Fire Alarm Intelligibility

Chris Nolan
chris.nolan@honeywell.com
416-525-9898
Fire Alarm Intelligibility Agenda

- Definition
- Codes
- Factors
- Design
- Test
What is Voice Intelligibility

Definition: A measure of being understood or comprehended (distinguishable and understandable).

More specifically, intelligibility is concerned with evaluating reductions of the modulations of speech that cause undesired reductions in speech comprehension.
Code Requirements?

2006 Ontario Building Code

3.2.6.13. Voice Communication System

(1) A voice communication system or systems conforming to Article 3.2.4.22. shall be provided in a building if,

(a) the floor of the top storey, is more than 36 m above grade, or

(b) a floor area or part of a floor area located above the third storey is designed or intended for use as a Group B, Division 2 or 3 occupancy.

3.2.4.22. Voice Communication Systems

(1) A voice communication system required by Subsection 3.2.6. or Clause 3.3.2.4.(14)(f) shall consist of,

(a) a 2-way communication system in each floor area, with connections to the central alarm and control facility and to the mechanical control centre, and

(b) loudspeakers operated from the central alarm and control facility that are designed and located so as to be audible and the messages intelligible in all parts of the building, except that this requirement does not apply to elevator cars.
2010 National Building Code

3.2.4.22

2) The voice communication system described in Clause (1)(b) shall be capable of broadcasting prerecorded, synthesized, or live messages with voice intelligibility meeting or exceeding the equivalent of a common intelligibility scale score of 0.70.

7) Except where a fire alarm system shall be installed on occupant load...
Codes?

2010 National Building Code: Appendix A-3.2.4.22(1b)

…Suggests that the SPL should be at least 15dBA above the ambient is required for audibility
…references NFPA72, Annex A.7.1.4 for CIS measuring requirements and guidance on the proper design of intelligible voice and alarm systems.
Factors Affecting Intelligibility

- Human Factors
- Signal-to-Noise Ratio
- Reverberation/Echoes
- Distortion
- Other
Human Factors

The talker
- Accents
- Microphone technique
- Talker’s background noise

The listener
- Language
- Age
Increasing the speaker SPL above background noise

• If a speech signal is 15dBA higher than the noise, the intelligibility loss is minimal

• Above 90dBA, the intelligibility of speech actually decreases with increasing SPL
Reverberation/Echoes

- Echoes is the effect of the original sound being reflected off of surfaces.
- Reverberation is the effect of sound being reflected off of surfaces from different directions (many small echoes).

- Speaker position and room’s material construction/obstructions have a significant impact.
Reverberation/Echoes

Normal

Reverb
Distortion

The speech waveform is “clipped” by some part of the electrical signal path within the fire alarm system exceeding the capacity of the components.

- Poor quality or damaged speakers
- Overloaded amplifiers
- Installation errors
- Operator shouting into the microphone

Normal  Reverb
Other

- Furnishings and decorations
- Building occupant activities
- Environmental noise
Designing for Intelligibility

1. Speaker Selection
2. Speaker Spacing & Placement
3. Sound Pressure Level (SPL)
4. Dealing with Echo and Reverberation
5. (Optional) Modeling Software
Speaker Selection

How to choose the “right” speaker for the job

- Speaker Construction
  - Size
  - Testing springs
  - Tap settings

- Ceiling vs Wall Mount
  - Use ceiling whenever possible. They provide even sound, cover a larger area, and are cheaper to install

- Frequency Response
  - Wider frequency response. Human ear hears 64Hz to 23,000Hz so select speakers with frequency response from 150Hz to 11,000Hz
Speaker Selection

Test Results of Three (3) Popular Brands of Speakers
Speaker Spacing & Placement

Real Dispersion
Angle (120°) where SPL decreases by 6 dB at ear level which is the maximum distance of the speaker

Rule of Thumb: Speakers should be spaced at two times the ceiling height
Speaker Spacing & Placement

- **1.4 x Spacing; only used in areas with very low background noise & reverberation.**

- **Edge-to-Edge; common for most areas.**

- **Minimum Overlap; used in areas of high ceilings or high reverberation.**

- **Full Overlap; excellent intelligibility for the most difficult areas but typically requires modeling.**

The Rule of Thumb Model results in edge-to-edge spacing. The lighter blue outer edges represent sound falloff.

Regardless of whether you choose a square or hexagonal pattern, edge-to-edge spacing results in falloff along the edges. Square patterns also result in the large dead zones shown in red. Hexagonal patterns reduce, but do not eliminate these dead zones.
Speaker Spacing & Placement

Wall Speaker Placement
(Ceilings greater than 15’)

- Suggest the use of Horn Type Speaker since they cover a larger area than simple rectagonal wall mount speakers

- Position speaker so that all sound travels in the same direction to avoid reverberation and sound cancelling

For best coverage speaker horns should be mounted 15’ off the floor and tilted at a 60° angle.
Speaker Spacing & Placement

Wall Speaker Placement
(Large Venues)

- 60 Feet
- 40 Feet

The proper pattern for mounting speaker horns. All horns point in the same direction with 60 feet downrange spacing and 40 feet spacing side-to-side.

Quiet Areas <70 dB
1 horn per 4,000 square feet

Moderate Areas 71-85dB
1 horn per 2,500 square feet

Noisy Areas >85dB
1 horn per 1,200 square feet

Never point speaker horns at each other. The sounds cancel each other, cause reverberation, distortion, and delay.
Speaker Spacing & Placement

Ambient Noise Level = 52 dBA
+15 dB above = 67 dBA
Lose 6 dB every double distance
Need to cover 40 feet (10-20-40)
79 dbA @ 10 ft
73 dbA @ 20 ft
67 dbA @ 40 ft

Wall Speaker Coverage Example
Sound Pressure Level (SPL)

- Selecting the right wattage tap
- An “intelligible” system must provide above 15 dBA above the ambient noise of the room
- From manufacturers specs, select a wattage tap that yields the required SPL

### Table C1

<table>
<thead>
<tr>
<th>Area</th>
<th>Sound Absorption</th>
<th>Typical dBA Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Office</td>
<td>Soft</td>
<td>40 to 50</td>
</tr>
<tr>
<td>Hospital</td>
<td>Soft</td>
<td>45 to 55</td>
</tr>
<tr>
<td>Hotel Lobby</td>
<td>Normal</td>
<td>50 to 60</td>
</tr>
<tr>
<td>Average Office</td>
<td>Normal</td>
<td>50 to 65</td>
</tr>
<tr>
<td>Restaurant</td>
<td>Normal</td>
<td>50 to 65</td>
</tr>
<tr>
<td>Bank</td>
<td>Normal</td>
<td>45 to 55</td>
</tr>
<tr>
<td>Department Store</td>
<td>Normal</td>
<td>55 to 65</td>
</tr>
<tr>
<td>Noisy Restaurant</td>
<td>Hard</td>
<td>70 to 75</td>
</tr>
<tr>
<td>Busy Office</td>
<td>Normal</td>
<td>70 to 75</td>
</tr>
<tr>
<td>Auditorium</td>
<td>Normal</td>
<td>70 to 75</td>
</tr>
<tr>
<td>Supermarket</td>
<td>Hard</td>
<td>70 to 75</td>
</tr>
<tr>
<td>Average Factory</td>
<td>Hard</td>
<td>65 to 90</td>
</tr>
<tr>
<td>Average Assembly Line</td>
<td>Hard</td>
<td>70 to 75</td>
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<tr>
<td>Printing Area</td>
<td>Hard</td>
<td>80 to 90</td>
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<tr>
<td>Machine Shop</td>
<td>Hard</td>
<td>80 to 95</td>
</tr>
<tr>
<td>Noisy Factory</td>
<td>Hard</td>
<td>90 to 100</td>
</tr>
</tbody>
</table>
Dealing with Echo/Reverberation

Reverberation

- Dependent on room’s dimension, construction, material, and objects in room.
- Worse if the speakers are louder than necessary, use more speakers at lower power tap settings.
- Ceiling speakers will create less reverberation than wall mount when set at the proper wattage tap.
- If possible, aim speakers towards soft surfaces like carpets to minimize reflections.
- Acoustic treatment (e.g. drapes, wall hangings, carpeting, etc.) reduce reverberation.
Dealing with Echo/Reverberation

Echo

- Material construction and obstructions have a significant impact
- Position speakers to minimize reflections on walls
- Avoid positioning speakers near corners or other concave surfaces
Modeling Software

To model the distribution of direct sound levels as well as total sound levels, the signal-to-noise ratio and speech intelligibility

- Ease EVAC
- Simplex itool
- Bose Modeler
EASE EVAC Modeling Software

Entry Of Room Based On Floor Image
EASE EVAC Modeling Software

Material Assignment
EASE EVAC Modeling Software

Material Assignment
EASE EVAC Modeling Software

Auto Arrange Function
EASE EVAC Modeling Software

Direct SPL Mapping
EASE EVAC Modeling Software

Intelligibility Mapping
EASE EVAC Modeling Software

Formal Report Generation
Intelligibility Testing

“New” Annex D in NFPA-72 2010

• Intended to provide guidance on the planning, design, installation, and testing of voice communication systems.

• The majority of this annex contains recommendations for testing of the intelligibility of voice systems and is not required by code in Canada.
Intelligibility Testing

- **Subject-Based Methods**
  - Phonetically Based; 256 – 1000 words to a panel of listeners.
  - Modified Rhyme Test; rhyme test to a panel of listeners

- **Quantitative Methods**
  - Common Intelligibility Scale (CIS); not a method but a standardized scale to which measurements are be taken
  - CIS score of 0.0 is totally unintelligible and 1.0 is perfectly intelligible
Intelligibility Testing

Portable digital speech meter
- Displays results in CIS or STI formats
- Factors in the effects of room acoustics and background noise
- Audio and RS232 computer interface
Intelligibility Testing

CAN/ULC-S537-04:

5.10 SIGNAL DEVICES

5.10.1 Each audible signal device and visible signal device shall be inspected and tested to confirm operability, including the following functions, as applicable:

B The intelligibility of voice messages shall function as intended throughout the area served by the device;

C The audibility of the alert signal and/or alarm signal and of voice messages shall function as intended throughout the area served by the device. (Refer to Appendix C6.3, Signalling Device Sound Level Measurement);
Thank you for attending!

Chris Nolan
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