# Fire Alarm Intelligibility and Occupant Notification Systems

# Who am I?

- John Swanson
- Deputy State Fire Marshal (MN)
- Previous member – IBC Fire Safety Committee
- NFPA 72 Technical Committee
- Instructor for International Code Council and National Fire Academy
- Appointed by MN Gov. Mark Dayton to Board of Architecture & Engineering (2013)


MINNESOTA PUBLIC SAFETY
STATE FIRE MARSHAL
EST. 1905

# Fire & Life Safety Interests…

- Fire Alarm Systems

# Fire & Life Safety Interests…

- Fire Alarm Systems


- School Fire Safety

# Fire & Life Safety Interests…

- Fire Alarm Systems


- School Fire Safety

- Autism/Fire & Life Safety

# Miscellaneous Information

- Restrooms
- Breaks
- Roster
- Informal
- Participate
- Please ask questions


"You're not allowed to use the sprinkler system to keep your audience awake."

# Introductions

- Please introduce yourself:
  - Employer
  - Years of experience in the industry?
  - Years of experience dealing with/reviewing fire alarm systems?


# Agenda

- Introductions
- NFPA 72
  - 2010 → 2013 → 2016
- Emergency Voice Alarm Communication
  - IFC
  - Voice Intelligibility

# Terminology

- Intelligibility – The quality or condition of being intelligible [NFPA 72 (16): 3.3.134]
- Intelligible-Capable of being understood; comprehensible; clear [NFPA 72 (16) 3.3.135]

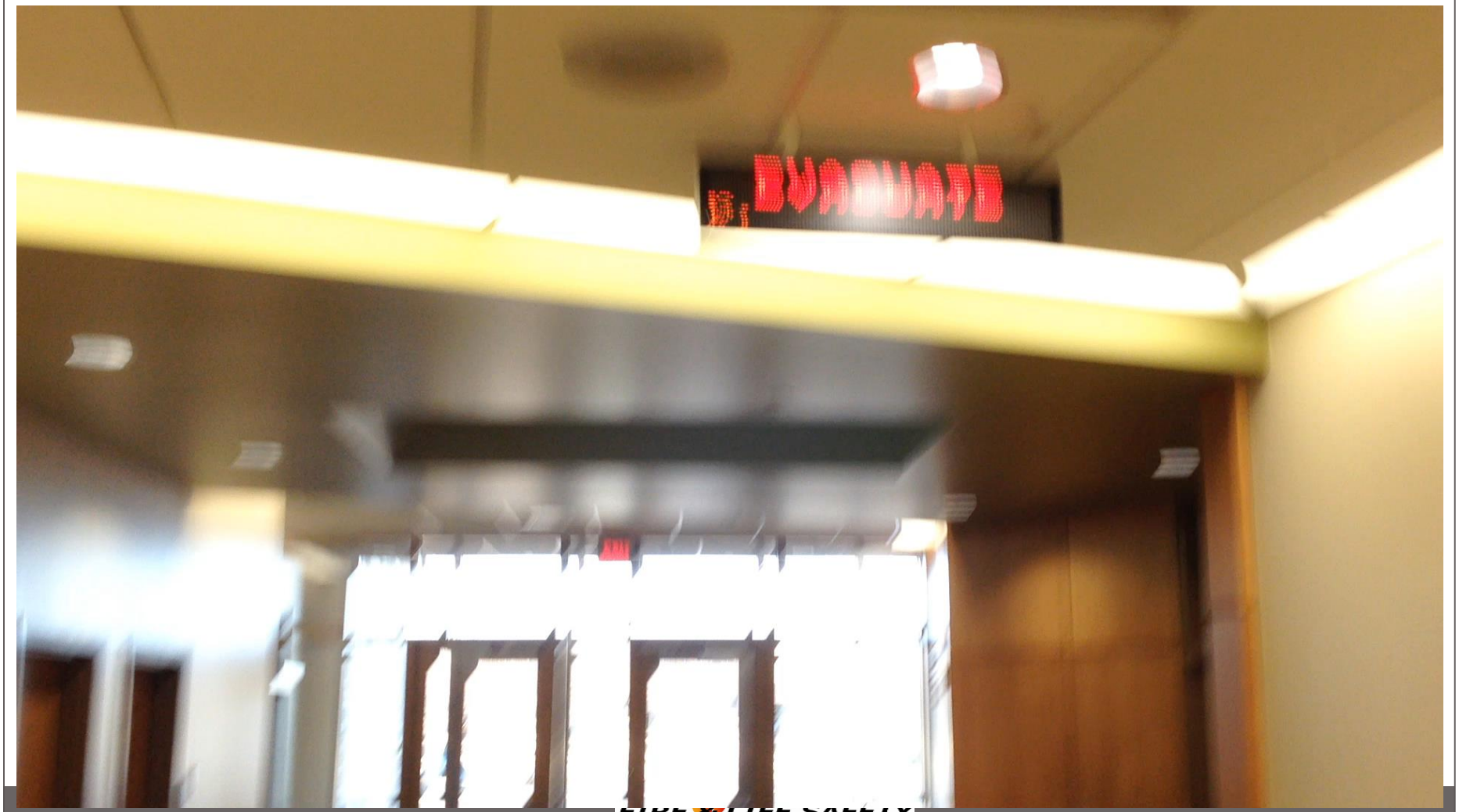
# Emergency Voice Alarm

- Emergency voice alarm communication
  - System is multi-functional and can be used for various purposes including:
    - Emergency/Safety messages (severe weather, lockdown, etc.)
    - General paging
    - Background music

# Emergency Voice Alarm

- Ancillary functions must not impair the required operation or function of the ECS system
  - ECS must take precedence over general paging, background music, etc.
  - Some systems allow remote access
    - Remote access must not impair normal system functions

# Emergency Voice Alarm



# Emergency Voice Alarm

- IBC/IFC require an emergency voice alarm communication system in the following occupancies:
  - Assembly > 1,000 people

# Emergency Voice Alarm

- IBC/IFC require an emergency voice alarm communication system in the following occupancies:
  - High-Rise Buildings

# Emergency Voice Alarms

- IBC/IFC allow the means of egress sizing (exit width) to be reduced when building is protected with an automatic sprinkler system and an emergency voice alarm communication system.
- Many design professionals are taking advantage of this new section.

# Section 1005.3.1-Stairways

- The capacity of the means of egress shall be calculated by multiplying the occupant load by 0.3 inch/occupant.
  - Exception: For other than H and I-2, multiply the occupant load by 0.2 when building is protected with an automatic sprinkler system and an emergency voice alarm communication system is provided.

# Section 1005.3.2-Other Egress Components

- IBC/IFC Section 1005.3.2 – The capacity of the means of egress shall be calculated by multiplying the occupant load by 0.2 inch/occupant.
  - Exception: For other than H and I-2, multiply the occupant load by 0.15 when building is protected with an automatic sprinkler system and an emergency voice alarm communication system is provided.

# Occupant Notification

- Emergency voice/alarm communication
  - System must be designed/installed in accordance with NFPA 72 (chapters 18 & 24)
  - Voice instructions must be approved by the fire code official
    - Default will produce pre-programmed voice instructions
    - Alternate languages may be necessary

# Chapter 18 – Changes

- 18.4.10 Voice Intelligibility
- 18.4.10.1 Acoustically distinguishable spaces (ADS) are to be determined during design of a voice notification system.
- 18.4.10.2 ADS shall be identified by the system designer as needing or not needing voice intelligibility.

# Audibility vs. Intelligibility

- Audibility – Can you hear the signal?

- Intelligibility – Can you understand the signal?

# System Classifications

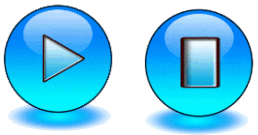
- One-Way Emergency Communications Systems:
  - In-building ECS systems
  - In-building mass notification systems
  - Wide-area mass notification systems
  - Distributed recipient mass notification systems

# System Classifications

- Two-way emergency communication systems:
  - Two-way in building wired emergency communication systems
  - Two-way radio communication enhancement systems
    - See IFC section 510 in 2012 IFC
  - Areas of refuge systems
  - Elevator and stairway communication systems

# System Classifications

- Voice evacuation messages shall be preceded and followed by a minimum of two cycles of the temporal 3 pattern (FIRE)
  - Two cycles of the temporal 4 pattern for CO
  - In areas where sleeping accommodation is provided, the tone must be low frequency in the sleeping area.



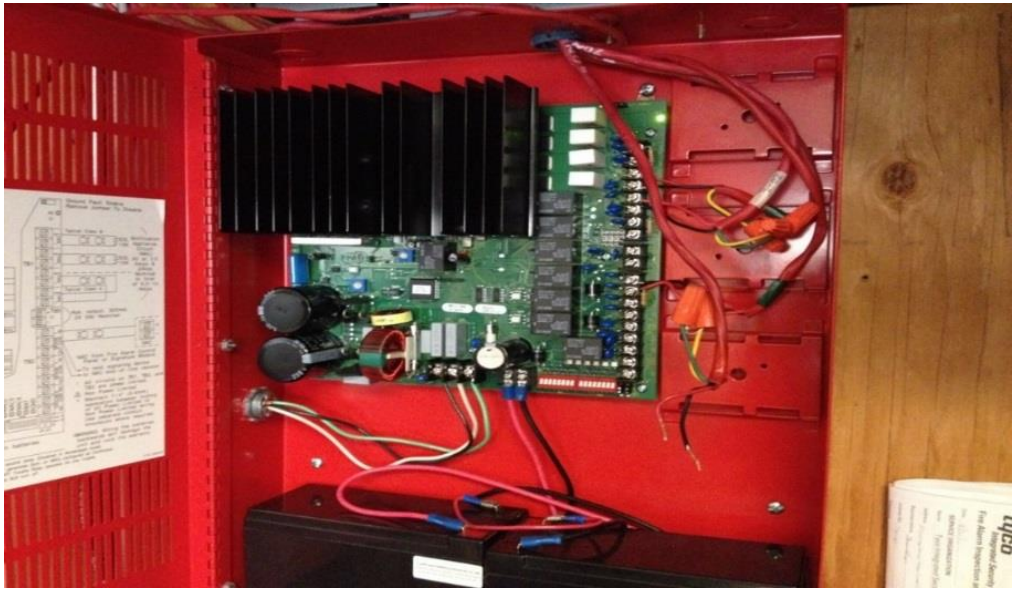
3000 Hz

# Operating Controls

- Controls for the ECS system shall be in a location approved by the AHJ

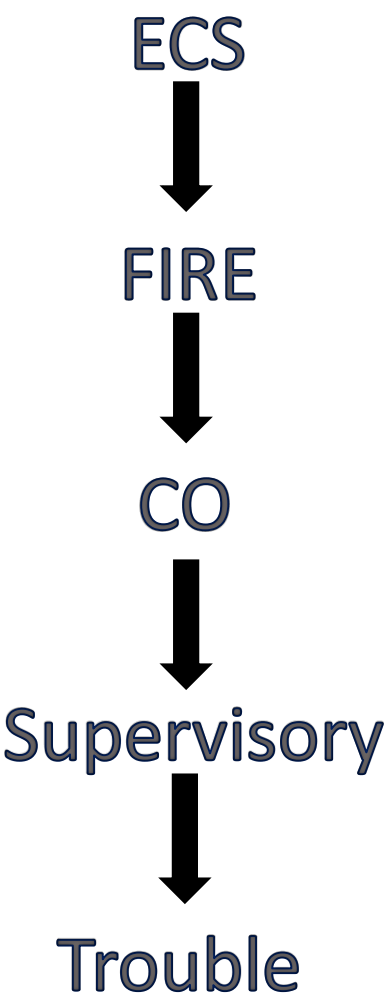
# Operating Controls

- Controls shall be located in a secure area OR the panel must be kept locked to prevent unauthorized access and tampering



# Signal Priority

- Emergency communication systems, when approved, can take precedence over all other signals
  - Change occurred in 2010 edition of NFPA 72
  - Considered a significant change to how FIRE signals are treated in buildings



# Voice Alarm Messages

- Voice messages shall not be required to meet the audibility requirements for public mode signaling, but shall meet intelligibility requirements.
  - Chapter 14 does not require voice signals to be measured for audibility.
  - Sound produced from a voice system is modulated and a meaningful measurement cannot be determine.

# Voice Alarm Systems

- Areas that may not require voice intelligibility (18.4.10.2.1):
  - Private office
  - Private bathrooms;
  - Mechanical/elevator equipment rooms or similar areas;
  - Elevator cars
  - Kitchen/storage rooms/closets

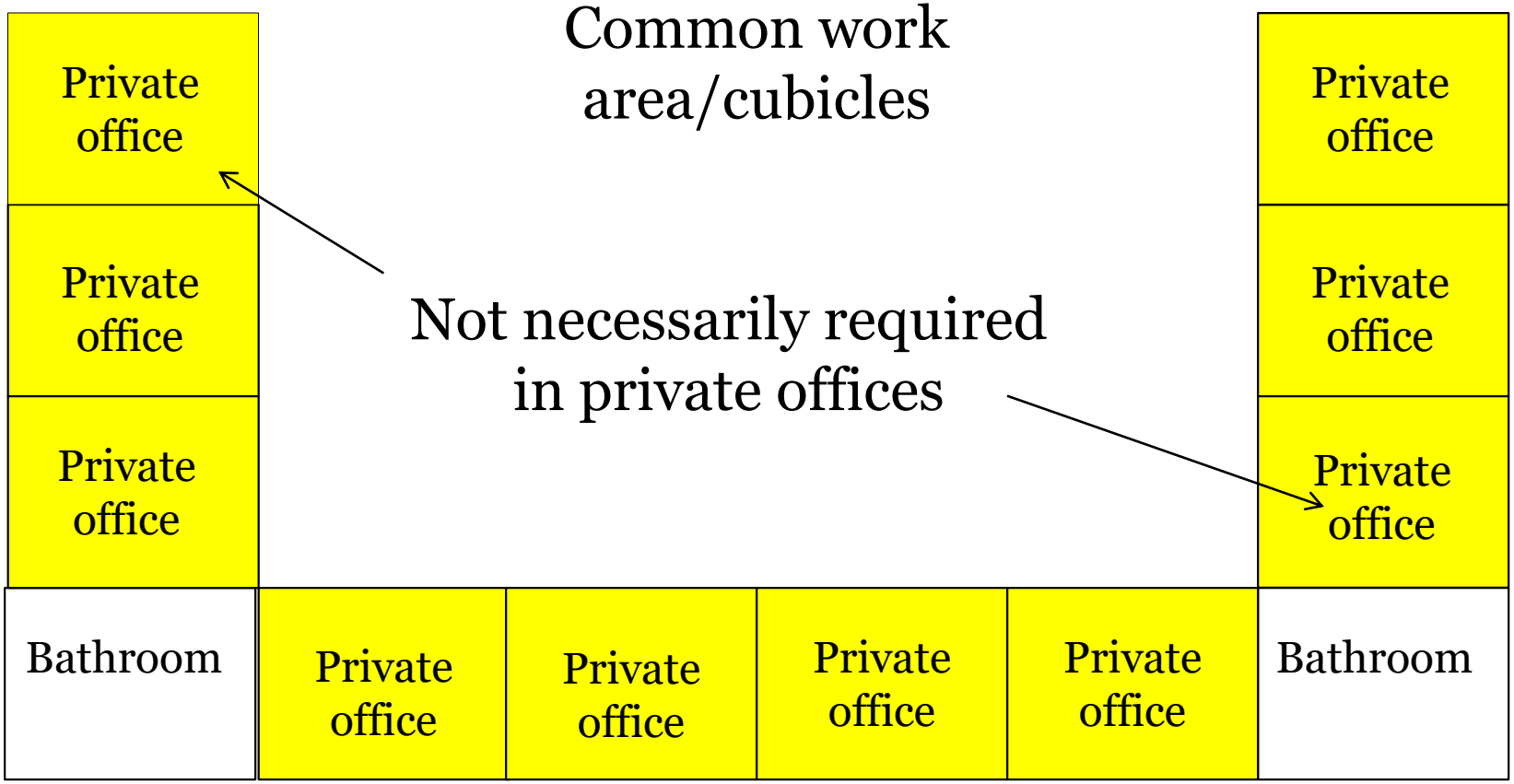
# Voice Alarm Systems-Office Building

<table>
<tr><td>Private office</td><td colspan="4" rowspan="3">Common work area/cubicles<br><br>All areas (common area, private office, and bathrooms are considered an “acoustically distinguishable space” or ADS.</td><td>Private office</td></tr>
<tr><td>Private office</td><td>Private office</td></tr>
<tr><td>Private office</td><td>Private office</td></tr>
<tr><td>Bathroom</td><td>Private office</td><td>Private office</td><td>Private office</td><td>Private office</td><td>Bathroom</td></tr>
</table>

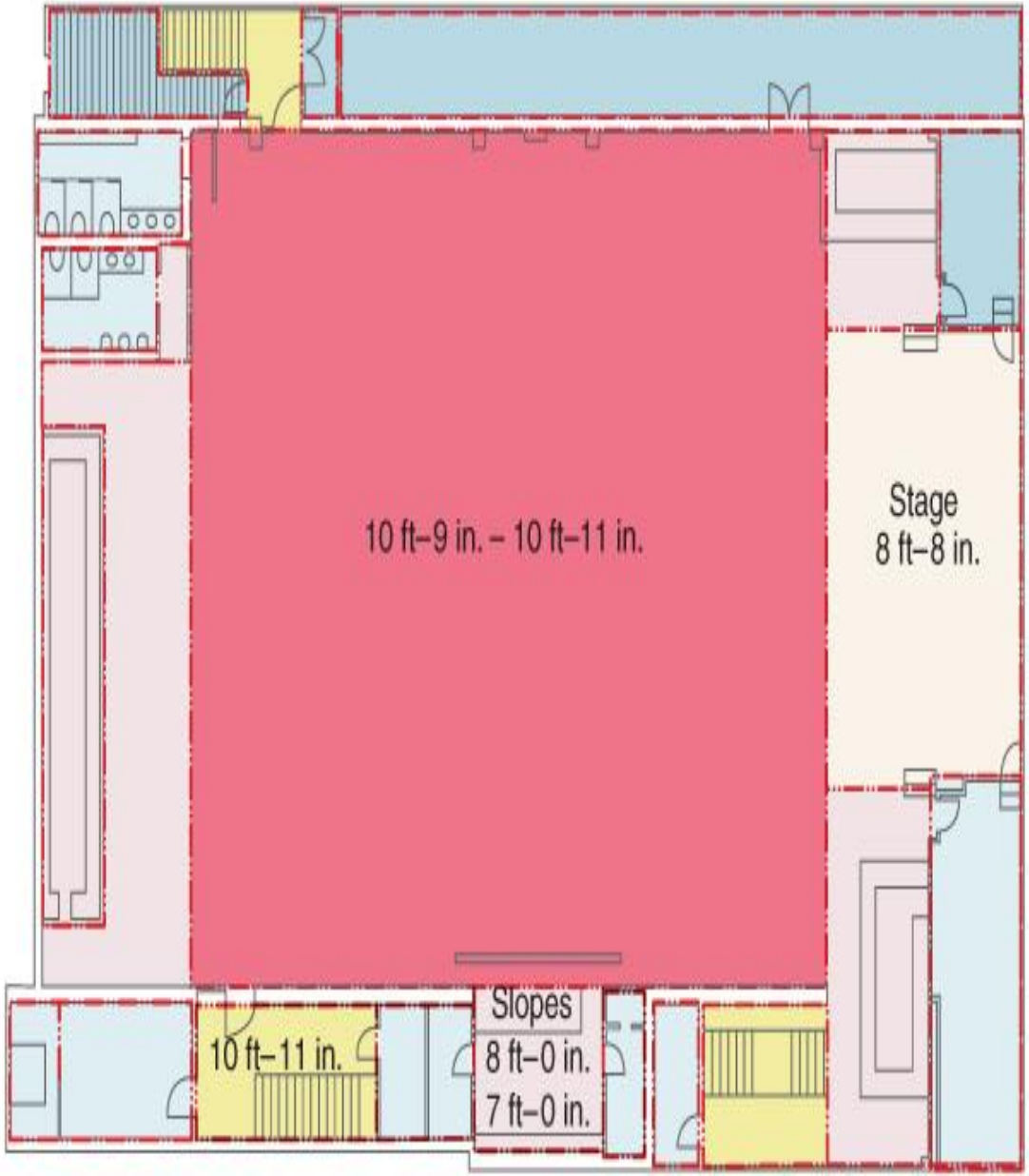
# Voice Alarm Systems-Office Building

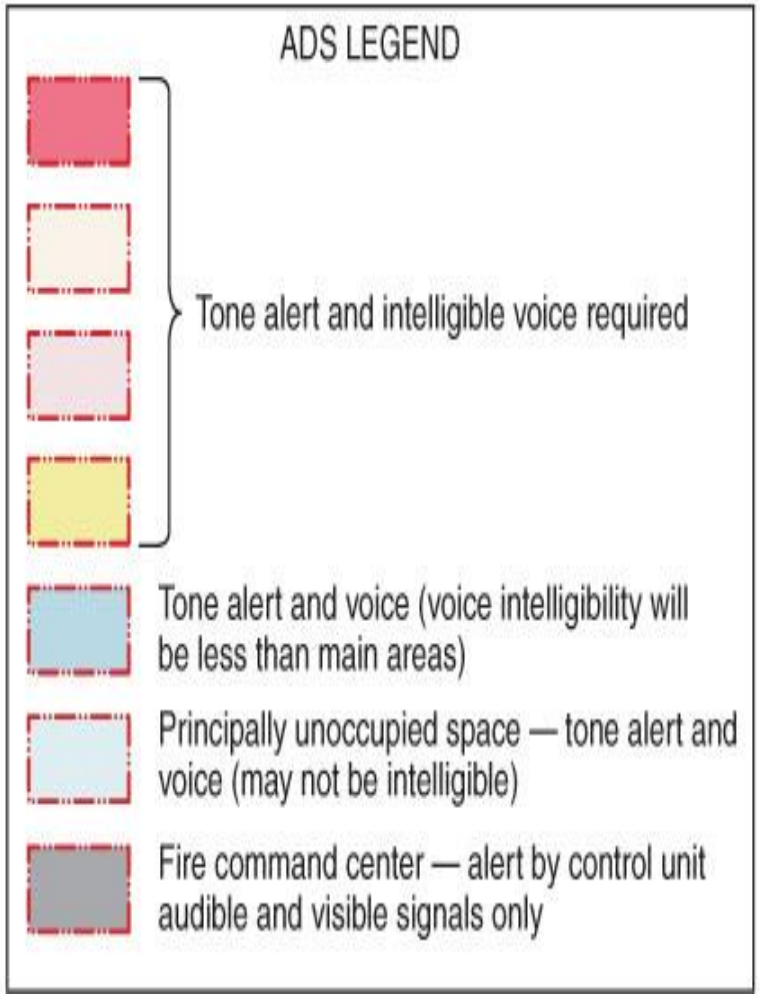
| | | | | | |
|---|---|---|---|---|---|
| Private office | Common work area/cubicles<br>**Intelligibility Required** | | | | Private office |
| Private office | | | | | Private office |
| Private office | | | | | Private office |
| Restroom | Private office | Private office | Private office | Private office | Restroom |

# Voice Alarm Systems-Office Building



# Voice Alarm – Nightclub Example



# Voice Alarm Systems

- Voice systems, when required shall reproduce pre-recorded, synthesized, or life messages with voice intelligibility (NFPA 72: 18.4.10)
- Where no listed loudspeaker exists to achieve intelligibility, non-listed loudspeakers are permitted (24.3.1.2, 2016 edition)

# Design Considerations


# Design Considerations

- Acoustically distinguishable spaces (ADS) can be separated by zone or a portion thereof
- ADS can be distinguished by walls, different acoustics in a space, or the use characteristics of the space such as ambient noise levels

# Design Considerations

- For smaller spaces in a building, usually defined as 400 sq. ft. or less, walls will define the ADS
- For spaces with moveable walls or partitions, each space shall be designed as a separate ADS

# Design Considerations

- For loud areas, typically areas with an ambient sound pressure level of 85 dBA or higher, voice intelligibility may not be possible.
- Other approved notification methods may be necessary
  - Strobes
  - Graphic signs

# Design Considerations

- It is necessary for the designer to consult with the architect and interior designer to know what design features will be used in each ADS
- High ceiling areas may need to be treated differently than lower ceiling areas

# Design Considerations

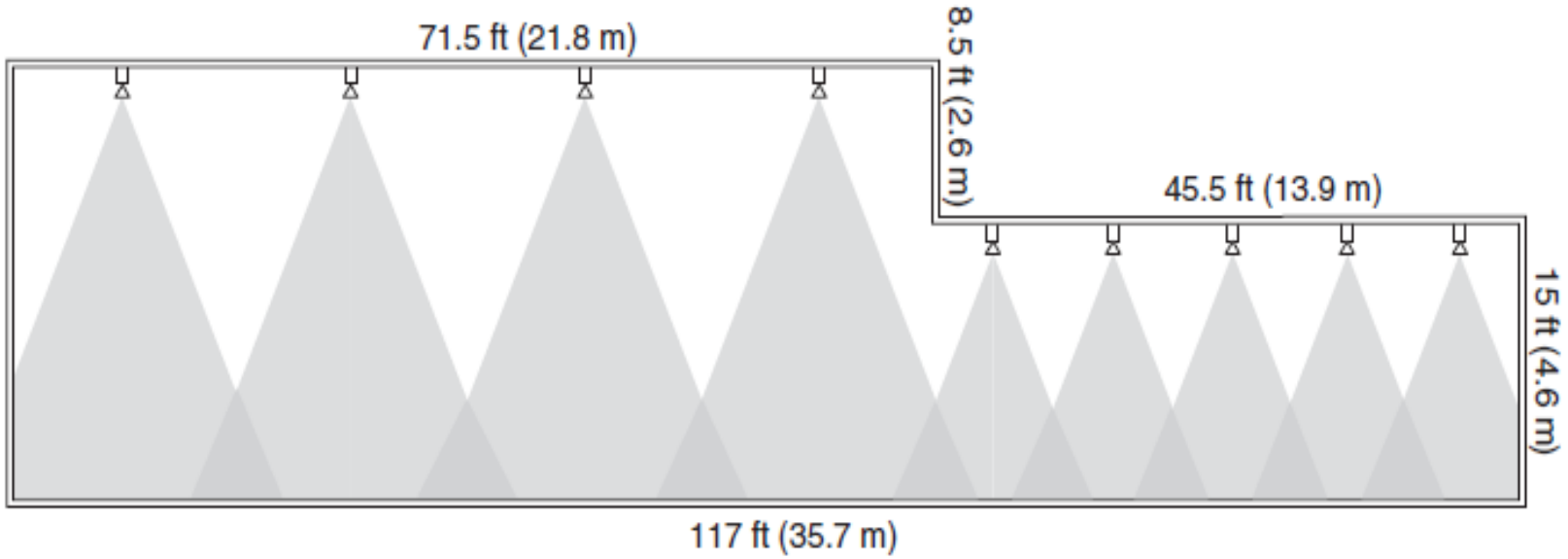



**FIGURE D.2.3.1.7** Illustration Demonstrating Effect of Ceiling Height. *(Source: R. P. Schifiliti Associates, Inc.)*

# Design Considerations

- ADS should be consistent in size and furnishings
- A change in materials/furnishings will likely separate one ADS from another
  - Change from carpet to hard tile
  - Consistent sound sources (decorative waterfalls, large glassed in areas, etc.)
- Corridors and stairwells will typically be individual ADS

# Design Considerations

- Certain ADS may require higher bandwidth speakers in order to achieve intelligibility
  - Large open areas can be challenging to maintain intelligibility and avoid reverberation
  - Reverberation (voice messages bouncing off objects in the room) can be very problematic for voice intelligibility.

# Design Considerations

- From a design perspective, use caution using higher bandwidth speakers unless necessary to overcome certain acoustical or ambient conditions
  - Higher bandwidth speakers will require more power
  - This will increase the amplifier, wire size and power supply requirements ($$$)

# Design Considerations

- Intelligibility is considered acceptable when 90% of the measurement locations within each ADS have:
  - Speech transmission index (STI) of not less than 0.45
  - Average STI of not less than 0.50
  - Another method is known as the Common Intelligibility Scale (CIS)

# Design Considerations


Speech Intelligibility may be expressed by a single number value. Two scales are most commonly used: STI and CIS

# Design Considerations

- Buildings or areas in buildings with high ambient noise levels may be impossible to provide intelligibility
- Areas where sound pressure level exceeds 90 dBA, speech transmission and intelligibility can be challenging
- Consider alternate communication methods such as signs, displays or horn/strobes
- Remember…the intent is to provide occupant notification

# Speech Intelligibility Testing

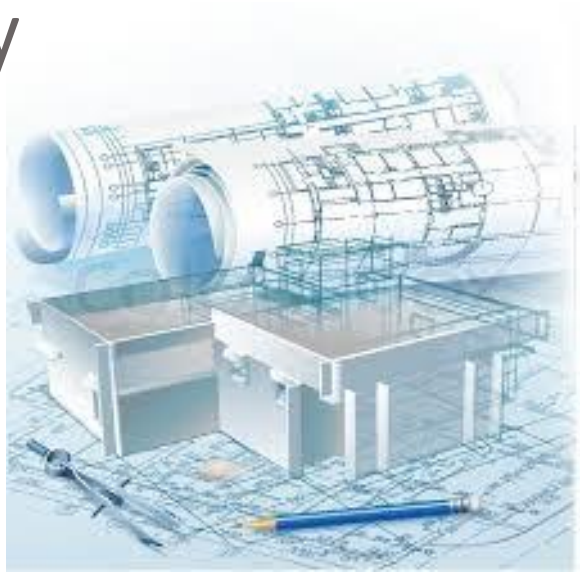
- Two methods for testing speech intelligibility:
  - Subject (human) based testing
  - Instrument based testing

# Speech Intelligibility Testing

- Construction in the building or area being tested should be completed to receive accurate intelligibility readings
- Construction and interior design features WILL have an impact on sound and speech transmission
  - Lack of ceiling tiles in place
  - Carpet on walls

# Speech Intelligibility Testing

- For additional design and testing considerations, please see Annex D in NFPA 72
  - Annex D – Speech Intelligibility



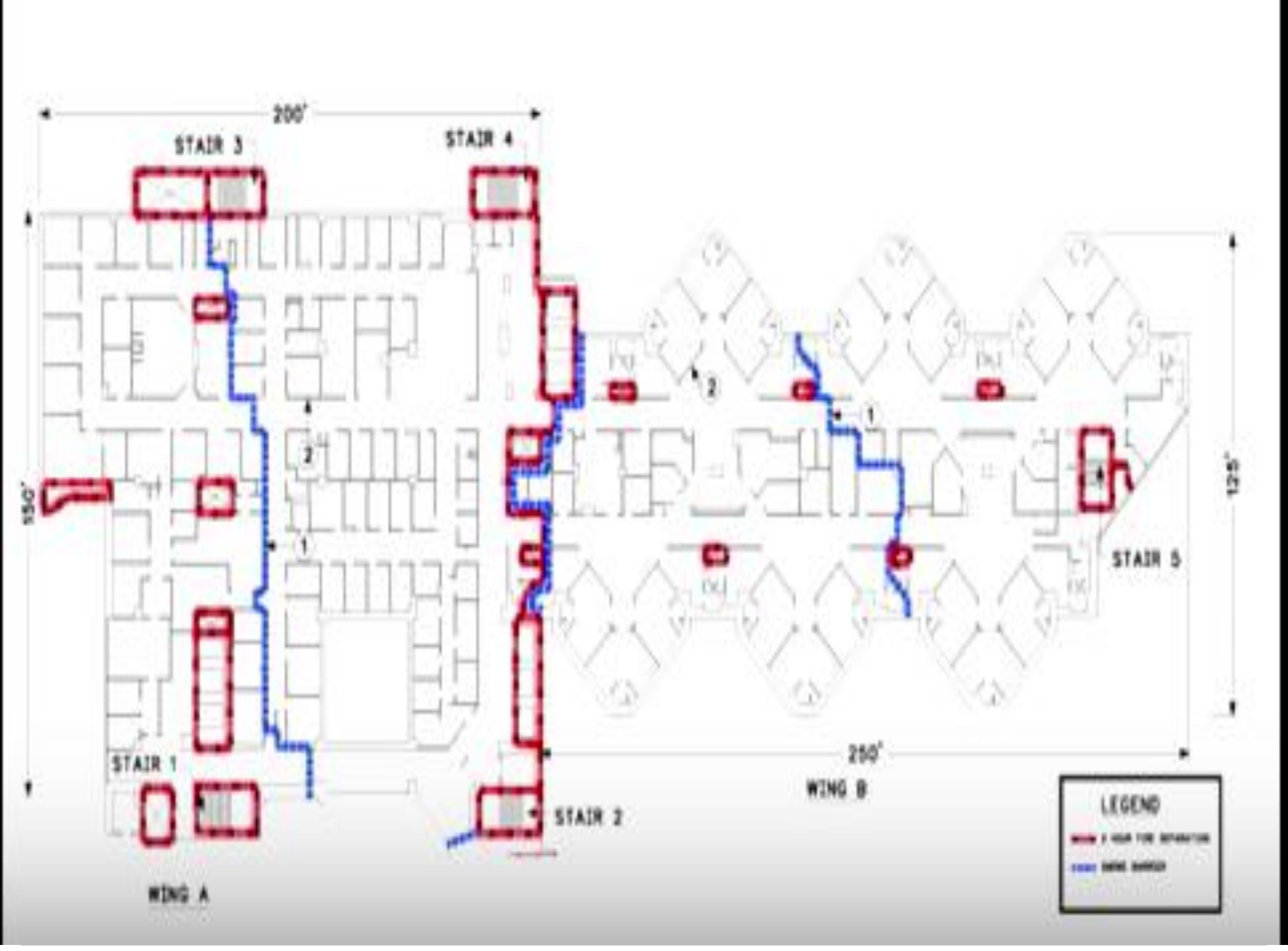
# Questions ???

# Occupant Notification Systems



# Notification Signal

- The type of notification signal must match the evacuation scheme for the facility:
  - Total evacuation,
  - Zoned evacuation,
  - Occupant relocation,
  - Defend in place strategies.
- Notification zones shall be consistent with the emergency response or evacuation plan for the protected premises.


200'
STAIR 3
STAIR 4
150'
125'
STAIR 5
250'
STAIR 1
STAIR 2
WING A
WING B
LEGEND

# Chapter 18 – Notification Appliances

- The use of the T3 pattern shall only be used where evacuation of the building or relocation inside the building is desired.
- The T3 signal shall not be used where occupants are practicing defend-in-place.

# Notification Signals - Types


- Public Mode (most common):
  - General evacuation signal,
- Private Mode:
  - Attendant signal:
    - No evacuation signal,
    - Usually a coded voice message or chimes.

# Chapter 18 – Notification Appliances

- 18.3.3 Physical Construction
  - 18.3.3.2 Notification appliances used for other purposes than fire cannot say “FIRE” on them.


# Audible Alarm Synchronization

- Section 18.4.2.4-The three-pulse temporal pattern must be synchronized throughout the evacuation zone.
  - Synchronization is necessary to preserve the temporal 3 pattern.

# Sound Levels – Public Mode

- 15 dBA above average ambient sound; or,
- 5 dBA above average ambient sound level lasting 60 seconds
- If ambient sound level is greater than 105 dBA, visual notification appliance is required,

# Sound Levels – Public Mode

- 110 dBA is maximum allowed

***TABLE A.18.4.3*** *Average Ambient Sound Level According to Location*

| ***Location*** | ***Average Ambient Sound Level (dBA)*** |
|---|---|
| Business occupancies | 55 |
| Educational occupancies | 45 |
| Industrial occupancies | 80 |
| Institutional occupancies | 50 |
| Mercantile occupancies | 40 |
| Mechanical rooms | 85 |
| Piers and water-surrounded structures | 40 |
| Places of assembly | 55 |
| Residential occupancies | 35 |
| Storage occupancies | 30 |
| Thoroughfares, high-density urban | 70 |
| Thoroughfares, medium-density urban | 55 |
| Thoroughfares, rural and suburban | 40 |
| Tower occupancies | 35 |
| Underground structures and windowless buildings | 40 |
| Vehicles and vessels | 50 |

# Protective Covers

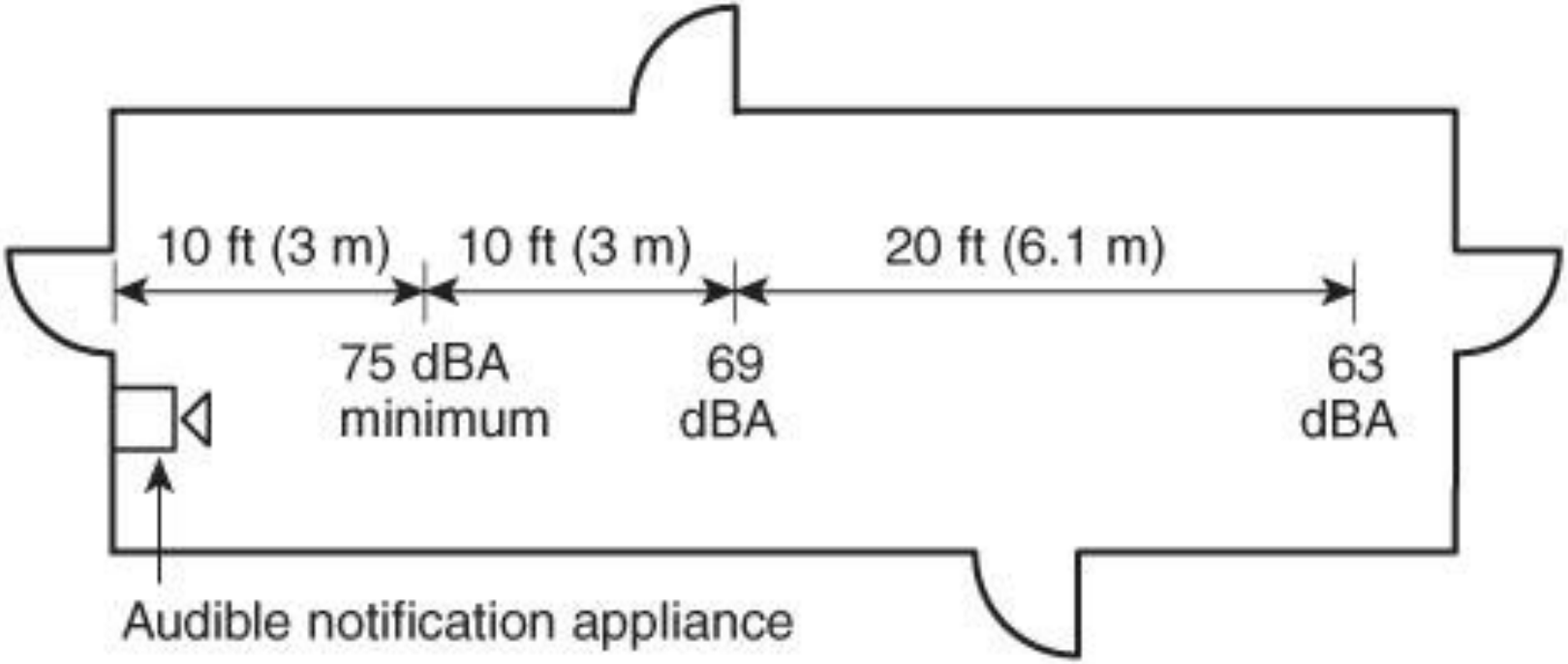
- Protective covers used with notification appliances must be listed for the particular device.
  - Unlisted equipment can degrade the effectiveness of the audible signal or visible strobe.

# The Distance Effect on Sound Pressure Level

| Distance from Appliance | Sound Pressure Level |
| --- | --- |
| 10 ft. | nameplate value |
| 20 ft. | - 6 dBA |
| 40 ft. | - 12 dBA |
| 80 ft. | - 18 dBA |

# The Distance Effect on Sound Pressure Level

- Rule of Thumb is the output of an audible appliance is reduced by 6 dB if the distance between the appliance and the listener is doubled.



# The Distance Effect on Sound Pressure Level

## Speaker Rated at 84 dBA at 10 feet

10 ft. → 84 dBA

20 ft. → 78 dBA

40 ft. → 72 dBA

80 ft. → 66 dBA

# The Walls and Doors Effect on Sound

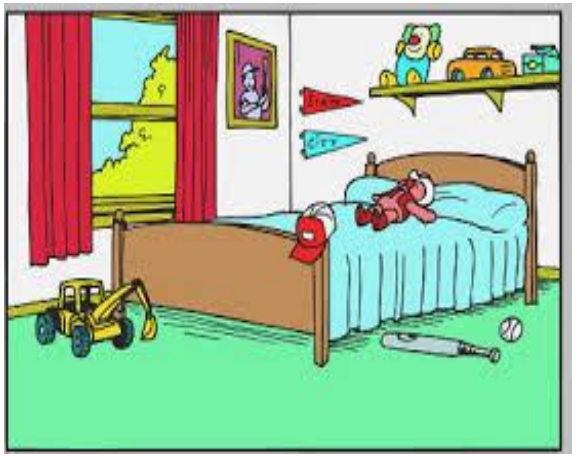
## The Effect of Walls and Doors on Sound Transmission

| | Avg. Loss | Typical Range |
|---|---|---|
| Open Door | 8 dBA | 4-12 dBA |
| Closed Door | 17 dBA | 10-24 dBA |
| Sealed Door | 28 dBA | 22-34 dBA |
| Stud Wall | 39 dBA | 32-42 dBA |

Source: NIST Handbook 119 “Quieting: A Practical Guide to Noise Control”: D.A. Robinson, Univ. of MA, “Sound Transmission Loss From Corridors to Rooms: Implications for Locating Fire Alarm Sounders”

# Sound Levels – Sleeping Areas

- Section 18.4.5
- 15 dBA above ambient average sound level,
- 5 dBA above maximum sound level (lasting 60 seconds), or
- 75 dBA minimum measured at pillow level
- Whichever is greater.
- This will usually require an appliance in the dwelling unit.



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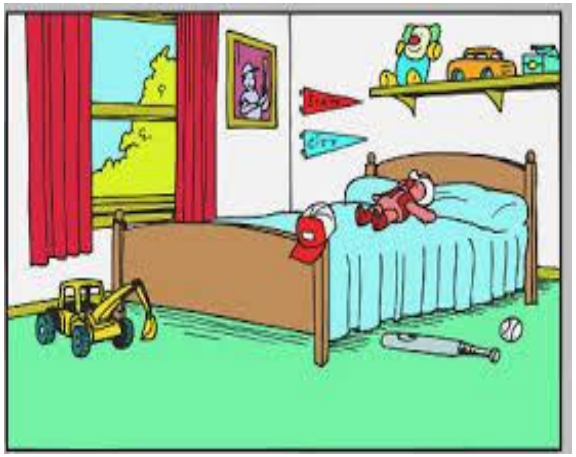
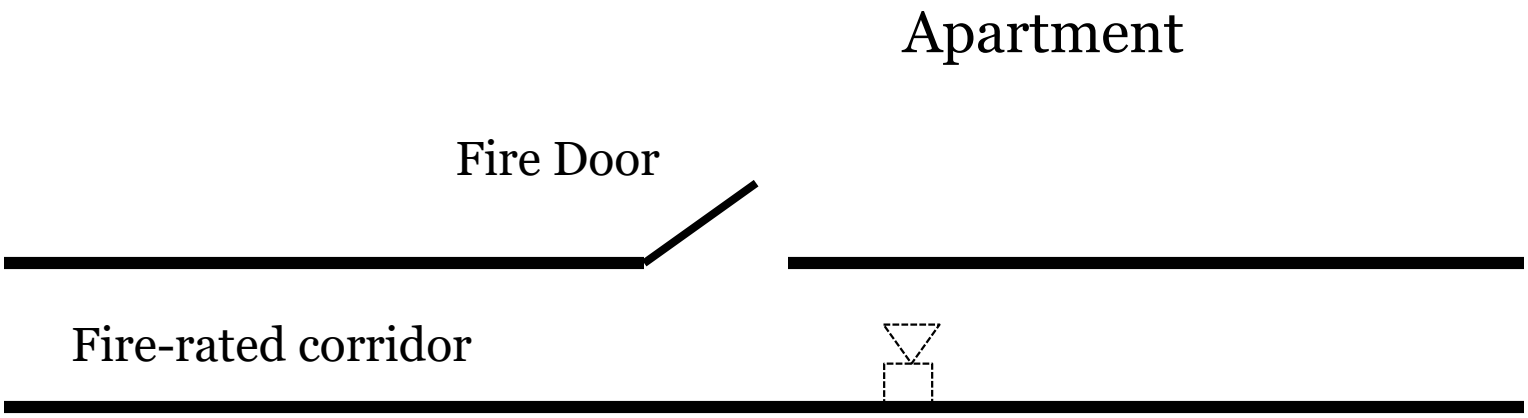


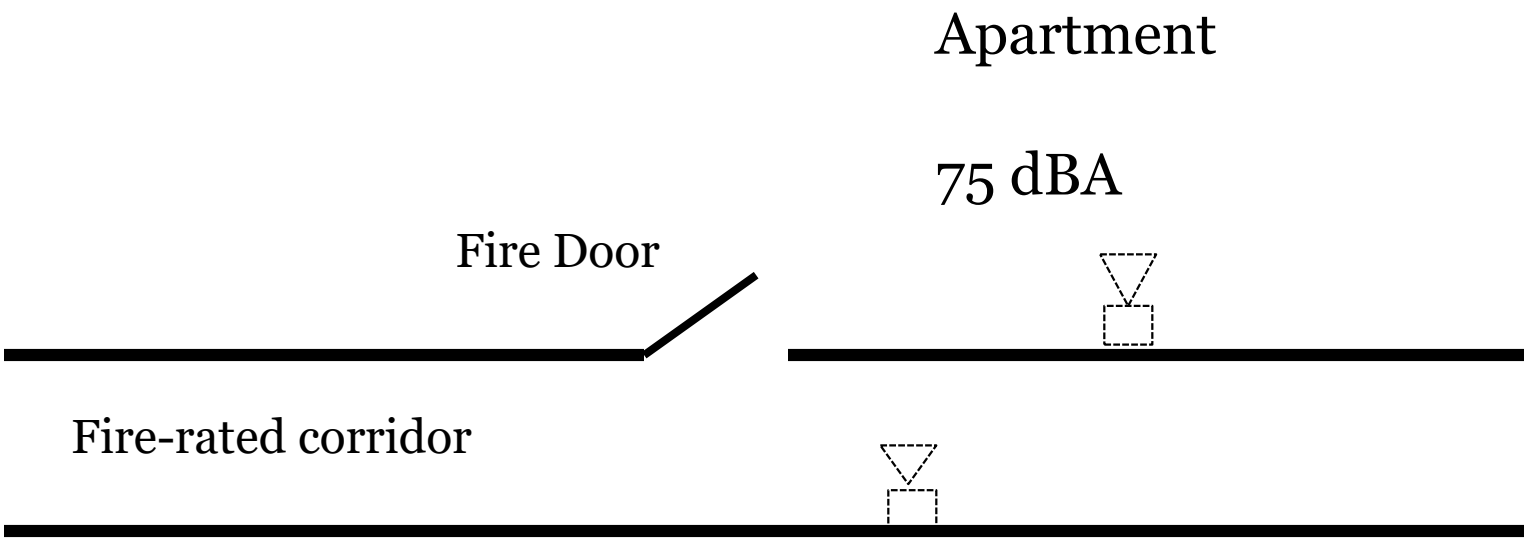
# Alert Tones in Sleeping Areas

- Same for public and private operating mode
- 70 dBA min. 1999
- 75 dBA since 2002
- Remember, NFPA 72 is <u>not</u> a retroactive document
  - It is necessary to research the standard in effect at the time

# Alert Tones in Sleeping Areas-INCORRECT

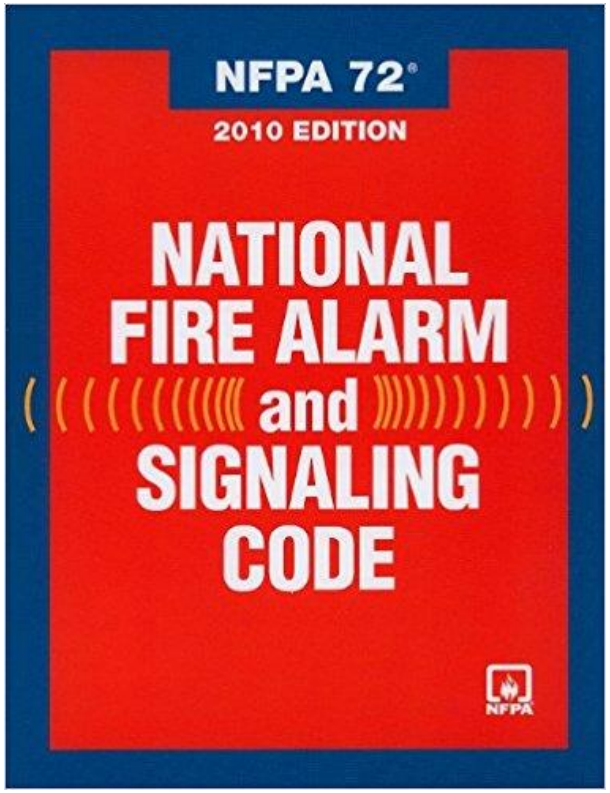


# Alert Tones in Sleeping Areas-CORRECT



# Low Frequency Notification

- Requirement for low frequency notification first found in NFPA 72, 2010 edition.
  - Effective date of 1/1/14
  - Effective upon adoption for smoke alarms (chapter 29)



# Low Frequency Alert Tone for Awakening

- 520 Hz Square Wave
  - Systems (Chapter 18) – effective January 1, 2014
  - Household (Chapter 29) – effective on adoption


520 Hz Sq. Wave  3000 Hz

## Waking Effectiveness: High Risk Groups

**-School aged children:** Thirteen percent of civilian fire fatalities in residential buildings were under the age of 10 [1]

**-Alcohol/drug impaired:** It's suspected that over 27% of civilian fatalities in residential buildings are linked to alcohol, drug or chemical influence [1]

**-People with hearing loss:** More than 34.5 million people in the US are hard of hearing [2]

Sources:


1. USFA, Civilian Fire Fatalities in Residential buildings 2008-2010 Report
2. Working Effectiveness of alarms for adults who are hard of hearing, NFPA Dorothy Bruck; Ian Thomas, June 2007

# Why the change?

- Background:
  - Study done by Victoria (Australia) University
  - Study tried to determine why people were not waking to the fire alarm signal
  - Nearly 50% of the participants with mild to severe hearing loss slept through the 3000 Hz smoke alarm signal
  - The higher 3000 Hz signal also was not as effective at waking children

# Why the change?

- Background:
  - In the 1970s and early 1980s standard horns were replaced with low-current and more efficient high frequency horns.
  - When this happened some stated they couldn't hear the newer alarms as well.
  - Both devices measured 85 decibels at 10 feet;
  - The issue was the frequency, not the sound output.

# Why the change?

- People with hearing loss have trouble hearing high frequencies than low.
- The 520 Hz square wave signal awoke nearly 100% of the participants in the test.
- Low frequency signal is 6-10 times more effective than the high frequency devices

# Why the change?

- Due to the results from the Victoria University study, in 2006, the Fire Protection Research Foundation (FPRF) funded two additional research studies on the issue
- Focus was on the effectiveness of the 3000 Hz tone on high risk groups
  - Waking effectiveness of alarms and adults who are hard of hearing
  - Waking effectiveness of alarms for the alcohol impaired

THE FIRE PROTECTION RESEARCH FOUNDATION
Research in support of the NFPA mission

# FPRF Study

- The studies tested six signals:
  1. 400 Hz Square wave signal
  2. 520 Hz Square wave signal
  3. 3000 Hz pure tone (standard)
  4. Bed shaker (under mattress)
  5. Pillow shaker
  6. Strobe light in T-3 pulse



# FPRF Conclusions

- The low frequency signal with a fundamental frequency of 520 Hz is the most effective signal for waking people.
  - Low frequency signal woke 92% between 55 dBA and 75 dBA
  - 3000 Hz signal woke 56% between 55 dBA and 75 dBA
- The low frequency signal is superior bed/pillow shakers and strobe lights.

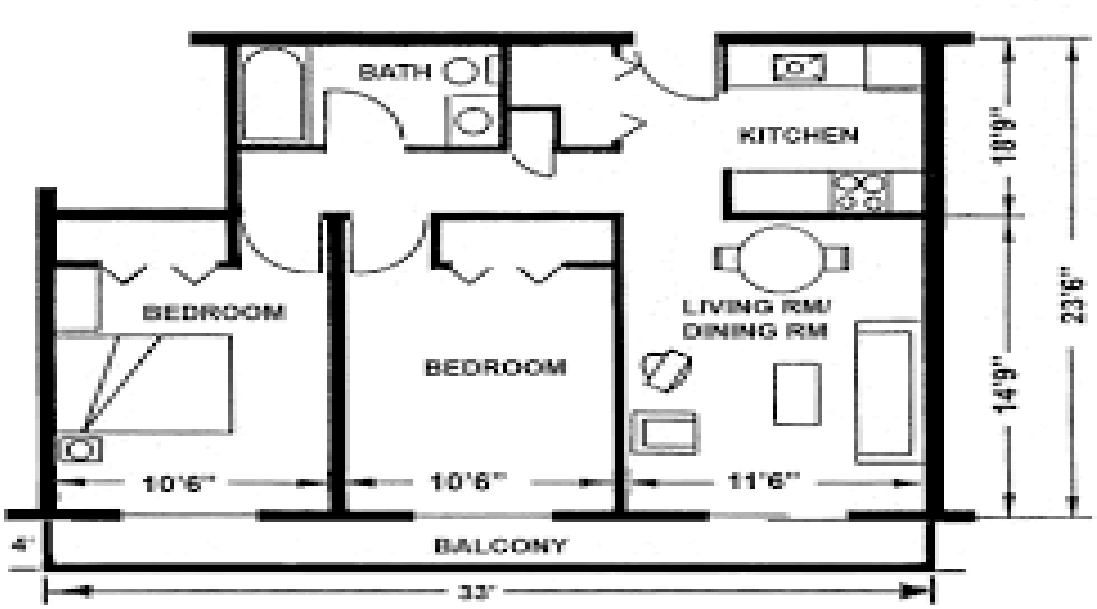
# Sounder Base Activation

# In what occupancies will this apply?

- Low frequency sounders will be required for new fire alarm system installations in:
  - Hotel/motels
  - Assisted living
  - Dormitories
  - Apartments
- Not required in:
  - Hospitals*
  - Nursing homes
  - Prisons
  - Child Care Centers

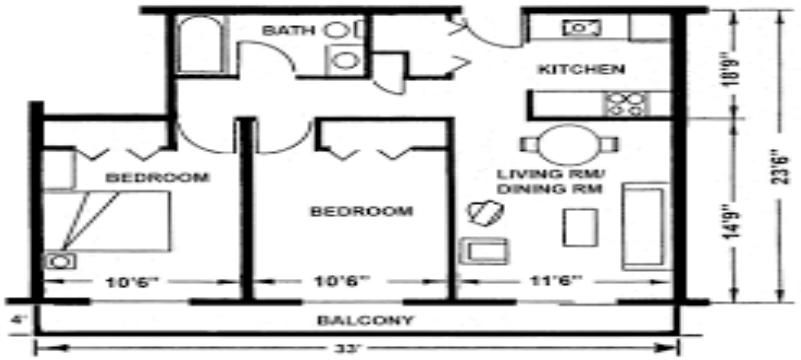
# Question ???

- Are low frequency sounders required in the bedroom and the common areas of a dwelling/sleeping unit or just the bedrooms?



# Question ???

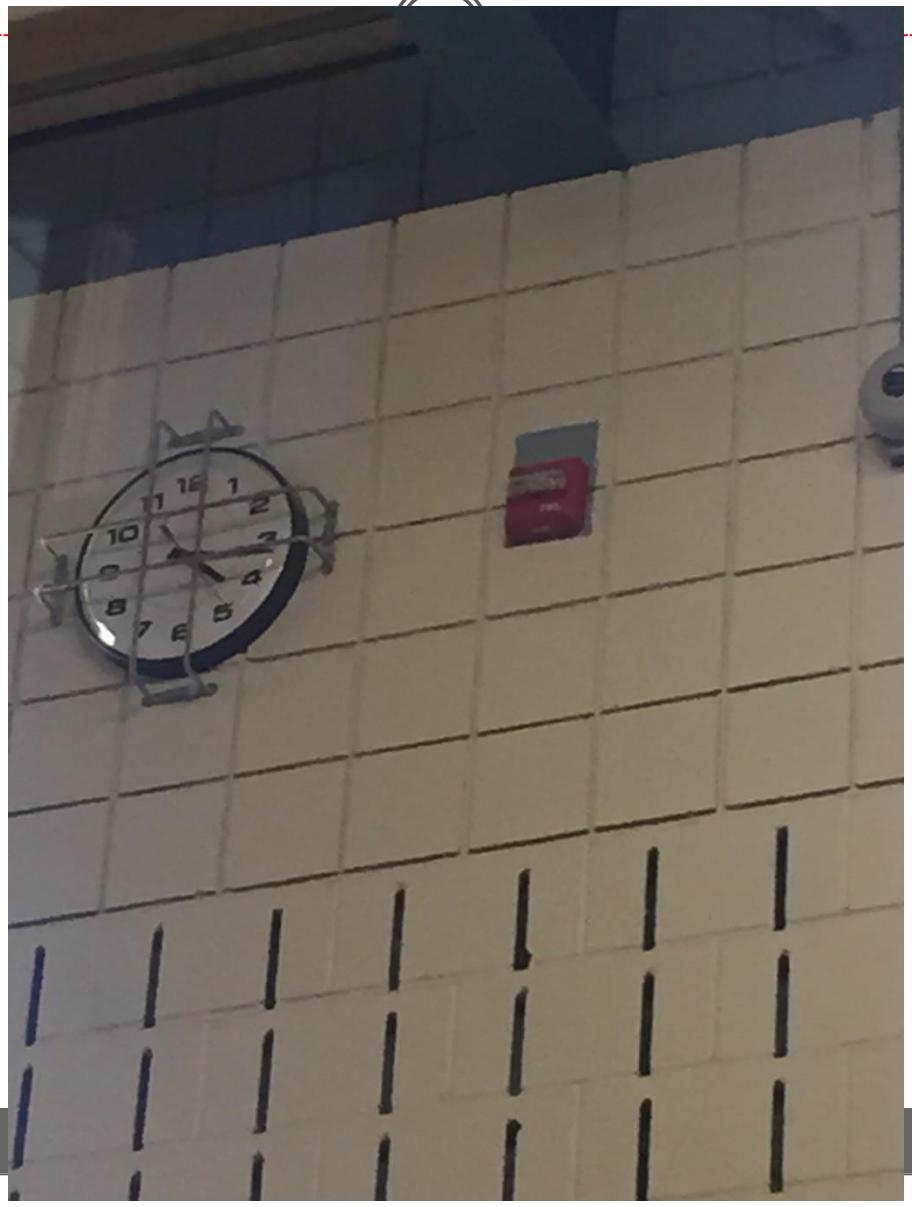
- A.18.4.5.2 (13)-The intent of this section is to require the low frequency signal in areas used for sleeping and areas that might reasonably be used for sleeping.
- This would require low frequency in the bedroom and the living room area.



# Notification Appliances-Visible

- Section 18.5.4-Wall mounted visible appliances shall be not less than 80 inches and not greater than 96 inches above the finished floor
- Performance-based design option for spacing and location
  - Must be designed by a licensed engineer
- Number and placement depends on the room size and light output of the strobe

# Notification Appliances-Visible



# Notification Appliances-Visible

# Notification Appliances-Visible

# Visible Appliances-Wall Mounted

***TABLE 18.5.5.4.1(a)*** *Room Spacing for Wall-Mounted Visible Appliances*

| Maximum Room Size | | Minimum Required Light Output [Effective Intensity (cd)] | |
|---|---|---|---|
| ft | m | One Light per Room | Four Lights per Room (One Light per Wall) |
| 20 × 20 | 6.10 × 6.10 | 15 | NA |
| 28 × 28 | 8.53 × 8.53 | 30 | NA |
| 30 × 30 | 9.14 × 9.14 | 34 | NA |
| 40 × 40 | 12.2 × 12.2 | 60 | 15 |
| 45 × 45 | 13.7 × 13.7 | 75 | 19 |
| 50 × 50 | 15.2 × 15.2 | 94 | 30 |
| 54 × 54 | 16.5 × 16.5 | 110 | 30 |
| 55 × 55 | 16.8 × 16.8 | 115 | 30 |
| 60 × 60 | 18.3 × 18.3 | 135 | 30 |
| 63 × 63 | 19.2 × 19.2 | 150 | 37 |
| 68 × 68 | 20.7 × 20.7 | 177 | 43 |
| 70 × 70 | 21.3 × 21.3 | 184 | 60 |
| 80 × 80 | 24.4 × 24.4 | 240 | 60 |
| 90 × 90 | 27.4 × 27.4 | 304 | 95 |
| 100 × 100 | 30.5 × 30.5 | 375 | 95 |
| 110 × 110 | 33.5 × 33.5 | 455 | 135 |
| 120 × 120 | 36.6 × 36.6 | 540 | 135 |
| 130 × 130 | 39.6 × 39.6 | 635 | 185 |

NA: Not allowable.

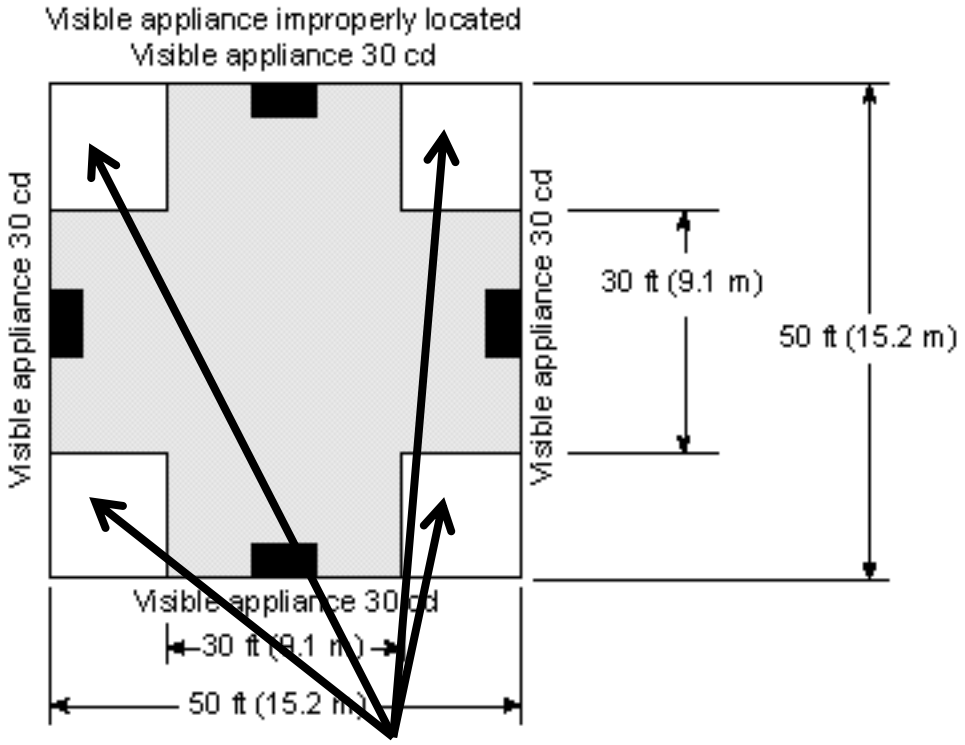
# Visible Appliances-Ceiling Mounted

*TABLE 18.5.5.4.1(b) Room Spacing for Ceiling-Mounted Visible Appliances*

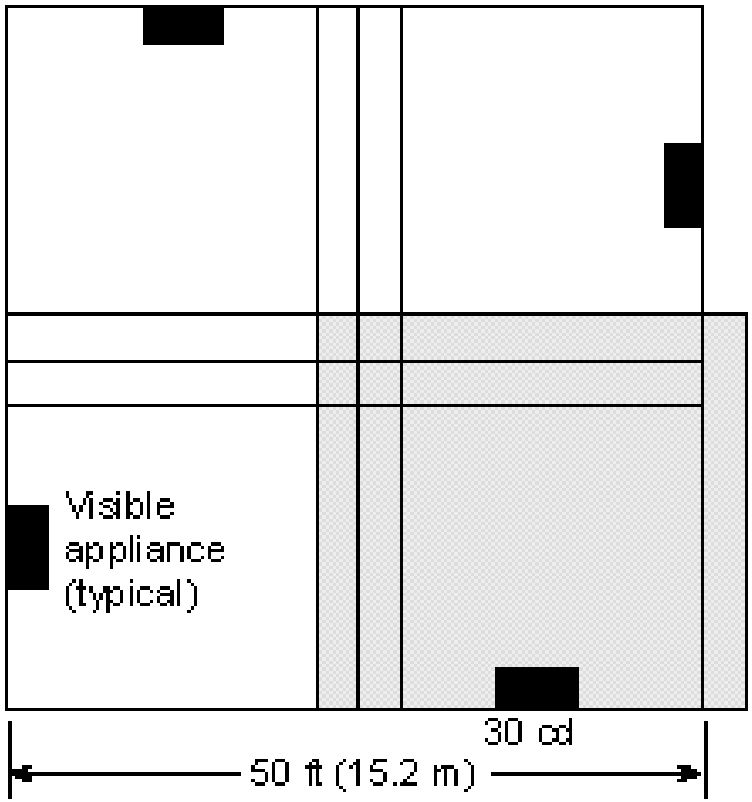
| Maximum Room Size | | Maximum Lens Height* | | Minimum Required Light Output (Effective Intensity); One Light (cd) |
|---|---|---|---|---|
| ft | m | ft | m | |
| 20 × 20 | 6.1 × 6.1 | 10 | 3.0 | 15 |
| 30 × 30 | 9.1 × 9.1 | 10 | 3.0 | 30 |
| 40 × 40 | 12.2 × 12.2 | 10 | 3.0 | 60 |
| 44 × 44 | 13.4 × 13.4 | 10 | 3.0 | 75 |
| 20 × 20 | 6.1 × 6.1 | 20 | 6.1 | 30 |
| 30 × 30 | 9.1 × 9.1 | 20 | 6.1 | 45 |
| 44 × 44 | 13.4 × 13.4 | 20 | 6.1 | 75 |
| 46 × 46 | 14.0 × 14.0 | 20 | 6.1 | 80 |
| 20 × 20 | 6.1 × 6.1 | 30 | 9.1 | 55 |
| 30 × 30 | 9.1 × 9.1 | 30 | 9.1 | 75 |
| 50 × 50 | 15.2 × 15.2 | 30 | 9.1 | 95 |
| 53 × 53 | 16.2 × 16.2 | 30 | 9.1 | 110 |
| 55 × 55 | 16.8 × 16.8 | 30 | 9.1 | 115 |
| 59 × 59 | 18.0 × 18.0 | 30 | 9.1 | 135 |
| 63 × 63 | 19.2 × 19.2 | 30 | 9.1 | 150 |
| 68 × 68 | 20.7 × 20.7 | 30 | 9.1 | 177 |
| 70 × 70 | 21.3 × 21.3 | 30 | 9.1 | 185 |

*This does not preclude mounting lens at lower heights.

# Incorrect




# Correct




# Gaps in strobe coverage

# Visible Strobes –Sleeping Areas

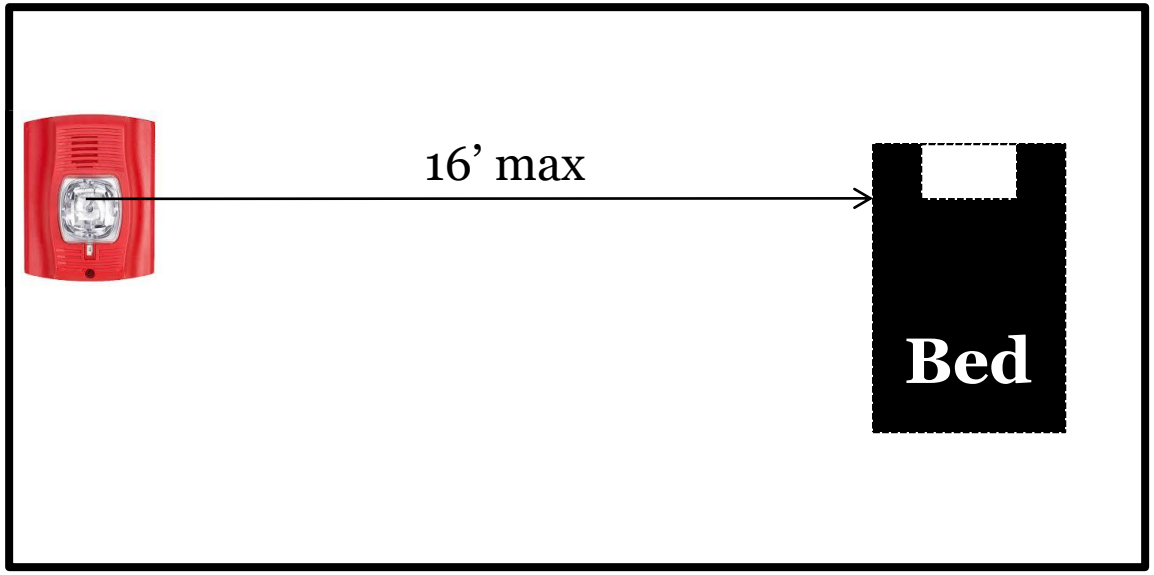
- Visible appliances ≥ 24” from the ceiling must be rated for a minimum of 110 cd
- Visible appliances < 24” from the ceiling must be a minimum of 177 cd rating

*TABLE 18.5.5.7.2 Effective Intensity Requirements for Sleeping Area Visible Notification Appliances*

| *Distance from Ceiling to Top of Lens* | | |
|---|---|---|
| *in.* | *mm* | *Intensity (cd)* |
| ≥24 | ≥610 | 110 |
| <24 | <610 | 177 |

# Visible Appliances-Sleeping Areas

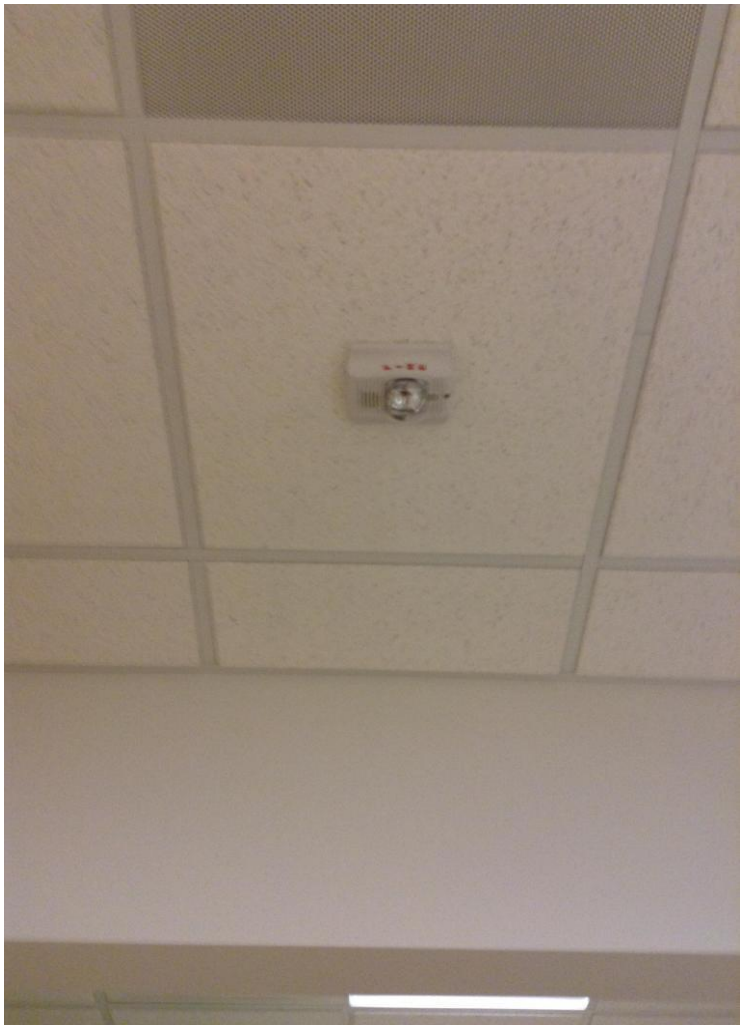
- Rooms greater than 16 feet in any dimension shall have a visual appliance within 16 feet of the pillow.



# Visible Strobes

- Visible appliances are installed in one of two orientations:
  - Wall mounted
  - Ceiling mounted
- Strobes are listed for a certain orientation and cannot be used interchangeably.
  - Wall mounted strobes cannot be mounted on the ceiling or vice versa.

# Incorrect Installations



# Questions ???

# Contact Info

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