October 2010

Guidelines:

Meeting NFPA 72-2010
and DOD Intelligibility Requirements

SYSTEM SENSOR®

NFPA 72-2010 includes a new section outlining intelligibility requirements for voice evacuation systems. The inclusion of these requirements will necessitate changes in how these systems are designed and installed.

Because intelligibility is a relatively new concept to fire and life safety systems, System Sensor is providing this whitepaper to help designers and installers understand the concept of intelligibility and how it applies to notification systems, new terminology included in the code, how to determine which spaces must meet intelligibility requirements, and factors that affect intelligibility. In addition, it will focus on applying the code.

Intelligibility and Key Terms Defined

NFPA 72-2010 defines intelligibility as the quality or condition of being intelligible (3.3.124). It defines intelligible as capable of being understood; comprehensible, clear (3.3.126). Those familiar with the code will recognize that this is a slight change from NFPA 72-2007, which defined intelligibility as audible voice information that is distinguishable and understandable (3.3.211).

These definitions can be ambiguous. What is clear and understandable to one person may not be to another. Therefore, it is important to know how to properly design for and predict intelligibility for each installation based on more objective factors. Perhaps an easier way to look at intelligibility is as the measure of the effectiveness of speech, or the percentage of a message that is understood correctly.

There are several other key terms to be aware of in order to properly understand and apply intelligibility requirements. **Acoustically Distinguishable Space (ADS)** is a term added to NFPA 72-2010. Establishing ADSs is foundational to planning an intelligible system. **Speech Transmission Index (STI)** or **(STIPA)** is the most common quantitative methodology for measuring intelligibility using a test meter. It is a weighted average of the response to fluctuating modulation frequencies. The **Common Intelligibility Scale (CIS)** was created to map all quantitative intelligibility measurement methods to the same scale so that all different results can be compared.

Emergency Communication System (ECS) is an NFPA term that refers to large, site-wide notification systems, while **Mass Notification System (MNS)** is a military term used for the same types of systems. Intelligibility would relate to the voice evacuation system portion of a fire or ECS system.

Factors That Affect Intelligibility

Designing an intelligible system can be complicated by a variety of factors. While the properties of the speaker chosen have some impact on the intelligibility of a system, most factors have to do with the occupancy itself. So while important, speaker choice will not always ensure intelligibility. Below are some of the main factors that impact intelligibility.

Signal-to-Noise Ratio

Signal-to-noise ratio is a comparison of the sound level that is being produced by the speaker to the ambient or background noise in the room. In order to help achieve the needed intelligibility, it is important to ensure the speaker sound output is 10 to 15 dB over ambient noise. NPFA 72-2010, Chapter 18, calls for an average 15 dB over ambient. Going any higher than this results in diminishing returns in terms of improving intelligibility. Therefore, if a better intelligibility score is needed, more speakers should be used at lower tap settings as opposed to increasing the sound output on the existing speakers.

As Figure 1 shows, when installing speakers, each time the power output or number of installed speakers is doubled, the sound output increases by 3 dB. Each time the distance between the listener and sound source is doubled, there is a 6 dB loss in loudness.
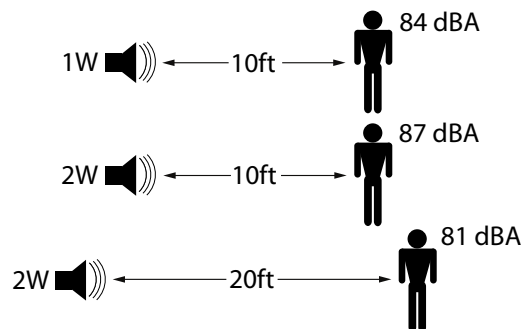

Figure 1: Signal-to-Noise Ratio

Frequency Response

For voice evacuation, speakers ideally should have a frequency range between 150 and 11,000 Hertz (Hz) because this is the frequency range that an adult voice produces. Underwriters Laboratories (UL) requires and tests for a narrower frequency range, between 400 and 4,000 Hz, because this is closer to the average range in which humans can hear sound efficiently.

When measuring frequency response, it is important for frequency to be as flat as possible to produce the most intelligible sound. The flatter the response over the frequency range, the better the speaker intelligibility will be.

Harmonic Distortion

The average person can detect as little as 2 percent distortion when listening to sound output. Once the sound output reaches 15 percent distortion, it is considered non-intelligible. *UL allows up to 20 percent distortion over the range 710-3,550 Hz. However, this would make for a poor sounding speaker. Therefore, the least amount of measurable distortion is desired.*

There are many factors that affect harmonic distortion, such as tolerance of the message generator and amplifier, loading of the audio amplifiers (load vs. available power), or mechanical factors, including wires touching the cone of the speaker, excessive voltage drop in the speaker line, vibration caused by poor installation, and damaged speakers. In addition, all manufactured equipment has distortion built into it. All of these different factors build on each other and have a cumulative effect on intelligibility.

Reverberation

Reverberation is the persistence of a sound through echoes and reflections after the initial sound source is removed. These echoes and reflections are the main reason why it is often difficult and sometimes impossible to achieve a required intelligibility score in certain environments, like large, open areas with very reflective surfaces. If echoes are spaced too closely together, the sound cannot be clearly distinguished by the listener, so minimizing reverberation is key to achieving the intelligibility score desired.

Some of the main factors that affect reverberation include room size, the reflective properties of the surfaces in the space, the orientation of the speaker, and the sound output of the speaker.

Talker and Listener Abilities

There is great variation in the human element relating to intelligibility, specifically around the abilities of the talker and listeners. Talker abilities that could affect intelligibility would include accents, dialects, diction, frequency of voice, etc. Listener ability is the sensitivity of a listener's hearing.

Intelligibility in the Code

While previously located in the Annex of NFPA 72-2007, intelligibility requirements have been written into the body of the code for NFPA 72-2010 (Chapters 18 and 24). For intelligibility, Chapter 24 states that the system should be capable of reproducing intelligible messages in accordance with Chapter 18.

As noted earlier, ADS is an important new term added to the NFPA 72-2010 code. An ADS is "an emergency communication system notification zone, or subdivision thereof, that might be an enclosed or otherwise physically defined space, or that might be distinguished from other spaces due to acoustical, environmental, or use characteristics, such as reverberation time and ambient sound pressure level" (section 3.3.2). Some factors that might acoustically distinguish spaces within a given area include floor, wall, and ceiling materials; ceiling heights; and ambient noise conditions.

According to the NFPA Code (18.4.10.1), each ADS is determined by the system designer during the planning and design phase of any system. In addition, each ADS shall be identified as requiring or not requiring voice intelligibility (18.4.10.2). Finally, when intelligibility is required by the AHJ, ADS assignments have to be submitted for review and approval (18.4.10.3).

One of the main goals of the new wording around ADSs and the intelligibility requirement in NFPA 72-2010 is to help avoid over-designing and testing systems to meet intelligibility requirements in areas deemed "impossible" based on criteria identified in the ADS assignation phase.

System Layout and Design

Additional information in Chapter 24 provides requirements for laying out an intelligible voice evacuation system for an ECS. Section 24.4.1.2.2.1 requires:

- The speaker layout of the system shall be designed to ensure intelligibility and audibility

- Intelligibility shall first be determined by ensuring that all areas in the building have the required level of audibility

- The design shall incorporate speaker placement to provide intelligibility

In order to lay out speakers for a voice evacuation system, there are several things one needs to know about the speakers and the environment in which they will be placed. The following information is needed to meet NFPA requirements:

- The average ambient background noise level of the area

- Room characteristics, i.e., length, width, and height of the ceiling and reflectivity of the surfaces in the room

- The coverage angle or polar plot of the speaker

For more information on optimizing speaker layout, see the System Sensor publication, *Applications Guide: Voice Evacuations Systems*, which can be accessed for free at www.systemsensor.com.

In addition, commercially available software programs can be used to simplify the design of intelligible voice evacuation systems. One such application is the EASE software, which is used by sound designers to model acoustical properties for specific environments and speaker configurations.

With the proper speaker and layout information, EASE can help predict the intelligibility of a voice system before installation. System Sensor provides SpectrAlert Advance speaker data files at www.systemsensor.com/ease for use with this software.

To obtain an intelligibility prediction using EASE software, designers import the speaker information into the software along with other variables such as room materials, ceiling height, and speaker positioning. The software then provides intelligibility predictions based on the information provided.
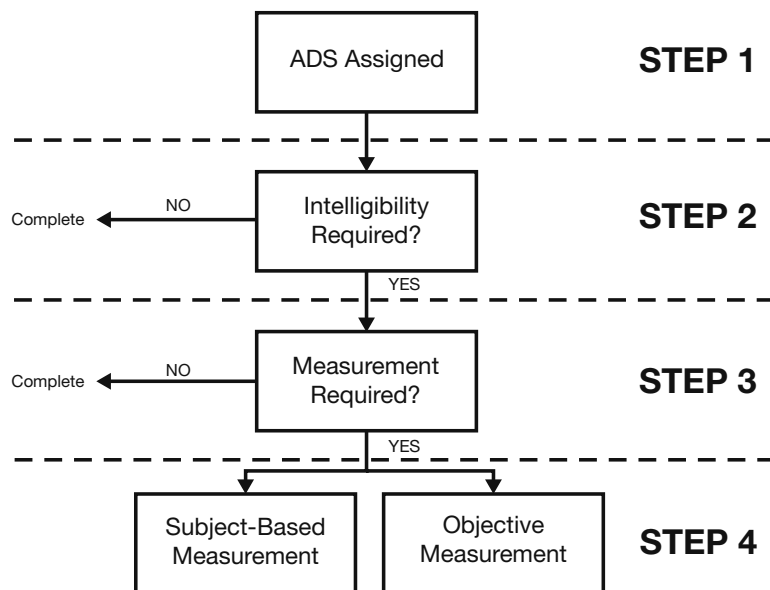
Applying the Code

Figure 2: Applying NFPA 72-2010

Figure 2 illustrates the process involved in following NFPA 72-2010 intelligibility requirements. In Step 1, the process starts with determining the different ADSs within an occupancy. In Step 2, designers determine if intelligibility will be required. An example of where intelligibility would not be required is an area deemed impossible. If not, the process is complete. If intelligibility is required, designers move on to Step 3.

In the new Chapter 18 for Notification Appliances, NFPA 72 states that within the ADS, where intelligibility is required, voice communications systems shall reproduce prerecorded, synthesized, or live messages with voice intelligibility (18.4.10). In each of these defined spaces, measuring for intelligibility may or may not be required.

For example, in some areas, such as hotel rooms and some office spaces, the code may require intelligibility but not testing or verification. In these cases, it is adequate to ensure those conducting the testing can hear and understand the messages in these small spaces. The code assumes that occupants will also be able to understand these messages. In the cases when measurement is not required, the process is complete.

If measurement is required, then Step 4 is deciding what type of measurement will be performed.

Testing and Measurement

When intelligibility is required and must be measured, quantitative methods using an intelligibility meter are typically used. Intelligibility meters, which measure either STI or CIS scores, are the most accurate and practical means of conducting intelligibility testing.

There are also a number of subjective test methods that use a group of people who listen to a passage that is spoken or played over the speaker system. The group is then asked to recall how much of the passage they understood to determine the intelligibility score. The two main types of tests done in this manner are the Modified Rhyme Test and Phonetically Balanced word score. To get more detailed information on intelligibility testing, review Annex D in NFPA 72-2010.

In most cases, however, the more practical method is to use a meter. Following are the basic steps of performing intelligibility testing using a meter.

1. **Calibrate the meter** – At the beginning of each testing period the meter should be calibrated using the instructions supplied by the manufacturer.

2. **Measure ambient dB**

3. **Measure dB with test tone** – Run the intelligibility test tone and ensure that the dB reading with the tone is at least 15 dB over ambient.

4. **Set the meter for intelligibility testing** – Check to ensure that the meter is set properly. Most intelligibility meters also do other types of acoustical testing.

5. **Choose a scale** – Make sure that the proper testing scale is selected.

6. **Run the intelligibility test**

7. **Record the intelligibility score** – Make note of the score and move on to your next test area. Many meters have the ability to save your test data internally to be downloaded to a computer at a later time.

Note from CSA: The alert tone is to be 15+ dBA over ambient to evaluate audibility in Public Mode.

However, intelligibility is different than audibility. Adjust STIPA signal volume so that it closely matches the pre-recorded voice message volume level being delivered. The voice message is what you want to be intelligible, not the alert tone. It does no good to set STIPA signal at a high level if your voice message is very soft.

Find a point (such as between speakers) - take a dBA reading of voice message. Then turn on and adjust your STIPA signal level so the output closely matches the voice message output at the same location. Then take your STI/CIS readings. Record your STI/CIS value and the dBA level at each location.

You can raise your STIPA signal level by 3 dBA to see if your STI/CIS value gets better. If it does, than adjust your speaker tap setting one level for each 3 dBA output desired (within volt drop limits). Make sure to turn your STIPA level back down to match voice message level for rest of testing.

Make sure to record if your results are in STI or CIS units as they are different.

Note from CSA: NFPA 72 no longer requires the STI / CIS values as there are too many variables based on the particular space. See Appendix D for guidance. DOD documents do have requirements.

NFPA 72-2010 Acceptability Criteria

When conducting intelligibility testing, especially for an ECS, NFPA 72-2010 requires that 90 percent of all measurements taken in an ADS meet the required intelligibility scores in order to be considered acceptable:

- Measured STI of not less than 0.45 (0.65 CIS)

- Average STI of not less than 0.50 (0.70 CIS)

It is important to note that these requirements fall on the lower end of the intelligibility scale. An STI score of 0.45 is on the lowest end of the score range that is considered fair and 0.50 is also considered a fair score. As a result, these score requirements should not require excessive over-design.

DOD Acceptability Requirements

The Department of Defense (DOD) has its own requirements for mass notification, including requirements for speaker intelligibility. The requirements for the Army and Air Force are more stringent than NFPA 72-2010 requirements. These branches require a minimum STI score of 0.70. The Navy and Marines require a minimum STI score of 0.50, which matches the requirement for NFPA 72-2010.

All MNS projects in the military are required to verify the intelligibility scores using either the STI or CIS scales. All measurements should be taken at the head level for each space, depending on what that space is used for. Furthermore, the military requires that an intelligibility meter be used to take three intelligibility measurements at each location. The mean of these three readings shall then be used to compute the intelligibility score.

Summary

Designing a voice evacuation system to meet current intelligibility requirements can be challenging, even for experienced designers, because of the wide variations of independent factors that can influence intelligibility. However, NFPA requirements have been designed to limit the complexity of these systems by minimizing the potential for over-design. Therefore, the best approach is to be familiar with NFPA requirements and definitions before attempting to design a voice evacuation system for intelligibility.

In addition, other tools and resources are available to simplify this process, including design software like EASE, intelligibility meters, and learning resources such as System Sensor applications guides, online design tools, and webinars. You can learn more at the links and resources below:

- SpectrAlert Advance EASE Speaker Data: www.systemsensor.com/ease
- Online Training and Seminars: www.systemsensor.com/training
- Intelligibility Requirements Webinar: www.systemsensor.com/webinars
- Free Applications Guides: www.systemsensor.com/html/applicat.html
- Online Design Tools: www.systemsensor.com/tools
- The National Electrical Manufacturers (NEMA) Emergency Communications Audio Intelligibility Applications Guide

For more information regarding the recent revisions to
NFPA 72-2010 and DOD Intelligibility requirements, please contact:

System Sensor
3825 Ohio Avenue
St. Charles, Illinois 60174
1-800-sensor2
www.systemsensor.com