REAL PEOPLE
MAKE UP LIFE SAFETY

IMPROVING FIRE ALARM INTELLIGIBILITY THROUGH TECHNOLOGY

LARRY RIETZ
DIRECTOR
JENSEN HUGHES

JENSEN HUGHES
Advancing the Science of Safety

IMPROVING FIRE ALARM INTELLIGIBILITY THROUGH TECHNOLOGY

2019 Potter Conference

LARRY D. RIETZ, SET | 18 OCTOBER 2019

jensenhughes.com

Improving Fire Alarm Intelligibility Through Technology

Agenda

+ Code Requirements Regarding Intelligibility
+ Practical Suggestions for Improving Loudspeaker Design
+ New Technology in Fire Alarm Loudspeaker Design

Presentation Disclaimer

Portions of this program are reprinted with permission from NFPA 72® – 2019 Edition, *National Fire Alarm and Signaling Code*, Copyright © 2018, National Fire Protection, Quincy, MA (and previous editions). This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

NFPA 72® is a registered trademark of the National Fire Protection Association, Quincy, MA 02169.

This presentation does not reflect the official position of the National Fire Protection Association.

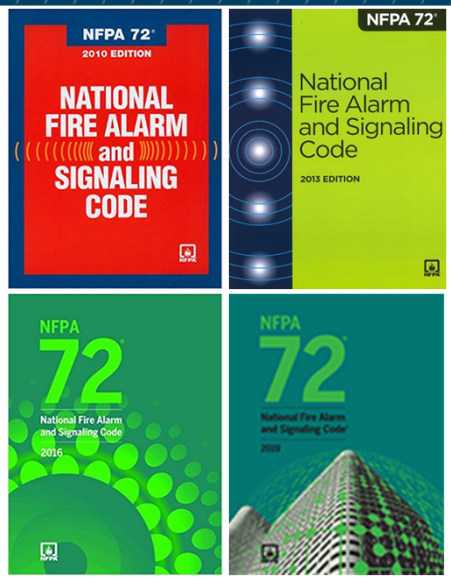
Products featured or pictured in this presentation are for informational purposes only and shall not be construed as an endorsement of any product or manufacturer.

1 *Code Requirements Regarding Intelligibility*

Code Requirements Regarding Intelligibility

NFPA 72 Addresses Intelligibility:

- Intelligibility is a Defined Term [3.3.144]
  - "Quality or condition of being intelligible." [See 3.3.145]
- Acoustically Distinguishable Spaces (ADS) [3.3.6]
- Prerecorded and manual voice messages shall be intelligible per Chapter 18 [14.4.11]
  - Not required to be Quantitative

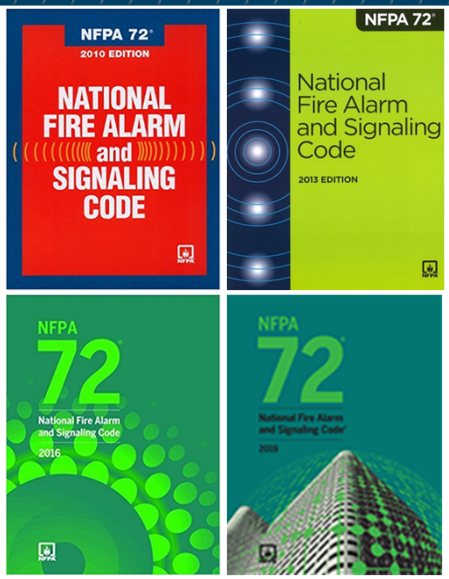


jensenhughes.com

Code Requirements Regarding Intelligibility

NFPA 72 Addresses Intelligibility:

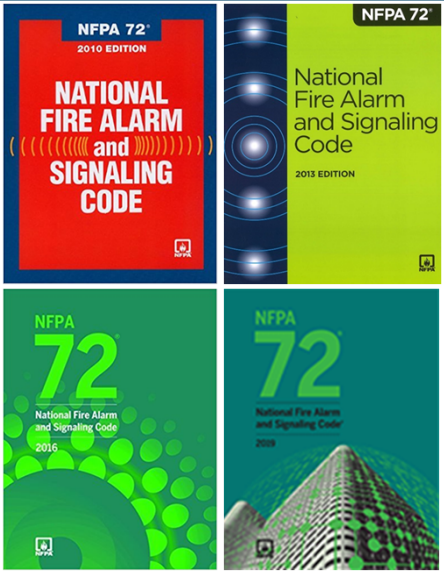
- Voice messages may not meet sound pressure (dB) levels of audibility requirements [18.4.1.6]
- Intelligibility required where a system designer states the ADS must have voice intelligibility [18.4.11]
  - ADS must be documented
  - Intelligibility not required in all ADS



Code Requirements Regarding Intelligibility

NFPA 72 Addresses Intelligibility:

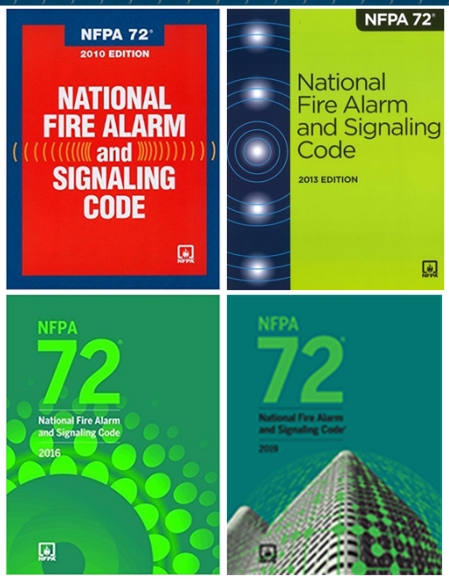
- Systems shall be capable of voice intelligibility [24.3.1.1]
  - Prerecorded, synthesized, or live microphone, live telephone handset, and live radio
- Non-listed loudspeakers shall be permitted to achieve intelligibility [24.3.1.2]



Code Requirements Regarding Intelligibility

NFPA 72 Addresses Intelligibility:

- Loudspeaker layout shall be designed to ensure intelligibility and audibility [24.4.2.2.1(1)]
  - Shall consider required level of audibility [24.4.2.2.1(2)]
- Intelligibility shall require a fire alarm system/ECS to deactivate all audible and visual notification that interferes with intelligibility [24.5.22.1.3]



Code Requirements Regarding Intelligibility

Global Change to NFPA 72-2019

Two Related Terms are Now Applied Consistently Throughout:

- Speaker
- Loudspeaker

Changes High Power Speaker Array (HPSA) to High Power Loudspeaker Array (HPLA)

Code Requirements Regarding Intelligibility

History of Allowance of Nonlisted Loudspeakers

- Not allowed in 2010 or 2013 Edition

24.4.2.12.3 Where no listed device exists for the detection required by the emergency response plan, nonlisted devices shall be permitted to be used if their failure will not impair the operation of the mass notification system.

- 2016 Edition: New 24.3.1.2
  - "Where no listed loudspeaker exists to achieve…"

24.3.1.2* Where no listed loudspeaker exists to achieve the intelligibility requirements of the Code for a notification zone, nonlisted loudspeakers shall be permitted to be installed to achieve the intelligibility for that notification zone.

- 2019 Edition: Revised 24.3.1.2
  - "Where listed loudspeakers do not achieve…"

24.3.1.2* Where listed loudspeakers do not achieve the intelligibility requirements of the Code for a notification zone, nonlisted loudspeakers shall be permitted to be installed to achieve the intelligibility for that notification zone.

Code Requirements Regarding Intelligibility

Reminder of Loudspeaker Listings:

- UL 1480 Speakers for Fire Alarm and Signaling Systems, Including Accessories
  - Edition 6, January 28, 2016
  - Uses the Reverberant Chamber Test
  - Applies to speakers rated at 300 V or less, for fire alarm and signaling systems and intended for indoor and/or outdoor installation.
  - Does "not" cover speakers which are intended for commercial or professional audio applications (see UL 1480A, UL 1492, UL 6500, UL 813, UL 1419, UL 2017, and the like)

SIGNALING UL LISTED

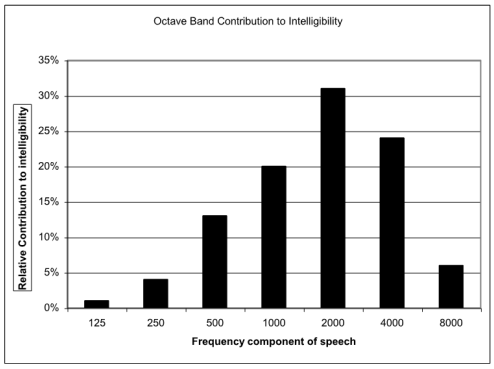
- CAN/ULC-S541 Speakers for Fire Alarm Systems, Including Accessories
  - Uses the Anechoic Chamber Test

Code Requirements Regarding Intelligibility

UL 1480 Audibility

- Confirmed for Audible Output of 75 dBA or greater
  - Measured at 1 Watt at 10 ft (sensitivity)
  - Powered from a source of pink noise
  - Over a range of 400 Hz – 4,000 Hz.

- Human Speech
  - Ranges over seven octaves from 125 Hz to 8,000 Hz
    - Majority of intelligibility falling between 500 Hz – 4,000 Hz
  - Sounds that make up words is created by amplitude modulation of those frequencies



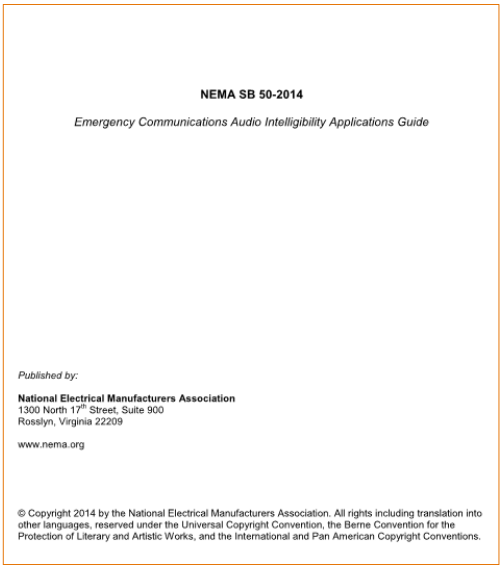
NEMA SB 50-2014S ©2014 National Electrical Manufacturers Association

jensenhughes.com

Code Requirements Regarding Intelligibility

NEMA SB 50

- Emergency Communications Audio Intelligibility Applications Guide
  - Published by National Electrical Manufacturers Association
  - 2014 Edition
  - Available at www.nema.org
- Basic Explanation of:
  - Ohm's Law and the Decibel
  - The Nature of Speech
  - Room Acoustics
  - Speaker Basics
  - Speech Intelligibility



NEMA SB 50-2014

Emergency Communications Audio Intelligibility Applications Guide

Published by:

National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, Virginia 22209

www.nema.org

jensenhughes.com

Code Requirements Regarding Intelligibility

Annex D – Speech Intelligibility

Speech Intelligibility ANNEX **D**

- Added in 2010 Edition, Updated Since Then
- Based on NFPA Fire Protection Research Foundation project in October 2008
- Includes guidance on the planning, design, installation, and testing of voice communication systems
  - Test protocols, limitations and concerns
  - Acoustically Distinguishable Spaces
  - Quantitative Measurements (STI, CIS, ALCons, etc.)
- Article: "Voice Intelligibility for Emergency Voice/Alarm Communications Systems"
  - Available only in the NFPA 72 Handbook

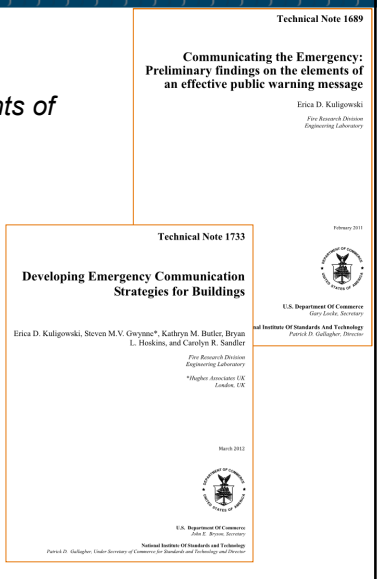
Voice Intelligibility for Emergency Voice/Alarm Communications Systems

Robert P. Schifiliti, P.E., FSFPE
R. P. Schifiliti Associates, Inc.

Code Requirements Regarding Intelligibility

NIST Technical Notes

- *Communicating the Emergency: Preliminary findings on the elements of an effective public warning message*
  - Technical Note 1689
  - February 2011
  - Appropriate emergency message content and dissemination techniques
- *Developing Emergency Communication Strategies for Buildings*
  - Technical Note 1733
  - March 2012
  - Technology, approaches, and public response to emergency notification of various types
- Available from www.nist.gov



2 *Practical Suggestions for Improving Loudspeaker Design*

Practical Suggestions for Improving Loudspeaker Design

Understand What May Effect System Intelligibility?

- Voice Generator / Signal Source
- Message Recording Quality / Method
- Signal Processing
- Amplifier
- Circuiting
- Loudspeaker Placement
- Loudspeaker Equipment

GREATEST IMPACT BY SYSTEM DESIGNER!

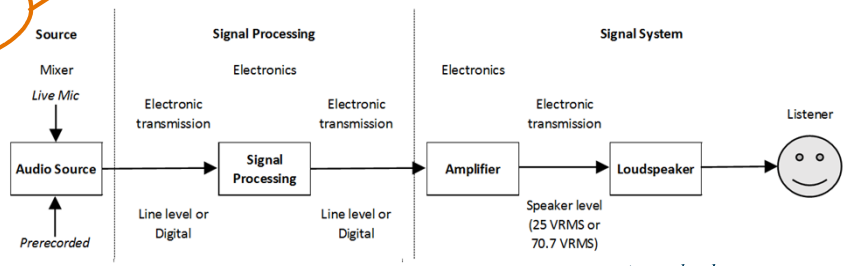


Diagram based on *Designing Mass Notification Systems* by Wayne D. Moore, PE

jensenhughes.com

Practical Suggestions for Improving Loudspeaker Design

Common Acoustic Properties

- Floor
  - Carpet
  - Tile
- Ceilings
  - Height
  - Acoustical Ceiling Tile / Hard Lid
  - Cloud Ceilings
- Walls
  - Glass / Curtain Wall
  - Drywall / Brick
  - Fabric

Common Environmental or Use Properties

- Occupancy Load
- Mechanical Equipment
- Workshops / Plants / Mills
- Existence of Sound Sources
- Acoustically Challenging Spaces

Practical Suggestions for Improving Loudspeaker Design

25 Vrms vs. 70.7 Vrms

- Most loudspeakers are dual voltage
- 25Vrms:
  - Good for smaller facilities
  - Typically requires 12, 14, or 16 AWG
- 70.7Vrms:
  - Reduces the current and power loss
  - Typically use 16 or 18 AWG wiring
  - Loudspeakers may have more power taps
  - Can be added onto more easily
  - Circuits may require conduit

ALLOWABLE LENGTH (FEET) FOR 25 VRMS AUDIO CIRCUITS WITH 0.5dB (12.5%) LOSS							
WIRE SIZE (AWG)	RESISTANCE PER 1000' PAIR (OHMS)	NOMINAL POWER IN LOAD (load impedance ohms)					
		10W (61)	15W (41)	20W (31)	30W (20)	40W (15)	50W (12.5)
12	3.2	1130	775	575	390	290	230
14	5.2	700	475	350	240	175	140
16	8.0	450	300	225	150	110	90
18	13.0	290	190	140	95	70	57

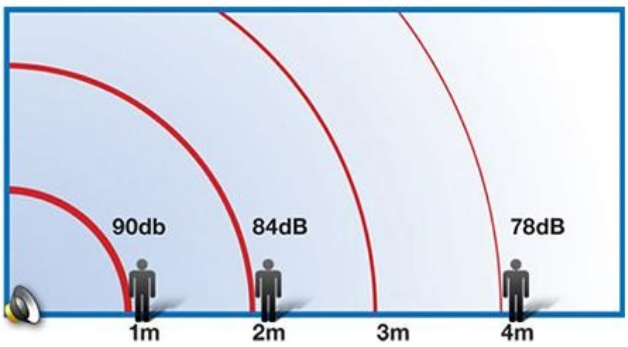
ALLOWABLE LENGTH (FEET) FOR 70 VRMS AUDIO CIRCUITS WITH 0.5dB (12.5%) LOSS									
WIRE SIZE (AWG)	RESISTANCE PER 1000' PAIR (OHMS)	NOMINAL POWER IN LOAD (load impedance ohms)							
		10W (490)	15W (327)	20W (245)	30W (163)	40W (122)	60W (81)	100W (49)	200W (24.5)
10	2.0		9900	7300	5000	3700	2500	1450	730
12	3.2	9100	6200	4600	3100	2300	1600	910	460
14	5.2	5600	3800	2800	1900	1400	950	560	280
16	8.0	3600	2400	1800	1200	900	600	370	180
18	13.0	2300	1500	1100	750	560	370	230	

Decide BEFORE Starting the Design and Document!

Practical Suggestions for Improving Loudspeaker Design

Design Tip 1: Understand the Inverse Square Law

- Double the distance, sound intensity will diminish by 6 decibels (dB)
- Increasing the power to a loudspeaker will not change this law
  - Increasing power may increase distortion!
- Select loudspeakers with sufficient efficiency or higher sensitivity
- More efficient the speaker, the lower the amplifier power required to achieve the same sound pressure level



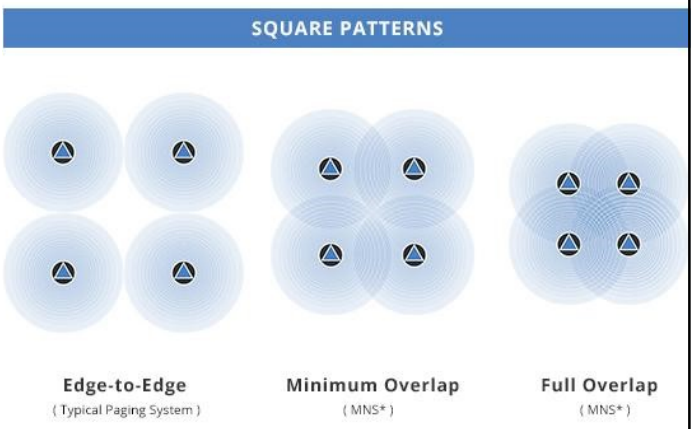
Speaker efficiency is more important than power handling!

Graphic Courtesy: Quam Nichols Company; Chicago, IL

Practical Suggestions for Improving Loudspeaker Design

Design Tip 2: Coverage – Not Power

- Should be no 'dead' spots
- 'Minimum' to 'Full Overlap' is recommended
- Remember to consider the room's acoustic properties



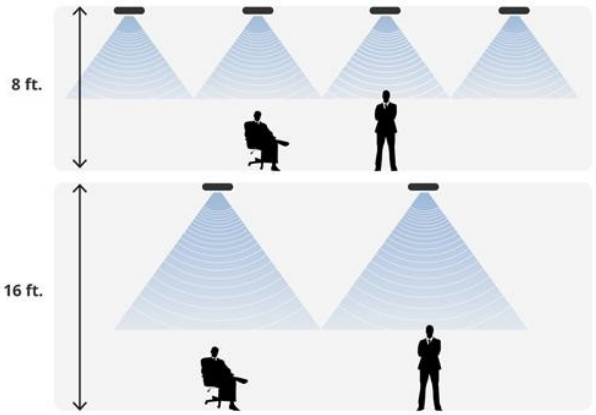
Intelligibility Increases with Coverage – Not Power!

Graphic Courtesy: Quam Nichols Company; Chicago, IL

Practical Suggestions for Improving Loudspeaker Design

Design Tip 3: Speaker Placement is Critical

- Don't rely on audio reflection for coverage
- Position loudspeakers for 100% coverage at listening height
- Lower ceilings will have closer spacing
- ADS definition must include ceiling height



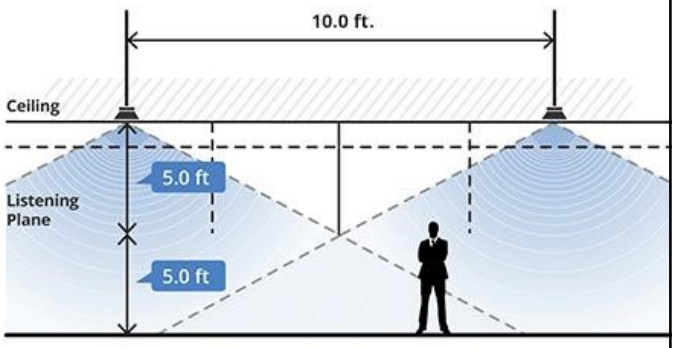
Speaker Placement is Critical to Effective Coverage!

Graphic Courtesy: Quam Nichols Company; Chicago, IL

Practical Suggestions for Improving Loudspeaker Design

Design Tip 4: Understand the Listening Plane

- Need 100% coverage at the listening plane
- No more than 6 dB loss from each source
- Design for minimum to full coverage, not edge-to-edge

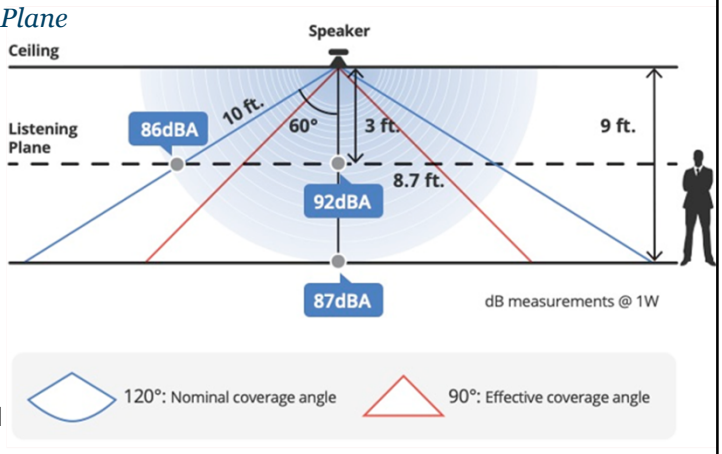


Graphic Courtesy: Quam Nichols Company; Chicago, IL

Practical Suggestions for Improving Loudspeaker Design

Design Tip 4: Understand the Listening Plane

- Need 100% coverage at the listening plane
- No more than 6 dB loss from each source
- Design for minimum to full coverage, not edge-to-edge
- Strike a balance between nominal and effective coverage angles.



Intelligibility Requires Effective and Balanced Coverage!

Graphic Courtesy: Quam Nichols Company; Chicago, IL

Practical Suggestions for Improving Loudspeaker Design

Design Tip 5: Wall-Mounted Loudspeakers

- Advantages:
  - For corridors, fewer speakers and less amplifier power may be needed
  - Mounting can be on more than one wall
  - Places sound directly into the listener area
  - Combination speaker/strobe units permit the installation of one appliance

Graphic and Content Courtesy: NEMA SB 50-2014S © 2014 National Electrical Manufacturers Association & Fire Alarm Audio Applications Guide © 2005 Tyco Safety Products

Practical Suggestions for Improving Loudspeaker Design

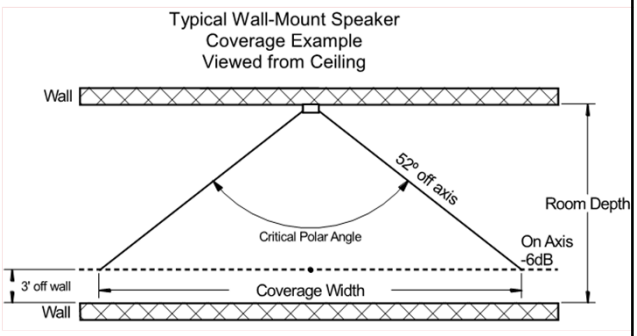
Design Tip 5: Wall-Mounted Loudspeakers

- Disadvantages:
  - Sound field more likely to encounter obstructions and changes to intelligibility
  - Low, hard ceilings reverberate sound off the ceiling and down to the listener, thus reducing intelligibility
  - Need to calculate loudspeaker distribution differently

Practical Suggestions for Improving Loudspeaker Design

Design Tip 5: Wall-Mounted Loudspeakers

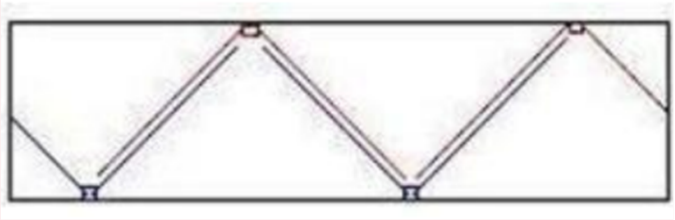
- Loudspeaker design depends on the listener location in the room
- Calculations must be done with the listener at the farthest distance from the speaker
- Farthest distance is 3 feet off of the opposite wall



Practical Suggestions for Improving Loudspeaker Design

Design Tip 5: Wall-Mounted Loudspeakers

- Goal is still to minimize sound pressure level variations in the protected area
- Loudspeaker coverage may require coverage overlap patterns



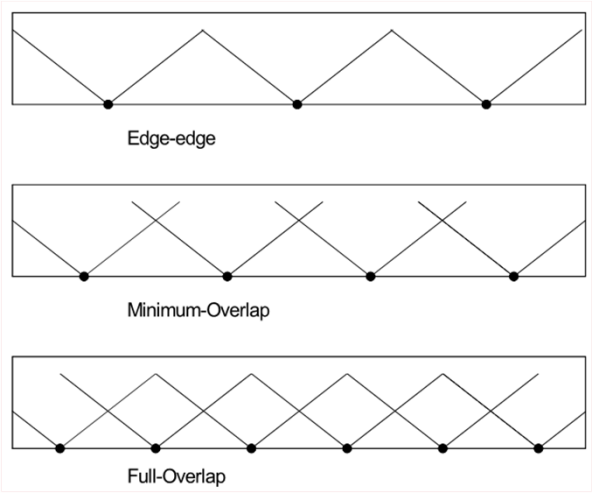
Wall-Mounted Speakers (In Feet)	
Room Width	Coverage Width 3 Feet from Wall Opposite Speaker
10 Feet	18 Feet
12 Feet	23 Feet
14 Feet	28 Feet
16 Feet	33 Feet
18 Feet	38 Feet
20 Feet	44 Feet

Graphic and Content Courtesy: NEMA SB 50-2014S © 2014 National Electrical Manufacturers Association & Fire Alarm Audio Applications Guide © 2005 Tyco Safety Products

Practical Suggestions for Improving Loudspeaker Design

Design Tip 5: Wall-Mounted Loudspeakers

- Preference is to use a single row pattern
- Edge-to-edge or tighter spacing patterns should be used
- Rooms greater than 20 feet wide should not be treated with a single wall of loudspeakers
- Never aim two wall-mounted loudspeakers directly at each other!



Intelligibility Can Be Obtained When Using Wall-Mounted Loudspeakers!

Graphic and Content Courtesy: NEMA SB 50-2014S © 2014 National Electrical Manufacturers Association & Fire Alarm Audio Applications Guide © 2005 Tyco Safety Products

Practical Suggestions for Improving Loudspeaker Design

Design Tip 6: Apply the Correct Amplification

- After loudspeaker layout is complete, clearly note your notification zone boundaries
- Notification appliance circuits shall NOT extend outside of a notification zone
- Select your loudspeaker wattage
- Select your circuit pathway
- Provide the correct amplification to power each circuit
- Provide a 25% safety factor for future expansion and field construction changes

Proper Circuiting, Power, and Amplifiers Improve Intelligibility!

3 New Technology in Loudspeaker Design

New Technology in Loudspeaker Design

Voice Fire Alarm Systems Through Time

jensenhughes.com

New Technology in Loudspeaker Design

Loudspeakers Through Time

jensenhughes.com

New Technology in Loudspeaker Design

Fire Alarm Loudspeaker Commonalities

- Size: 4” Cone
- Voltage: 25 Vrms or 70.7 Vrms
- Frequency: 400 Hz to 4,000 Hz
- Power: ¼ W, ½ W, 1 W or 2 W
- Supervisory Voltage for Circuit Integrity

New Technology in Loudspeaker Design

High Fidelity Loudspeakers

- Increases Frequency Range!
  - 300 Hz – 8,000 Hz
  - 200 Hz – 10,000 Hz
- Still Uses 4” Cone
- Some Caution is Appropriate

New Technology in Loudspeaker Design

Loudspeaker Size

+ Better bandwidth for intelligibility
+ Often larger power settings
+ Requires more real estate!
+ Often only for 70V or higher

New Technology in Loudspeaker Design

It's Hip to Be Square!

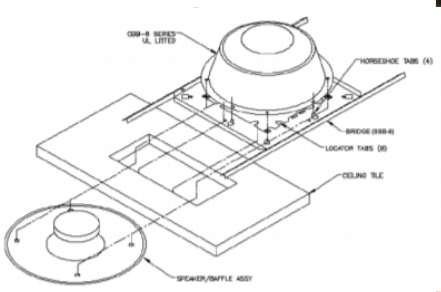
+ 8" Loudspeaker Cone
+ 2'x2' Housing
+ Options for strobe mounting!

Graphic Courtesy: Quam Nichols Company; Chicago, IL

New Technology in Loudspeaker Design

Installation Time

- No ceiling tile cutting
- No accessories



New Technology in Loudspeaker Design

Wide-Area Outdoor Applications

- 70 dBA at 2,800 ft.
- 1600 Watts (4 modules)
- Unknown Freq.
- 56” High
- 266 lbs

- 70 dBA at 2,800 ft.
- 1600 Watts (4 modules)
- 200 – 2,000 Hz.
- 72” High
- 320 lbs.

- 135 dBA Output
- 74 dBA at 3,938 ft.
- 1600 Watts
- 175 – 6,000 Hz.
- 26.2” High
- 50 lbs.

- 70 dBA at 2,880 ft. (360°)
- 800 Watts(8 horns)
- 300 – 6,000 Hz.
- 103” High
- 208 lbs.

New Technology in Loudspeaker Design

It's Cool to be Omni!

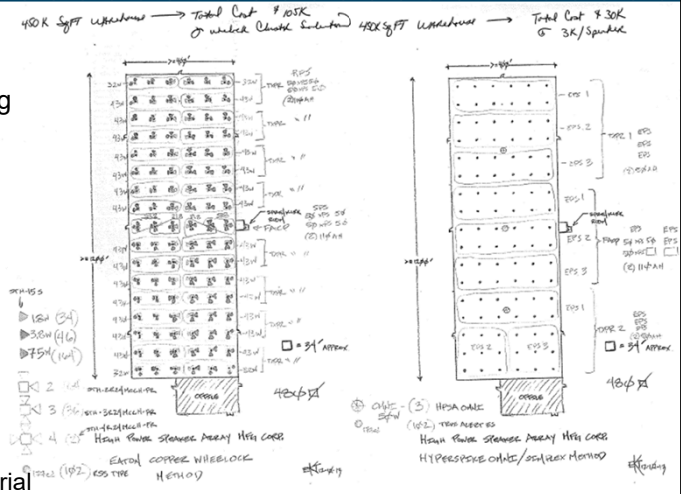
- 70 Vrms
- 50W (116 dB), 100W (119 dB), 200W (122 dB)
- 18.38" Diameter x 10.5" High
- 19 lbs.
- 0.85 STI
- Applications:
  - Manufacturing
  - Warehouses
  - Hangers
  - Large Assembly

TCPA Omni

New Technology in Loudspeaker Design

It's Cool to be Omni!

- Case Study: 450,000 sq. ft. Manufacturing Facility
- Quoted with standard 15W horn solution
  - 244 15W Cluster Loudspeakers
  - Total Cost $105,000
- Quoted with HyperSpike TCPA-Omni
  - 3 TCPA-Omni Loudspeakers
  - Total Cost $30,000
- Savings
  - Significantly Less Installation Labor + Material Cost
  - Lower Requirement for Battery Back-up, etc.



New Technology in Loudspeaker Design

It's Cool to be Omni!

+ Less Speakers + Higher Power = Better Intelligibility!

244 x 15W Loudspeakers

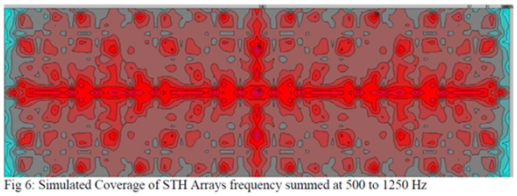
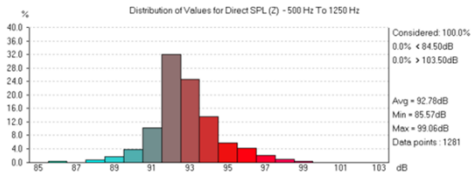


Fig 6: Simulated Coverage of STH Arrays frequency summed at 500 to 1250 Hz



3 x Omni Loudspeaker (100W)

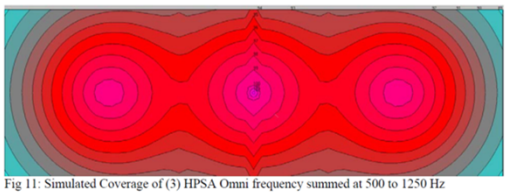
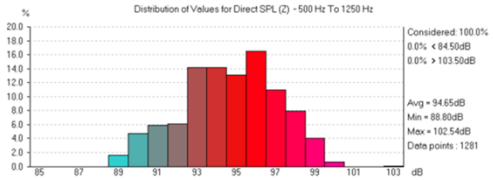


Fig 11: Simulated Coverage of (3) HPSA Omni frequency summed at 500 to 1250 Hz



New Technology in Loudspeaker Design

Small and Mighty!

+ 360° Omni-Directional Coverage
+ 41 Vrms (Requires transformer to connect to fire panel)
+ 650 W
+ 134 dB Peak SPL
+ 0.5 square mile range
+ 12.8" Diameter x 8" High
+ 20 lbs
+ UL1480A and C1D2 Certified

MA-Micro

New Technology in Loudspeaker Design

Small and Mighty!

- Applications:
  - Campus Open Spaces
  - Outdoor athletic facilities
  - Parking Lots
  - Arenas
  - Manufacturing Facilities
  - Temporary Alerting

MA-Micro

New Technology in Loudspeaker Design

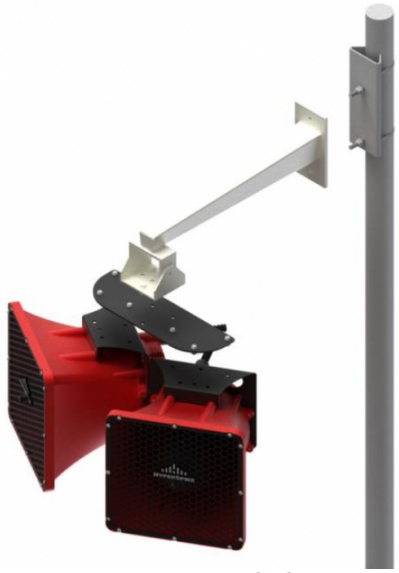
Efficiency Rules!

- UL 1480 Listed
- 25, 70, 100 Vrms (also available 4 & 8 Ohm)
- 0.5 – 24 W (at 25 or 70 Vrms)
- 139 dB Peak SPL at 1M
- 10.1” H x 10.1” W x 11.3” D
- 9 lbs.
- Class 1, Division 2

New Technology in Loudspeaker Design

Efficiency Rules!

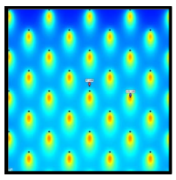
- \+ Applications:
  - Everything!
  - High Ambient Environments
  - Manufacturing
  - Parking Garages
  - Stadiums
  - Large Assembly



New Technology in Loudspeaker Design

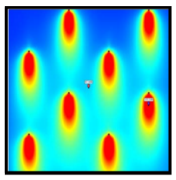
Efficiency Rules!

The "Gold Standard"

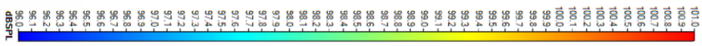


- 41 speakers
- 7.5W each
- Total 307.5W

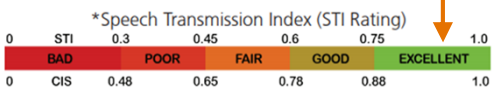
HyperSpike® TCPA-10

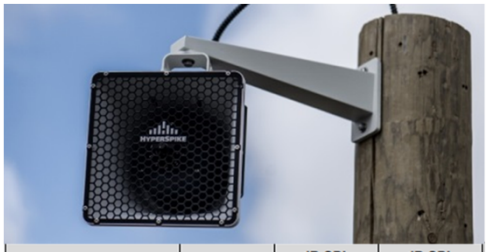


- 8 speakers
- 24W each
- Total 192W



STI score of Excellent!



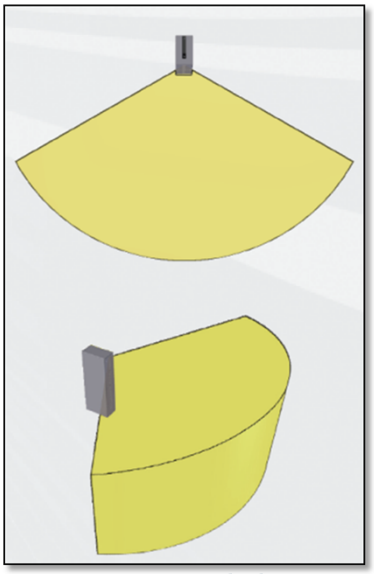


Input Voltage	Watts	dB SPL (Peak @ 1m)	dB SPL (Max @ 1m)
25	0.5	119	114
25	1	122	117
25	1.5	124	119
25	2	126	121
25	3	128	123
70	4	129	124
70/100	8	131	126
70	12	133	128
70/100	16	134	129
70/100	24	136	131
100	32	137	132
100	45	139	134

New Technology in Loudspeaker Design

New Superior Solution for Reverberant Environments!

- Unique Beam Forming – Lower reflections of hard surfaces
- Line Array Effect – Same sound regardless of distance
- 102 dB – 120 dB Max at 1m
- 250 Hz – 15 kHz
- 4.9”W x 2.9”D x 6.6”H up to 46.5”H
- 3 – 15 lbs.
- Three Configurations – 4/8/16 Ohm, 25/70/100Vrms
  Requires optional transformer to connect to fire panel
- 4 Versions – 2, 4, 8, 16
- Power 20W – 200W



New Technology in Loudspeaker Design

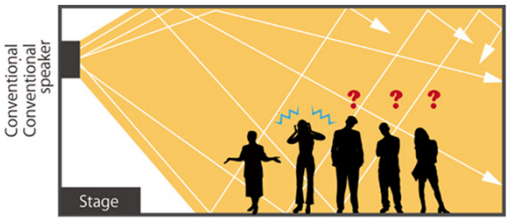
New Superior Solution for Reverberant Environments!

- Applications:
  - Parking Garages
  - Airplane Hangers and Airport Terminals
  - Gymnasiums
  - Atriums
  - Distribution Centers
  - Large Conference Rooms
  - Office Spaces, Cafeterias
  - Corridors & Tunnels

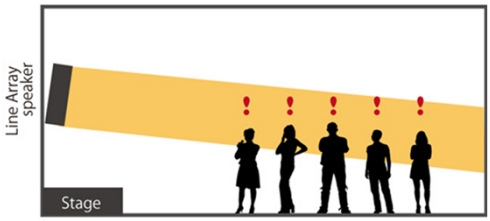
New Technology in Loudspeaker Design

New Superior Solution for Reverberant Environments!

- **How does it work?**
- It controls vertical dispersion
- It puts sound where needed – at the listener's ears!
- It does not put sound where harmful to intelligibility – not adding to harmful reverberation and echoes!



Conventional speaker disperses sound energy horizontally and vertically, prompting reflection.



Directional characteristics of Line Array speaker can be easily controlled, minimizing detrimental reflections.

Improving Fire Alarm Intelligibility Through Technology

What will you do differently?

- *Remember:*

✓ Understand the Code Requirements to provide intelligibility for your designs!

✓ Apply our six design tips for improving loudspeaker designs!

✓ Use the best and most modern technology for improving intelligibility!

Questions?

THANK YOU!

JENSEN HUGHES
Advancing the Science of Safety

(i)
Larry D. Rietz
SET
Director, Denver

lrietz@jensenhughes.com
720-442-5939

jensenhughes.com