LA AFB Fitness Center

Colin White
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Overview

- Building Overview
- Applicable Codes and Standards
- Building Details
- Floor Plans
- Occupancy
- Prescriptive Design
  - Structural Fire Protection
  - Automatic Sprinkler System
  - Detection and Alarm System
  - System Operation and Smoke Management
  - Egress Analysis
- Performance-Based Design
  - Fire Scenario 1
  - Fire Scenario 2
- Issues
- Conclusion
Building Overview

- Physical Fitness center for the U.S. Air Force located on LAAF in California
- Building divided into three major areas
  - Gymnasium
  - HAWC/Admin
  - Fitness Center
Applicable Codes and Standards

- UFC 3-600-01 Fire Protection Engineering for Facilities (2016)
- UFC 3-410-01 Mechanical Engineering (2017)
- International Mechanical Code (2015)
- NFPA 1 – National Fire Code
- NFPA 13 – Standard for the Installation of Sprinkler Systems
- NFPA 70 – National Electric Code
- NFPA 72 – National Alarm and Signaling Code
Building Details

- Construction Type (1997 UBC)
  - II - 1-hr (A-2.1 Occupancy)
  - II - N (A-3 and B Occupancy)

- Occupancy Classification
  - A-2.1 Gymnasium
  - A-3 Fitness Center
  - B Office/Laundry
  - Occupancy: 1,055

- Building Size
  - Single Story
  - 34,516 SF
  - 32 ft Height
Building Details (Cont)

<table>
<thead>
<tr>
<th>IBC/IFC:</th>
<th>UBC/UFC:</th>
<th>NFPA:</th>
<th>NFIRS:</th>
<th>BOCA:</th>
<th>SBC:</th>
<th>COMMON TERMINOLOGY:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I-A</td>
<td>Type I-FR</td>
<td>I (443)</td>
<td>1</td>
<td>1-A</td>
<td>I</td>
<td>Fire Resistive, Non-combustible</td>
</tr>
<tr>
<td>Type I-B</td>
<td>Type II-FR</td>
<td>II (332)</td>
<td>1</td>
<td>1-B</td>
<td>II</td>
<td>Fire Resistive, Non-combustible</td>
</tr>
<tr>
<td>Type II-A</td>
<td>Type II-1 Hr.</td>
<td>II (222)</td>
<td>1</td>
<td>2-A</td>
<td>-----</td>
<td>Fire Resistive, Non-combustible</td>
</tr>
<tr>
<td>Type II-B</td>
<td>Type II-N</td>
<td>II (111)</td>
<td>3</td>
<td>2-B</td>
<td>IV-1 Hr.</td>
<td>Protected Non-combustible</td>
</tr>
<tr>
<td>Type III-A</td>
<td>Type III-1 Hr.</td>
<td>II (000)</td>
<td>4</td>
<td>2-C</td>
<td>IV-unp.</td>
<td>Unprotected Non-combustible</td>
</tr>
<tr>
<td>Type III-B</td>
<td>Type III-N</td>
<td>III (211)</td>
<td>5</td>
<td>3-A</td>
<td>V-1 Hr.</td>
<td>Protected Ordinary</td>
</tr>
<tr>
<td>Type IV</td>
<td>Type IV (H.T.)</td>
<td>III (200)</td>
<td>6</td>
<td>3-B</td>
<td>V-unp.</td>
<td>Unprotected Ordinary</td>
</tr>
<tr>
<td>Type V-A</td>
<td>Type V-1 Hr</td>
<td>IV (2HH)</td>
<td>2</td>
<td>4</td>
<td>III</td>
<td>Heavy Timber</td>
</tr>
<tr>
<td>Type V-B</td>
<td>Type V-N</td>
<td>V (111)</td>
<td>7</td>
<td>5-A</td>
<td>VI-1 Hr.</td>
<td>Protected Combustible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V (000)</td>
<td>8</td>
<td>5-B</td>
<td>VI-unp.</td>
<td>Unprotected Combustible</td>
</tr>
</tbody>
</table>

NFPA – National Fire Protection Association
NFIRS – National Fire Incident Reporting System
BOCA – BOCA / National Building Code
SBC – Standard / Southern Building Code
Occupancy

- IBC Occupancy same as UBC except A-2.1 becomes A-4
Prescriptive Design
## Structural Fire Protection

### TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Primary structural frame (^f) (see Section 202)</td>
<td>3(^a)</td>
<td>2(^a)</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Bearing walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Exterior (^e, f)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3(^a)</td>
</tr>
<tr>
<td>Interior</td>
<td>3(^a)</td>
<td>2(^a)</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonbearing walls and partitions</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Interior (^d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Floor construction and associated secondary members</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>(see Section 202)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof construction and associated secondary members</td>
<td>1(^{1/2})</td>
<td>1(^b, c)</td>
<td>1(^b, c)</td>
<td>0(^c)</td>
<td>1(^b, c)</td>
</tr>
</tbody>
</table>
### Structural Fire Protection (Cont)

<table>
<thead>
<tr>
<th>FIRE SEPARATION DISTANCE = X (feet)</th>
<th>TYPE OF CONSTRUCTION</th>
<th>OCCUPANCY GROUP H&lt;sup&gt;a&lt;/sup&gt;</th>
<th>OCCUPANCY GROUP F-1, M, S-1&lt;sup&gt;b&lt;/sup&gt;</th>
<th>OCCUPANCY GROUP A, B, E, F-2, I, R, S-2, U&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>X &lt; 5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>All</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5 ≤ X &lt; 10</td>
<td>IA</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10 ≤ X &lt; 30</td>
<td>IA, IB</td>
<td>2</td>
<td>1</td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>IIB, VB</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>1</td>
<td>1</td>
<td>1&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>X ≥ 30</td>
<td>All</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Fire Resistance Ratings

- **Columns and Beams**
  - Type IIA – Primary structural frame members need 1-hr rating
  - Type IIB – No required fire resistance rating

- **Roof Assemblies**
  - Same requirements as columns and beams

- **Exterior Walls**
  - Type IIA walls need 1-hr rating
  - All other walls exceed 30’ fire separation requirement

- **Interior Walls**
  - Non-load bearing wall don’t require fire resistance rating
  - Exception for walls between two occupancies

- **Doors Openings, Joints, and Penetrations**
  - Should match the assemblies they are integrated with
  - Some fire safing required where partitions meet corrugated metal deck
Automatic Fire Suppression

- Wet-pipe Sprinkler System
  - Protecting the kitchen hood
  - Wet-Chemical
  - Pre-Engineered
Hazard Classification

- Fitness Centers are Ordinary Hazard per UFC.
- Hose Stream and Area of Operation determined from NFPA 13
Hazard Classification (Cont)

- Quick Response sprinklers (K=5.6)

**TABLE 11.2.3.1.2 Hose Stream Allowance and Water Supply Duration Requirements for Hydraulically Calculated Systems**

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Inside Hose</th>
<th>Total Combined Inside and Outside Hose</th>
<th>Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light hazard</td>
<td>0, 50, or 100</td>
<td>0, 189, or 379</td>
<td>100 379</td>
</tr>
<tr>
<td>Ordinary hazard</td>
<td>0, 50, or 100</td>
<td>0, 189, or 379</td>
<td>250 946</td>
</tr>
<tr>
<td>Extra hazard</td>
<td>0, 50, or 100</td>
<td>0, 189, or 379</td>
<td>500 1893</td>
</tr>
</tbody>
</table>
Hydraulic Calculations

- Most remote area is the west side of the Gym
- Total coverage area required: 1,500 sq ft
  - Actual coverage area 1,570 sq ft
- POC demand
  - 404.3 gpm (80.6 psi)
Hydraulic Calculations

Most remote area is in the corner of Gym

Total coverage area required: 1,125 sq ft

Actual coverage area 1,131 sq ft

BOR demand

254 gpm (73 psi)
Demand vs. Supply

Legend
- City Water Supply
- Sprinkler Demand
- Hose Stream Demand

City Supply
93 PSI Static
88 PSI @ 1100 gpm

Hose Stream Allowance
250 gpm

Sprinkler Demand
80.6 PSI @ 404.3 gpm
Fire Detection and Alarm System

- Primary detection is via sprinkler system
- Smoke detectors in ducts and mech/elec rooms
- Combination strobe/horn notifiers throughout
- Mass notification system in accordance with UFC
Notifier Coverage
## Back-up Power Calculations

<table>
<thead>
<tr>
<th>Qty.</th>
<th>Model</th>
<th>Description</th>
<th>Supervisory Current (Amps)</th>
<th>Alarm Current (Amps)</th>
<th>Total Supervisory Current (Amps)</th>
<th>Total Alarm Current (Amps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PS-8</td>
<td>NAC Power Supply</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>7</td>
<td>ZNS-MCW</td>
<td>Multi-Candela (110 cd) 2-Wire Horn/Strobe Wall</td>
<td>0.00</td>
<td>0.24</td>
<td>0.00</td>
<td>1.71</td>
</tr>
<tr>
<td>6</td>
<td>ZNS-MCC</td>
<td>Multi-Candela (15 cd) Strobe Ceiling</td>
<td>0.00</td>
<td>0.06</td>
<td>0.00</td>
<td>0.40</td>
</tr>
</tbody>
</table>

|                      |                      | Total Supervisory and Alarm Current (Amps) | 0.13 | 2.24 |
|                      |                      | Total Standby and Alarm Sounding (Hours)   | 24   | 0.08 |
|                      |                      | Total Supervisory and Alarm Currents (Amp-Hours) | 3.12 | 0.19 |
|                      |                      | Total Supervisory Plus Alarm Currents (Amp-Hours) | 3.31 |
|                      |                      | Derating Factor                           | 3.97 |
|                      |                      | 2 Batteries Provided at                   | 7    |
## Worst Case Voltage Drop

<table>
<thead>
<tr>
<th>Qty</th>
<th>Model</th>
<th>Description</th>
<th>Alarm Current (Amps)</th>
<th>Total Alarm Current (Amps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>ZNS-MCW-FW</td>
<td>Multi-Candela (110 cd) 2-Wire Horn/Strobe Wall</td>
<td>0.24</td>
<td>0.48</td>
</tr>
<tr>
<td>6</td>
<td>ZRS-MCC-FW</td>
<td>Multi-Candela (15 cd) Strobe Ceiling</td>
<td>0.07</td>
<td>0.39</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Alarm Current</th>
<th>0.87</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Distance (Ft.)</td>
<td>450</td>
</tr>
<tr>
<td>Wire Gage (14) (Cir. Mims)</td>
<td>4110</td>
</tr>
<tr>
<td>%VD</td>
<td>8.57%</td>
</tr>
</tbody>
</table>

*Note: Cal Poly*
## System Operation and Smoke Mgmt.

<table>
<thead>
<tr>
<th>ACTION</th>
<th>MANUAL PULL STATION</th>
<th>SMOKE DETECTOR</th>
<th>DUCT SMOKE DETECTOR</th>
<th>TAMPER SWITCH</th>
<th>POST INDICATOR VALVE</th>
<th>WATER FLOW SWITCH</th>
<th>LOSS OF POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANNUNCIATE AT FIRE ALARM CONTROL PANEL</td>
<td>YES</td>
<td>YES</td>
<td>YES (SUPERVISORY)</td>
<td>YES (SUPERVISORY)</td>
<td>YES (SUPERVISORY)</td>
<td>YES</td>
<td>YES (TROUBLE)</td>
</tr>
<tr>
<td>ANNUNCIATE AT REMOTE ANNUNCIATOR</td>
<td>YES</td>
<td>YES</td>
<td>YES (SUPERVISORY)</td>
<td>YES (SUPERVISORY)</td>
<td>YES (SUPERVISORY)</td>
<td>YES</td>
<td>YES (TROUBLE)</td>
</tr>
<tr>
<td>ANNUNCIATE AT 24-HOUR ATTENDED REMOTE LOCATION</td>
<td>YES</td>
<td>YES</td>
<td>YES (SUPERVISORY)</td>
<td>YES (SUPERVISORY)</td>
<td>YES (SUPERVISORY)</td>
<td>YES</td>
<td>YES (TROUBLE)</td>
</tr>
<tr>
<td>ACTIVATE AUDIBLE/VISUAL ALARM SIGNAL THROUGHOUT BUILDING</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>SHUTDOWN RESPECTIVE AC UNITS</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>
Egress Analysis

- Three exits required for the gym
- Exits must meet the 1/3 rule for remoteness in sprinklered buildings
- Long dead end corridors are not allowed
Required Safe Egress Time

- ASET > RSET
- Occupant Characteristics
- Pre-Movement Time
- Evacuation Time
  - Discharge capacity per exit: 115 pep/min
  - About 3-4 mins for evacuation of the building
Performance-Based Design
Scenarios Recommended

1. An occupancy specific fire representative of a typical fire for the occupancy
2. An Ultra-Fast developing fire in the primary means of egress
3. A fire that starts in a normally unoccupied room
4. A fire that originates in a concealed wall or ceiling
5. A slowly developing fire, near a large occupancy, shielded from suppression
6. Most severe fire from highest possible fuel load
7. An outside exposure fire
8. An ordinary fire in a room with no detection or suppression
Scenarios Considered

- Laundry Room Fire
- Communications Room Fire
- Gym Bag Fire
- Sauna Fire (Selected)
- Foam Tumbling Mat Fire (Selected)
Fire Scenario – Sauna Fire

- Fire is located in the sauna in the male locker room
- Fire starts due to a towel left on the heating element
- Fire involves western red cedar planking
- 0.5 m² surface area
Fire Scenario – Sauna Fire

- The peak heat release rate of the fire is 250 kW/m²
- The fire grows as a $t^2$ fire with medium growth rate ($\alpha = 0.012 \text{ kW/s}^2$)

![Graph showing heat release rate over time](image)

**Figure 9.11** Cone Calorimeter heat release rate data for western red cedar.
Tenability Criteria - Visibility

- Visibility
  - 7 m for small spaces with familiar occupants

<table>
<thead>
<tr>
<th>Degree of familiarity with inside of building</th>
<th>Smoke density (extinction coefficient)</th>
<th>Visibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfamiliar</td>
<td>0.15 1/m</td>
<td>13 m</td>
</tr>
<tr>
<td>Familiar</td>
<td>0.5 1/m</td>
<td>4 m</td>
</tr>
</tbody>
</table>
### Tenability Criteria - Visibility

**Table 63.5** Reported effects of smoke on visibility and behavior

<table>
<thead>
<tr>
<th>Smoke density and irritancy</th>
<th>Approximate visibility (diffuse illumination)</th>
<th>Reported effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Unaffected</td>
<td>Walking speed 1.2 m/s</td>
</tr>
<tr>
<td>0.5 (1.15)</td>
<td>Nonirritant</td>
<td>Walking speed 0.3 m/s</td>
</tr>
<tr>
<td>0.2 (0.5)</td>
<td>Irritant</td>
<td>Walking speed 0.3 m/s</td>
</tr>
<tr>
<td>0.33 (0.76)</td>
<td>Mixed</td>
<td>30 % people turn back rather than enter</td>
</tr>
</tbody>
</table>

**Suggested tenability limits for buildings with:**

<table>
<thead>
<tr>
<th>Small enclosures and travel distances:</th>
<th>OD/m 0.2 (visibility 5 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large enclosures and travel distances:</td>
<td>OD/m 0.08 (visibility 10 m)</td>
</tr>
</tbody>
</table>
Tenability Criteria - Temperature

- 60 °C base on tenability in building with fire suppression
- 2.5 kW/m²

<table>
<thead>
<tr>
<th>Mode of heat transfer</th>
<th>Intensity</th>
<th>Tolerance time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation</td>
<td>&lt;2.5 kW · m⁻²</td>
<td>&gt;5 min</td>
</tr>
<tr>
<td></td>
<td>2.5 kW · m⁻²</td>
<td>30 s</td>
</tr>
<tr>
<td></td>
<td>10 kW · m⁻²</td>
<td>4 s</td>
</tr>
<tr>
<td>Convection</td>
<td>&lt;60 °C 100 %</td>
<td>&gt;30 min</td>
</tr>
<tr>
<td></td>
<td>saturated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 °C &lt;10 % H₂O⁰</td>
<td>12 min</td>
</tr>
<tr>
<td></td>
<td>120 °C &lt;10 % H₂O</td>
<td>7 min</td>
</tr>
<tr>
<td></td>
<td>140 °C &lt;10 % H₂O</td>
<td>4 min</td>
</tr>
<tr>
<td></td>
<td>160 °C &lt;10 % H₂O</td>
<td>2 min</td>
</tr>
<tr>
<td></td>
<td>180 °C &lt;10 % H₂O</td>
<td>1 min</td>
</tr>
</tbody>
</table>

Table 63.20 Limiting conditions for tenability caused by heat [18]

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⁰v/v
Tenability Criteria - Toxicity

- 1,500 ppm

Table 63.9  $C \cdot t$ product exposure doses for incapacitation and death by CO for different species at rest and during light activity

<table>
<thead>
<tr>
<th></th>
<th>Incapacitation</th>
<th>CO light activity</th>
<th>Fatal</th>
<th>CO light activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO at rest ppm · min</td>
<td>ppm · min</td>
<td>CO at rest ppm · min</td>
<td>ppm · min</td>
</tr>
<tr>
<td>Human 70 kg</td>
<td>80,000–100,000</td>
<td>30,000–35,000</td>
<td>~110,000–240,000</td>
<td>~60,000–190,000</td>
</tr>
<tr>
<td>Baboon ~20 kg</td>
<td></td>
<td>34,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macaque 3–4 kg</td>
<td>38,000–40,000</td>
<td>27,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rat ~ 300 g</td>
<td>30,000–40,000</td>
<td>22,000–36,000</td>
<td>162,000</td>
<td></td>
</tr>
</tbody>
</table>
Population Characteristics

- 1,055 people total, 550 in the gym.
- Typical office crowd, 30% female, 70% male.
  - 30% average body type
  - 3.9 ft/s walking speed
  - 70% favor the main entrance

Warning Time
- 30 for occupants in locker room 60 second for remainder

Pre-Movement Time
- Pre-movement time is short due to quick recognition.
- Fire occurring in a small space will quickly be recognized
- Time is set at around 30 sec
Egress Time

- Total egress time 396 seconds
- Queues start forming @ 70 sec
- Locker room empty @ 100 sec
Visibility

- 70 Seconds
- Untenable conditions in shower

Exits
Visibility

- 80 Seconds
- Untenable condition at west exit
Visibility

- 300 Seconds
- Exits blocked
Visibility

- 300 seconds
- 100 seconds before complete evacuation
Temperature

- 120 Seconds
- Locker room temperature already exceeds tenability

Exits
Fire Scenario – Foam Tumble Mat

- Fire is located in the gym adjacent to an exit
- Fire is started by phone charging
Fire Scenario – Foam Tumble Mat

- The peak heat release rate of the fire is 400 kW/m²
- The fire grows as a $t^2$ fire with an ultra-fast growth rate ($\alpha = 0.188$ kW/s²)
- 9 m² surface area
- One exit blocked
Occupants and Tenability

- Tenability conditions are similar to previous scenario
  - Visibility criteria is 10 m
- Occupants in Gym notice fire in 30 seconds and start movement in 60
  - Remainder start at 90 seconds
- Gym empties in 260 seconds
- Egress is complete in 388 seconds
Visibility

- 230 Seconds
- Two of three exits blocked
Visibility

- 360 Seconds
- 30 Seconds of exposure
Visibility

- Occupant conditions when tenability limit is reach in the gym
Issues

- Fire Suppression
  - System Leaks
  - Heavily loaded sprinklers

- Egress and Life Safety
  - Jammed Doors
  - Blocking pathways/exits

- Code Compliance
  - Space utilization
Conclusions

- Meets code in theory
  - Day to day operations could be improved
  - Lots of storage in the open
- Performance based analysis has revealed some issues with egress capacity
- Recommendations
  - Increased house keeping and greater vigilance when it comes to fire protection measures staff can take
  - Repair MNS and sprinkler system
  - Convert offices back into storage areas and move out of laundry area
  - Focus on regular preventative maintenance
  - Address occupancy levels to improve egress times
Questions