Robotic Manufacturing Science and Engineering Laboratory

Culminating Experience in Fire Protection

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Topics

- RMSEL Overview
- Prescriptive Design
  - Occupancy
  - Atrium
  - Structural Fire Protection
  - Fire Suppression
  - Fire Alarm System
  - Smoke Control
- Performance Based Evaluation
  - Required Safe Egress Time
  - Fire in the High Bay
  - Fire in the Atrium
RMSEL Overview

Robotic & Manufacturing Science and Engineering Laboratory

- Sandia National Laboratories / U.S. Department of Energy
- House office space, laboratories, and conference rooms
- Three story with atrium with smoke control system
  - Stairwell pressurization as well
- Large high bay space
- Large conference rooms
Applicable Codes

- **Regulatory Drivers**
  - U.S. Department of Energy (DOE) Order (O) 420.1B, *Facility Safety*
  - DOE O 6430.1A (1989), *General Design Criteria*
  - DOE O 5480.7A, *Fire Protection*

- **Consensus Standards**
  - 2012 International Building Code (IBC)
  - 2012 International Fire Code (IFC)
  - NFPA 13-2013, *Standard for the Installation of Sprinkler Systems*
  - NFPA 72-2013, *National Fire Alarm Signaling Code*

- **Guidance**
  - DOE Standard (STD) 1066-2012, *Fire Protection*
  - Sandia Corporation (Sandia) Construction Specifications
Occupancy

First Floor

Calculated occupant load 578
Average daily occupant load ~200

IBC 10291.2.4 – Three exits are required when occupant load greater than 500.

<table>
<thead>
<tr>
<th>Space</th>
<th>IBC</th>
<th>LSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>Business</td>
<td>Business</td>
</tr>
<tr>
<td>Conference</td>
<td>Assembly (A-3)</td>
<td>Assembly</td>
</tr>
<tr>
<td>Laboratories</td>
<td>Business</td>
<td>General Industrial</td>
</tr>
<tr>
<td>Storage</td>
<td>Storage</td>
<td>Storage</td>
</tr>
</tbody>
</table>
Occupancy (cont.)
Occupancy

- Third floor has only one exit
- 2012 IBC, Table 1021.2(2) requires a minimum of two exits
Atrium

- Atrium runs entire length of building
- Communicates to all three floors
- Smoke control
Atrium (continued)
Construction

- Constructed in 1995
  - NFPA 101-1991, LSC
- Construction Type
  - Type II-N (1991 UBC)
  - Type II-B (2012 IBC)
- Building Area Modifications
  - Approved Automatic Sprinkler System
  - Frontage Increase
- No fire-resistance required for exterior walls since fire separation distance is greater than 30 ft

### Building Characteristics

<table>
<thead>
<tr>
<th>Level</th>
<th>Approximate Floor Area [ft²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bsmnt</td>
<td>4,500</td>
</tr>
<tr>
<td>First</td>
<td>36,000</td>
</tr>
<tr>
<td>Second</td>
<td>24,000</td>
</tr>
<tr>
<td>Third</td>
<td>6,500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>71,000</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Direction</th>
<th>Length [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-S</td>
<td>~430 ft</td>
</tr>
<tr>
<td>E-W</td>
<td>~110 ft</td>
</tr>
</tbody>
</table>
Fire Barriers

- Section 404.6 of the IBC requires atrium spaces be separated from adjacent by 1-hour fire
- 2012 IBC - Table 508.4, *Required Separation of Occupancies*
  - 1-hour separation between A-3 and Business
Travel Distance

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>LSC [ft]</th>
<th>IBC [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business/B</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Assembly/A-3</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>General Industrial</td>
<td>250</td>
<td>250</td>
</tr>
</tbody>
</table>

Longest travel distance is 130 ft (office 2245)
## Fire Suppression

**High Bays**
- Density: 0.30 [gpm/ft²]
- Coverage Area: 2,500 [ft²]
- Sprinkler Head Coverage: <100 [ft²]
- Occupancy: EH1
- Hose Demand: 500 [gpm]
- Duration: 90 [min]
- Approximate Total Demand: 111,250 [gal]

**Everything else**
- Density: 0.17 [gpm/ft²]
- Coverage Area: 3,000 [ft²]
- Sprinkler Head Coverage: <130 [ft²]
- Occupancy: OH2
- Hose Demand: 250 [gpm]
- Duration: 60 [min]
- Approximate Total Demand: 45,600 [gal]
Fire Suppression (cont.)
Fire Alarm System

- Fire Alarm Control Panel – EST Quickstart
- Class A Circuits
- Photoelectric Smoke Det.
- Manual Pull Stations
- Intelligent Heat Det.
- Horn/Strobe – Wheelock
- Magnetic hold open devices for fire rated doors
- Reports to a Proprietary Central Alarm
Smoke Control

- **Active Smoke Control**
  - Four Smoke Removal Fans
    - 34,200 CFM
    - 25,300 CFM
    - 37,200 CFM
    - 27,200 CFM
  - Makeup air from HVAC

- **Stairwell Pressurization**
  - Not required per current IBC
  - Not required per past UBC
  - DOE design criteria
    - General statement for “smoke abatement”
  - Stairwell pressurization has been abandoned
Smoke Control

1994 UBC

- 402.2 – Smoke control required
  - Not dependent on number of floors
  - Sprinkler activated
- 402.7 – Standby power
- 402.9 – Acceptance of the system
- 905.2.5 – Minimum run time of 20 minutes
- Exhaust method
  - 10 ft above any walking distance

2012 IBC

- 404.5 – Smoke control required for atrium 3 stories or more
- 404.7 – Standby power
- 909.4.6 – Minimum run
  - Lesser of 20 min or 1.5 egress time
- 909.8 – Exhaust method
  - NFPA 92B
  - 6 ft above any walking surface
- NFPA 92B
PERFORMANCE BASED EVALUATION
Required Safe Egress Time

SFPE Hydraulic Model

- Assumptions
  - ¼ the occupants evacuate through the east stairwell
- East stairwell takes approximately 3 min
  - Accounts for multiple floors
- Assembly A-3 Occupancy
  - Approximately 55 seconds

Pathfinder (Steering Mode)

- Total time to evacuate 587 occupants is 85 seconds
- Most used exit is the east stairwell
- Approximately 35 seconds to evacuate the Assembly A-3 occupancy
Required Safe Egress Time (cont.)

2nd floor at 30 seconds

North
Required Safe Egress Time (cont.)

2\textsuperscript{nd} floor at 50 seconds

North
Required Safe Egress Time

- **RSET** = $t_d + t_n + t_{p-e} + t_e$
  - $t_d$ = time from ignition to detection
    - Fire in the high bay – property protection scenario
    - Fire in the Atrium – life safety scenario
  - $t_n$ = time from detection to notification (assumed fast – 0 sec)
  - $T_{p-e}$ = time from notification to evacuation commences
    - Assumed moderate length of time – 1 minute
      - Sandia conducts numerous drills throughout the year
      - Relatively high number of false alarms
      - Trained to put things away or gather belongings...”if safe to do so”
Fire in the South High Bay

- CFAST 6.3.0
- Design fire
  - Packaging materials (foam)
  - Upholstered chair as a surrogate
- Geometry
  - 11 m x 29 m x 10 m
  - Vent – personnel door
- Suppression
  - RTI = 300 (ms)\(^{1/2}\)
  - Activation Temp - 74°C

Figure 3-1.102 of the SFPE Handbook, 4th Edition
Fire in High Bay
Fire in the Atrium

- Design fire
  - Primary fuel – sofa
  - Secondary fuel – chairs
  - Ignition source – overheated charger (phone or computer)
Fire in Atrium (cont.)
Fire Atrium (cont.)

\[
\frac{\dot{Q}^*}{\delta_x} = 9.5
\]

Six Meshes
Finest – 0.125 m
Course – 1 m

<table>
<thead>
<tr>
<th>Material</th>
<th>(Y_{\text{CO}} \ [\text{g/g}])</th>
<th>(Y_{\text{Soot}} \ [\text{g/g}])</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM21</td>
<td>0.010</td>
<td>0.131</td>
</tr>
<tr>
<td>GM23</td>
<td>0.031</td>
<td>0.227</td>
</tr>
<tr>
<td>GM25</td>
<td>0.028</td>
<td>0.194</td>
</tr>
<tr>
<td>GM27</td>
<td>0.042</td>
<td>0.198</td>
</tr>
<tr>
<td>Average</td>
<td>0.028</td>
<td>0.188</td>
</tr>
</tbody>
</table>

Tenability Criterion
- Visibility < 13 m
Fire in the Atrium (cont.)

![Graphs showing predicted vs. measured values for smoke obscuration and concentration]
Fire in Atrium (cont.)

Figure 3-1.102 of the SFPE Handbook, 4th Edition
Fire in Atrium (cont.)

Unmitigated (i.e., no sprinkler or smoke control)
Second floor conference room - visibility lost in 72 seconds
Fire in Atrium (cont.)

Unmitigated (i.e., no sprinkler or smoke control)
Main Entrance - visibility lost in 104 seconds
Fire in Atrium (cont.)

Unmitigated (i.e., no sprinkler or smoke control)
NE stairwell - visibility lost in 134 seconds
Mitigated (i.e., sprinklers and smoke control)
Conference rm and main entrance lose visibility at 127
Mitigated (i.e., sprinklers and smoke control)
Conference room and main entrance lose visibility at 247s
### Fire in Atrium (cont.)

<table>
<thead>
<tr>
<th>Location (RSET)</th>
<th>Unmitigated</th>
<th>Mitigated – Sprinklers only</th>
<th>Mitigated – Smoke Cntrl only</th>
<th>Mitigated – Smk Cntrl &amp; Sprinkler</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2nd floor conference room (25/185 s)</strong></td>
<td>73</td>
<td>93</td>
<td>106</td>
<td>127</td>
</tr>
<tr>
<td><strong>Main entrance (undetermined)</strong></td>
<td>104</td>
<td>106</td>
<td>125</td>
<td>127</td>
</tr>
<tr>
<td><strong>2nd floor east stairwell (50/210 s)</strong></td>
<td>134</td>
<td>137</td>
<td>180</td>
<td>247</td>
</tr>
<tr>
<td><strong>Middle corridor exit (50/210)</strong></td>
<td>220</td>
<td>286</td>
<td>292</td>
<td>338</td>
</tr>
<tr>
<td><strong>South exit (55/215)</strong></td>
<td>352</td>
<td>424</td>
<td>398</td>
<td>560</td>
</tr>
</tbody>
</table>
Summary and Conclusions

- RMSEL generally meets or exceeds current code requirements
  - Smoke control
    - Provides benefit
    - Requires standby power
- Performance based evaluation
  - Smoke control and sprinklers allow RSET > ASET for all but one location
- Recommendations
  - Disposition the standby power code deficiency
- Questions?