Bachelor Enlisted Quarters

Fire Protection Life Safety Analysis

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Bachelor Enlisted Quarters
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Applicable Criteria

Unified Facilities Criteria (UFC)
• UFC 3-600-01, UFC 3-600-10N, and UFC 4-021-01

http://www.wbdg.org/

National Fire Protection Association (NFPA)
• NFPA 13, NFPA 13R, NFPA14, NFPA 72, NFPA 80, NFPA 90A, and NFPA 101

http://www.nfpa.org/
Applicable Criteria

International Building Code (IBC)

Occupancy classifications per IBC used to determine the following:

- Type of Construction
- Allowable Floor Area
- Building Height Limitations
- Fire Resistance Ratings of Structural Elements
- Building Separation Distance

Life Safety Code (NFPA 101)

Occupancy classifications per NFPA 101 used to determine the following:

- Means of Egress
- Occupant Load and Egress Capacity
- Interior Finishes
- Fire Resistance Ratings of Non-bearing Partitions
Building Code Summary

Occupancy Classification
- Mixed Residential Group R-1 and Business Group B with Accessory Assembly Group A-3

Construction Type
- TYPE IIA

Fire Resistance Ratings
- Structural Frame: 1 Hour (IBC Tables 601)
- Exterior Bearing Walls: 1 Hour (IBC Tables 601)
- Interior Bearing Walls: 1 Hour (IBC Tables 601)
- Exterior Nonbearing Walls and Partitions: 1 Hour (IBC Tables 601)
- Interior Nonbearing Walls and Partitions: 0 Hours (IBC Tables 601 - see LSC)
- Floor Construction: 1 Hour (IBC Tables 601)
- Roof Construction: 1 Hour (IBC Tables 601)
- Exterior Exposure Protection: 0 Hours (IBC Tables 704.8)
Building Code Summary

Fire Resistance Ratings

- Floor/Ceiling Assembly - 3½” lightweight concrete slab on fluted metal deck
- Structural Steel - Spray Applied Fireproofing
- Concrete Masonry Unit (CMU) - Interior Bearing Walls
- Separation from Incidental Use Areas – See Life Safety Code Summary
# Building Code Summary

## Allowable Floor Area

- **Tabular Area per Story - Group A-3**: 15,500 sq-ft (IBC Table 503)
- **Tabular Area per Story - Group B**: 37,500 sq-ft (IBC Table 503)
- **Tabular Area per Story - Group R-1**: 24,000 sq-ft (IBC Table 503)
- **Area Increase - Frontage**: 18,000 sq-ft (IBC Section 506.2)
- **Area Increase - Sprinkler**: Not Permitted (IBC Sections 504.2 & 506.3)
- **Allowable Area per Story**: 42,000 sq-ft (IBC Section 506.1)
- **Total Allowable Area**: 126,000 sq-ft (IBC Section 506.4(2))

## Building Height and Number of Stories

- **Allowable Average Roof Height**: 60 ft (IBC Table 503 & Section 504.2)
- **Allowable Number of Stories**: 4 Stories (IBC Table 503 & Section 504.2)
- **Building Height and Number of Stories Increase - Sprinkler**: Not Permitted (IBC Sections 504.2 & 506.3)
Classification of Occupancy

Bachelor Enlisted Quarters (BEQ):
- Residential - New Hotel and Dormitory Occupancy (NFPA 101 Chapter 28)
- Incidental Business, Industrial, and Storage Use

Common Building:
- Mixed New Assembly and Business Occupancies (NFPA 101 Chapters 12 and 38)
- Incidental Industrial and Storage Use

Occupant Load

Determined based on occupant load factors in NFPA 101 Table 7.3.1.2
- Bachelor Enlisted Quarter (BEQ) 508 Occupants
- Common Building 235 Occupants
Life Safety Code Summary

Egress Analysis
- Travel Distance to Exits
- Common Path of Travel
- Dead-end Corridors
- Number of Exits
- Exit Discharge
- Remoteness of Exits
- Egress Capacity
- Door Hardware

Interior Finishes
- Wall and Ceiling Finishes
- Floor Finishes
- Upholstered Furniture

Illumination of Means of Egress
- Emergency Lighting
- Exit Signs

Portable Fire Extinguishers
- 4A:80B:C (10 lb ABC Dry Chemical)
- Cabinets (UFC 3-600-01)
Life Safety Code Summary

Fire and Smoke Resistive Construction

Subdivision of Living Units and Corridors (BEQ)
- Corridor and Living Unit Walls – ½ hour (NFPA 101)
- Based on Construction Type – 1 hour (IBC)
- Fire-rated Door Assemblies – 20 minutes

Protection of Vertical Openings
- Convenience Opening at 1ST and 2ND Floor Lobby – 1 hour fire barrier
- HVAC Shafts – 2 hour fire barrier (NFPA 90A)
- Elevator Shafts – 2 hour fire barrier (UFC 3-600-10N)

Protection of Stairs
- Stair Shafts – 1 hour fire barrier
- Outside Stairs – 1 hour fire barrier
- Fire-rated Door Assemblies – 60 minutes

8-inch Concrete Masonry Units (CMU block)
Gypsum Shaft Wall Assemblies
Concrete Floor/Ceiling Assemblies
Life Safety Code Summary

Fire and Smoke Resistive Construction

Incidental Use (IBC Table 508.2)

Hazardous Areas (NFPA 101)

• Electrical Rooms – 1 hour fire barrier or smoke partition
• Telecomm (NMCI) Rooms – 1 hour fire barrier (UFC 3-580-10)
• Mechanical Rooms – Smoke partition
• Storage Rooms – Smoke partition
• Laundry Rooms – 1 hour fire barrier
• Elevator Machine Room – 2 hour fire barrier (UFC 3-600-10N)
Life Safety Code Summary

Firestop Systems

• Approved firestop systems provided at all through penetrations and joints in fire resistive construction. (NFPA 101 Section 8.5.6)
Site Fire Protection

Fire Service Underground
- NFPA 24 – Thrust Blocks, Flush Test, Hydrostatic Test

Fire Hydrants
- NFPA 291 – Hydrant Flow Test, Flow Capacity Identification
- Within 350 feet of all portions of the building exterior
- Located within 3 to 7 feet of fire department access roads
- At least one located within 150 feet of the fire department connection

Fire Department Access Road
- NFPA 1 – Width, Vertical Clearance
- Within 33 feet of the building exterior; 50 feet of an entrance
Fire Protection Systems

Automatic Fire Sprinkler

- A combination automatic wet-pipe fire sprinkler and manual Class I wet standpipe system.
- NFPA 13 – Common Building
- NFPA 13R – Bachelor Enlisted Quarters
- NFPA 14 – Bachelor Enlisted Quarters
- UFC 3-600-01 and UFC 3-600-10N
Automatic Fire Sprinkler

Common Building – Wet-Pipe Fire Sprinkler System
Hydraulic System – Ordinary Hazard Group I

• Location: Area #1 – Laundry Room
• No. of Sprinklers: 30 Sprinklers
• Density: 0.15 GPM/SQ-FT
• Designed Area of Discharge: 3000 – QR 40% Reduction = 1800 SQ-FT
• System Demand:
  643 GPM @ 38 psi (at BOR CB)
  643 GPM @ 60 psi (at BOR Main Riser)
• Hose Allowance: 500 GPM (UFC 3-600-01)
**Available Water Supply**

**Hydrant Flow Test (NFPA 291)**

- **STATIC PRESSURE:** 100 PSI
- **RESIDUAL PRESSURE:** 73 PSI
- **FLOWING:** 2500 GPM
- **SYSTEM DEMAND:** 643 GPM (+500 GPM HOSE) AT 60 PSI
- **ESTIMATED FIRE FLOW AT 20 PSI:** 4494 GPM
Automatic Fire Sprinkler

Bachelor Enlisted Quarters – Wet-Pipe Fire Sprinkler System

- Hydraulic System – Light Hazard (NFPA 13R Design)
- Location: Area #2 – 4TH Floor Unit
- No. of Sprinklers: 4 Sprinklers
- Density: 0.05 GPM/SQ-FT
- Designed Area of Discharge: Residential Hall Sprinklers are calculated at 16FTx16FT spacing flowing 14 GPM @ 8.2 psi
- System Demand: 47 GPM @ 46 psi (at BOR Main Riser)
- Hose Allowance: 250 GPM
Automatic Fire Sprinkler

Bachelor Enlisted Quarters – Wet-Pipe Fire Sprinkler System
Fire Alarm / Mass Notification System

- Combination Fire Alarm Mass Notification System (Voice System)
  - NFPA 70 and NFPA 72
  - UFC 3-600-01 and UFC 4-021-01
- Edwards EST3-Sixty Control Panel
  - UL 2572 Listed Mass Notification
  - UL 864 Listed Fire Alarm
- Remote Power Supplies
- Auxiliary Power Supplies
- Local Operating Console (LOC)
- Digital Alarm Communicator Transmitter (DACT)
Fire Alarm / Mass Notification System

Initiating Devices on Signaling Line Circuit (SLC)
- Manual Pull Stations
- Smoke Detectors
- Duct Smoke Detectors
- Water Flow Switches
- Tamper Switches

Notification Appliances on Notification Appliance Circuit (NAC)
- Strobes
- Speakers
- Speaker/Strobes
- Sprinkler Bell
<table>
<thead>
<tr>
<th>SEQUENCE OF OPERATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MANUAL PULL STATION</strong></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td><strong>ANNUNCIATE ALARM CONDITION AT FIRE CONTROL PANEL &amp; REMOTE ANNUNCIATOR</strong></td>
</tr>
<tr>
<td><strong>ANNUNCIATE TROUBLE CONDITION AT FIRE CONTROL PANEL &amp; REMOTE ANNUNCIATOR</strong></td>
</tr>
<tr>
<td><strong>ANNUNCIATE SUPERVISORY CONDITION AT FIRE CONTROL PANEL &amp; REMOTE ANNUNCIATOR</strong></td>
</tr>
<tr>
<td><strong>ACTIVATE AUDIBLE/VISUAL ALARM SIGNAL</strong></td>
</tr>
<tr>
<td><strong>TRANSMIT ALARM SIGNALS TO GOVERNMENT MONITORING STATION</strong></td>
</tr>
<tr>
<td><strong>TRANSMIT TROUBLE SIGNALS TO GOVERNMENT MONITORING STATION</strong></td>
</tr>
<tr>
<td><strong>TRANSMIT SUPERVISORY SIGNALS TO GOVERNMENT MONITORING STATION</strong></td>
</tr>
<tr>
<td><strong>ACTIVATE SOUNDER BASE IN UNIT OF EVENT</strong></td>
</tr>
<tr>
<td><strong>ACTIVATE VISUAL SIGNAL IN ADA UNITS</strong></td>
</tr>
<tr>
<td><strong>PRIMARY ELEVATOR RECALL</strong></td>
</tr>
<tr>
<td><strong>ALTERNATE ELEVATOR RECALL</strong></td>
</tr>
<tr>
<td><strong>FIREFIGHTER'S SERVICE VISUAL INDICATOR (FLASHING)</strong></td>
</tr>
<tr>
<td><strong>FIREFIGHTER'S SERVICE VISUAL INDICATOR (STEADY)</strong></td>
</tr>
<tr>
<td><strong>SHUNT ELEVATOR POWER</strong></td>
</tr>
<tr>
<td><strong>SHUT DOWN ASSOCIATED AIR HANDLER</strong></td>
</tr>
<tr>
<td><strong>RELEASE ROLL UP DOOR</strong></td>
</tr>
</tbody>
</table>
Fire Alarm / Mass Notification System

Smoke Detection Within Living Units

- Detector on Sounder Base – Local Audible Notification Appliance
- Speaker Within Living Units
- Strobe (ADA Living Units)
Fire Alarm / Mass Notification System
Fire Alarm / Mass Notification System

Battery Calculations
- Standby: 60 hours
- Alarm: 15 minutes

Voltage Drop Calculations
- Point to Point Method
- Class A Circuits
Performance-Based Design
Performance-Based Design

Scope
• Evaluate the performance of the prescriptive-based design.

Goals and Objectives
• Improve the survivability of occupants within the living unit.
• Provide protection to occupants outside the living unit and module.
• Ensure sufficient evacuation time is provided, such that occupants are not exposed to instantaneous or cumulative untenable conditions from smoke, heat, or flames.

Stakeholders
• Department of Defense (DoD)
• Naval Facilities Engineering Command (NAVFAC)
• Marines
• Design-Build Team
Performance-Based Design

Occupant Description

- Able-Bodied Marine
  - Men and Women
  - 18-28 Years of Age
  - Strong Healthy Bodies
  - No Physical Disabilities
  - Highly trained individuals in many aspects of survival, including firefighting
  - High level of confidence
  - Trained to limit hesitation, doubt, confusion, or uncertainty
  - Strong mental conditioning
  - Strong awareness of surroundings
Performance-Based Design

Room Description – Typical BEQ Living Unit

- Automatic Fire Sprinkler Protection
- Automatic Smoke Detection & Fire Alarm
- Fire Resistive Construction
  - Gypsum/CMU Walls
  - Fire-rated Door Assembly (Corridor)
- Operable Window
- Four Exhaust Diffusers
  - One Exhaust Duct with Subduct at 2 hour fire-rated shaft
- One Supply Diffuser
  - One Supply Duct with Fire Damper at 2 hour fire-rated shaft
- Ambient Temperature
  - 20°C
- Occupant Load
  - 2 Marines
Performance-Based Design

Design Fire Development
- Peak Heat Release Rate (HRR)
  - 2630 kW
- Fire Growth
  - t-squared Fire
  - Slow Developing
- Sprinkler Controlled (Steady HRR)
  - Activation Temperature 68°C
  - ~196 Seconds
  - ~330 kW
Performance-Based Design

Sprinkler Response Time – DETACT
~196 seconds

- Ceiling Height
- Radial Distance
- Ambient Temperature
- Actuation Temperature
- Response Time Index
  - Fast Response
  - RTI 50 (m-s)\(^{1/2}\)
  - Thermal Lag
- Fire Growth (t-squared fire)
- Fire Growth Coefficient
  - Slow Developing
- Water Flow Switch
  - 60 Second Time Delay
Performance-Based Design

Smoke Detector Response Time – DETACT

~44 seconds

- Actuation Temperature
  - 7.2°C Temperature Rise per NFPA 72 Appendix B
- Response Time Index
  - Fast Response
  - Low RTI
  - No Thermal Lag
- Photoelectric-Type (Light Scattering)
- Sounder Base (Local Audible Notification)
- No Time Delay
- Evacuation within Living Unit begins
Performance-Based Design

Performance Criteria – Tenability Limits

- **Goals**
  - Prevent incapacitation or death
  - Reduce exposure to heat and toxic gases

- **Untenable Conditions**
  - Heat Exposure – heat stroke, skin and respiratory tract burns
    - 60°C
  - Products of Combustion – carbon monoxide (CO), hydrogen cyanide (HCN), low oxygen (O2), and carbon dioxide (CO2)
    - Dependent on concentration levels and exposure time
    - 6000 ppm CO
  - Visibility within Corridor – reduced walking speed and eye irritation
    - 5 meters
Performance-Based Design

Room of Origin
• Typical BEQ Living Unit as described previously

Location of Design Fire
• Twin Lift-Top Bed with Mattress, Two Drawers, and Storage Headboard
• Polyurethane foam spring mattress with PVC ticking material
Performance-Based Design

Ignition Source

- The leading causes of fires in these facilities are as follow:

- **Cooking equipment**
  - Fires: 81%
  - Civilian Injuries: 41%
  - Direct Property Damage: 6%

- **Intentional**
  - Fires: 40%
  - Civilian Injuries: 9%
  - Direct Property Damage: 7%

- **Smoking materials**
  - Fires: 18%
  - Civilian Injuries: 12%
  - Direct Property Damage: 5%

- **Heating equipment**
  - Fires: 17%
  - Civilian Injuries: 14%
  - Direct Property Damage: 3%

- **Playing with heat source**
  - Fires: 2%
  - Civilian Injuries: 1%
  - Direct Property Damage: 0%

- **Candles**
  - Fires: 17%
  - Civilian Injuries: 10%
  - Direct Property Damage: 2%

- **Electrical distribution and lighting equipment**
  - Fires: 12%
  - Civilian Injuries: 12%
  - Direct Property Damage: 2%
Performance-Based Design

Fire Scenarios

• Fire Scenario No.1
  • All prescriptive requirements in place and functioning properly

• Fire Scenario No.2
  • Additional ventilation introduced to the room of origin through an open window

• Fire Scenario No.3
  • An unreliable or malfunctioning fire-rated door (open door) at corridor
  • A reduction in the number of available means of egress
Performance-Based Design

Predicting Flashover

- McCaffrey, Quintiere, and Harkleroad (MQH)
  - Area of Opening
  - Height of Opening
  - Total Area of Room

- Flashover is not anticipated based upon sprinkler controlled fire (steady)

<table>
<thead>
<tr>
<th></th>
<th>Closed Door Open Window</th>
<th>Open Door Closed Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRR at Flashover, $Q$ (kW)</td>
<td>1521</td>
<td>2005</td>
</tr>
<tr>
<td>Room Temperature at Flashover, $T$ ($^\circ$C)</td>
<td>435</td>
<td>518</td>
</tr>
<tr>
<td>Time to Reach Flashover, $t$ (sec)</td>
<td>421</td>
<td>483</td>
</tr>
<tr>
<td>Area of Opening, $A_0$ (m²)</td>
<td>1.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Height of Opening, $H_0$ (m)</td>
<td>1.2</td>
<td>2.1</td>
</tr>
<tr>
<td>Total Area of Room, $A_T$ (m²)</td>
<td>131</td>
<td>131</td>
</tr>
</tbody>
</table>
Performance-Based Design

FDS Heat Release Rate (HRR)
Performance Based Design

FDS Smoke Detector
Activation ~ 50 seconds
(~44 seconds DETACT)
Performance-Based Design

FDS Sprinkler Activation ~160 seconds (~196 seconds DETACT)
Performance-Based Design

FDS Sprinkler Activation ~160 seconds (~196 seconds DETACT)
Performance-Based Design

FDS Heat Exposure within Living Unit at 120 seconds
Performance-Based Design

FDS Heat Exposure at Corridor Door at 140 seconds
Performance-Based Design

FDS Heat Exposure within Corridor at 360 seconds
Performance-Based Design

FDS CO Exposure within Living Unit at 120 seconds (~60 ppm)
Performance-Based Design

FDS CO Exposure within Living Unit at 360 seconds (~400 ppm)
Performance-Based Design

FDS CO Exposure within Corridor at 360 seconds (~300 ppm)
Performance-Based Design

FDS Visibility within Living Unit at 160 seconds
Performance-Based Design

FDS Visibility within Corridor at 240 seconds
Performance-Based Design

FDS Visibility within Corridor at 300 seconds
Performance-Based Design

Summary of FDS Results

- Smoke Detector Response Time \(~50\ \text{seconds}\) (local alarm active)
- Sprinkler Response Time \(~160\ \text{seconds}\) (60 second time delay – flow switch)
  - Building Evacuation Alarm \(~220\ \text{seconds}\)
- Exposure within Living Unit
  - Temperatures at 2 meters begin to exceed 60°C \(~120\ \text{seconds}\)
  - CO exposure did not exceed 6000 ppm
  - Visibility at 2 meters begins to exceed 5 meters \(~160\ \text{seconds}\)
- Exposure within Corridor
  - Temperatures at corridor door begin to exceed 60°C \(~140\ \text{seconds}\)
    - Exit near living unit becomes unavailable
  - Temperatures at 2 meters begin to exceed 60°C \(~360\ \text{seconds}\)
  - CO exposure did not exceed 6000 ppm
  - Visibility at 2 meters begins to exceed 5 meters \(~240\ \text{seconds}\)
  - Visibility at 1 meter begins to exceed 5 meters \(~300\ \text{seconds}\)
Performance-Based Design

Estimated Evacuation Time (NFPA and SFPE Handbooks)

- Egress Component Analysis
  - Clear Width
  - Boundary Layer
- Calculated Flow (flow rate passing egress component)
  - Most Restrictive Egress Component – Corridor Doors
- Travel Distance and Speed
Performance-Based Design

Estimated Evacuation Time (NFPA HB)

- Egress Component Analysis

### Estimated Evacuation Time – BEQ

<table>
<thead>
<tr>
<th>Occupant Load Above 1st Floor</th>
<th>Number of Exits</th>
<th>$F_c$ Calculated Flow (occ./min)</th>
<th>Travel Time Between Floors (min)</th>
<th>Estimated Evacuation Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>368 Occupants</td>
<td>11</td>
<td>$44 \times 11 = 484$</td>
<td>0.36</td>
<td>1.12 (67 sec.)</td>
</tr>
</tbody>
</table>

### Estimated Evacuation Time – Common Building

<table>
<thead>
<tr>
<th>Occupant Load Above 1st Floor</th>
<th>Number of Exits</th>
<th>$F_c$ Calculated Flow (occ./min)</th>
<th>Travel Time Between Floors (min)</th>
<th>Estimated Evacuation Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>196 Occupants Main Level</td>
<td>4</td>
<td>$(112 \times 3) + 44 = 380$</td>
<td>N/A</td>
<td>0.52 (31 sec.)</td>
</tr>
<tr>
<td>41 Occupants Mezzanine</td>
<td>1</td>
<td>38</td>
<td>0.21</td>
<td>1.29 (77 sec)</td>
</tr>
</tbody>
</table>
Performance-Based Design

Estimated Evacuation Time – Pathfinder

- ~64 Seconds
Performance-Based Design

Conclusion

- Prescriptive-Based Design
  - Bachelor Enlisted Quarters designed and constructed in accordance with applicable criteria.
- Performance-Based Design
  - Improved the survivability of occupants within living unit.
    - Smoke Detection and Sprinkler Response Time
  - Provided protection to occupants outside living unit and module.
    - Fire Resistive Construction
  - Evacuation Time vs. Tenability Limits
    - 220 seconds (Evacuation Alarm) + 65 seconds (Evacuation Time)
    - 15 seconds before visibility limit is exceeded in corridor.
Questions