK10</td>
<td>No Activation</td>
</tr>
<tr>
<td>SPRK11</td>
<td>No Activation</td>
</tr>
<tr>
<td>SPRK12</td>
<td>No Activation</td>
</tr>
</tbody>
</table>

*1st Sprinkler activates at approximately 76s and horns and strobes are activated 60s later due to inherent system propagation and processing delay (aka lag time); therefore actual sprinkler alarm time is 136 s. The smoke detector will activate at 31 s like SC1A.
Fire Scenario 1B: FDS Visibility Conditions

Visibility at 176 s << 4 m @ 1.83m (6-ft) AFF in corridor. Does not meet ALL criterion. ✗
Temperature of Corridor @ 60 s and **176 s** (6-ft walking surface). At **176 s** temp. approx. **35°C < 60°C** – Scale never exceeds **55°C < 500°C** - **No Flashover** ✔️
Fire Scenario 1B: FDS CO Conditions

CO at 1.83 m (6-ft) at 31 s and 176 s; maximum scale = 95 ppm <1000 ppm  ✔️
Fire Scenario 1B: Smoke Layer Height

LAYER->HEIGHT

1.83 m (6ft) AFF
Fire Scenario 1B: Results Summary – Recommendations

- If occupants are NOT initially alerted by the presence of smoke, then:
  - Smoke Detector alarm will occur at **31 s**
  - 176 s for last person to evacuate 1st floor safely

ASET = 128 s – (SLIDE 43) **Visibility is the most limiting condition** – West exit is still clear at 176 s
RSET = 176 s
Overall Assessment: **FAIL**

Recommendations:
- Keep exits clear of obstructions and potential combustibles
- Limit amount of secondary combustibles in kitchenette
- Replace suspect, old or malfunctioning appliances
Other Fire Scenarios Considered

The following Design Fire Scenarios were considered, but not evaluated:

- Atrium fire (aka communicating space)
- Lab test apparatus fire
- Wood pallet fire on or in the loading dock
- Forklift fire
- Combustible commodity fire in a stairwell
- Portable evaporative cooler fire inside the loading dock area
- Chemical spill fire (basement) below:

FDS Basement View Showing Layout and Sprinkler Locations
## Fire Scenarios 1A and 1B: Tenability Criteria Comparisons

<table>
<thead>
<tr>
<th>Tenability Criteria</th>
<th>Scenario 1A (w/o Sprinklers)</th>
<th>Scenario 1B (w/ Sprinklers)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flashover</strong></td>
<td><img src="./success.png" alt="Success" /></td>
<td><img src="./success.png" alt="Success" /></td>
</tr>
<tr>
<td>(less than 500°C)</td>
<td>48°C</td>
<td>35°C</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(less than 60°C)</td>
<td><img src="./success.png" alt="Success" /></td>
<td><img src="./success.png" alt="Success" /></td>
</tr>
<tr>
<td><strong>CO Production</strong></td>
<td>300 ppm</td>
<td>95 ppm</td>
</tr>
<tr>
<td>(less than 1,000 ppm)</td>
<td><img src="./success.png" alt="Success" /></td>
<td><img src="./success.png" alt="Success" /></td>
</tr>
<tr>
<td><strong>Visibility</strong></td>
<td>0 meters</td>
<td>3 meters</td>
</tr>
<tr>
<td>(greater than 4 m)</td>
<td><img src="./failure.png" alt="Failure" /></td>
<td><img src="./failure.png" alt="Failure" /></td>
</tr>
</tbody>
</table>

**Overall Assessment:** Two of the three criterion fail for Scenario 1A (no sprinklers) and 1B (sprinklers), however whether or not sprinklers are present, Scenario 1B proves that they do make a considerable difference with the reduction of the amount of carbon monoxide and temperature produced from the design fire.
Corridor Storage Concerns
# Recommendations

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Reason</th>
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<tbody>
<tr>
<td>1 Replace ordinary response sprinklers with quick response</td>
<td>Some of the Cleanrooms have ordinary response automatic sprinklers and due to high air velocities, quick response are required.</td>
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<tr>
<td>2 Perform Waterflow Test</td>
<td>The flow test used for analysis is out of date by 4-years. NFPA requires recent flow test data to be used. Due to scheduling issues, a new flow test has not been able to be performed.</td>
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<td>3 Reconstitute sprinkler hydraulic calculations</td>
<td>Due to the unavailability of complete, updated sprinkler drawings and numerous sprinkler modifications over the life of the system, a sprinkler system evaluation should be done on each of the two systems serving the main building. This should include a complete set of drawings and hydraulic calculations that include all modifications that have been made to date.</td>
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<td>4 Perform fire alarm audible test of entire bldg.</td>
<td>Based on audible dB readings within the last few years, some of the areas of the building are deficient in coverage.</td>
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<td>5 Relocate items located in corridors</td>
<td>Recycling bins, news racks, tables, etc.</td>
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Exceptional service in the national interest

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