Acoustical Design for the A/E/C Industry

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AHR EXPO LAS VEGAS JAN 31 - FEB 2, 2022

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- Responsible for development of AMCA's education programs; staff liaison for the Education & Training Subcommittee
- Projects include webinars, online education modules, presentations at trade shows, AMCA Speakers Network and other duties as assigned.

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  - You must be present for the entire session and complete a post-session online evaluation. Partial credit cannot be given for anyone who arrives late, leaves early or does not complete the evaluation.
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Jeff Boldt, PE, FASHRAE, LEED® AP, HBDP

Managing Principal, IMEG Corp.

- Member ASHRAE SSPC-90.1; Chair Mechanical Subcommittee; Chair Hydronic & Elevator Work Groups
- Former member ASHRAE SSPC-189.1; Chair Acoustics Discussion Group
- Author: Advanced Energy Design Guide for Large Hospitals and AEDG for Small Healthcare Facilities
- Chair SGPC-36 – Advanced Control Sequences
- Member SSPC-215 – Operating System Duct Leakage
- Holds a BS in Mechanical Engineering from UW-Madison, and Studied Acoustics & Vibration Control at Heriot-Watt University

Search for “ASHRAE Seminar Recordings” or “Jeff Boldt Nerd”

Acoustical Design for the A/E/C Industry

Purpose and Learning Objectives

The purpose of this presentation is to cover basic terms related to acoustic design in the A/E/C industry and explain how such design has become fundamental.

At the end of this presentation you will be able to:

1. Outline ways to minimize indoor and outdoor noise.
2. Explain properties of human hearing.
3. Identify whether sound values are in sound power or sound pressure.
4. Describe both envelope and HVAC noise control measures.

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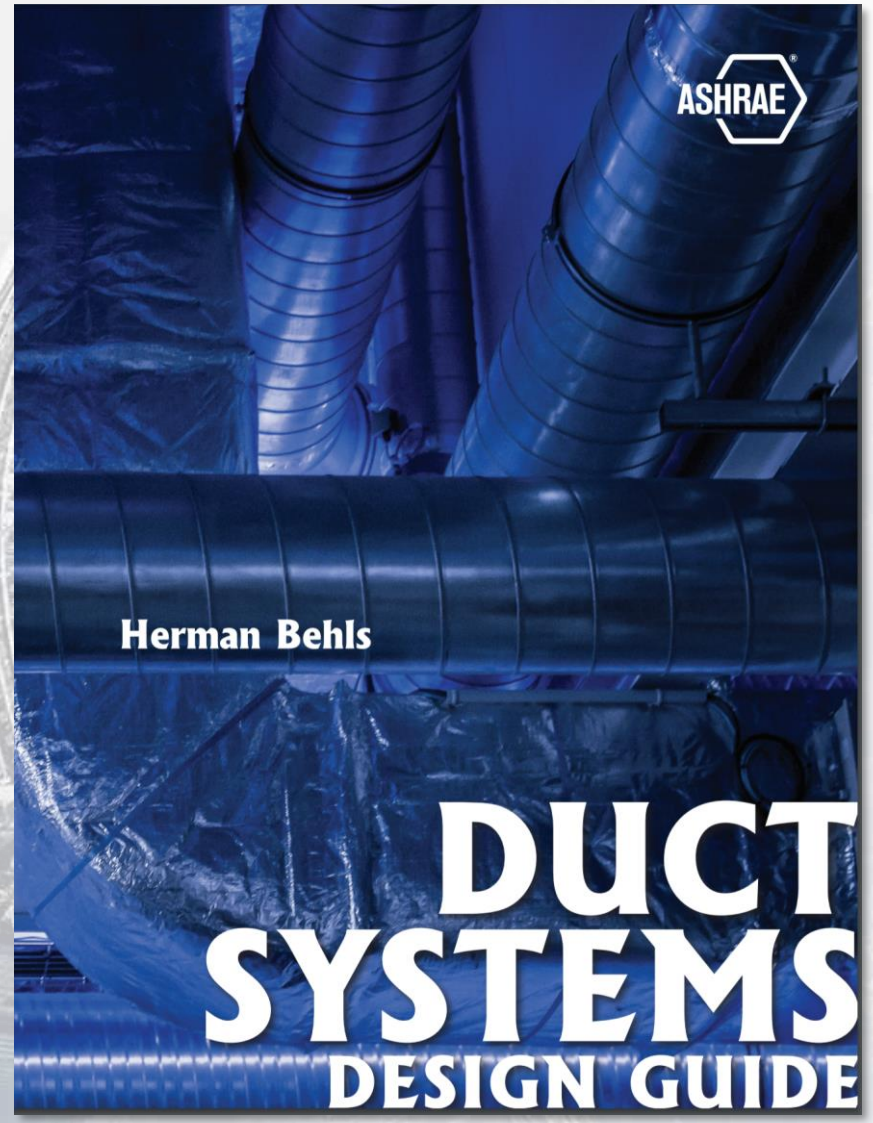
References

- ASHRAE Duct Systems Design Guide
  - Updated acoustics chapter, which contains more information than we have time for today
  - Excellent info about other aspects of duct design
- ASHRAE HVAC Applications Handbook
  - Chapter 49 – Noise and Vibration Control
- SMACNA Duct Design Guide
- Several AMCA Standards & Guides
  - My firm specifies AMCA certified air and performance for fans



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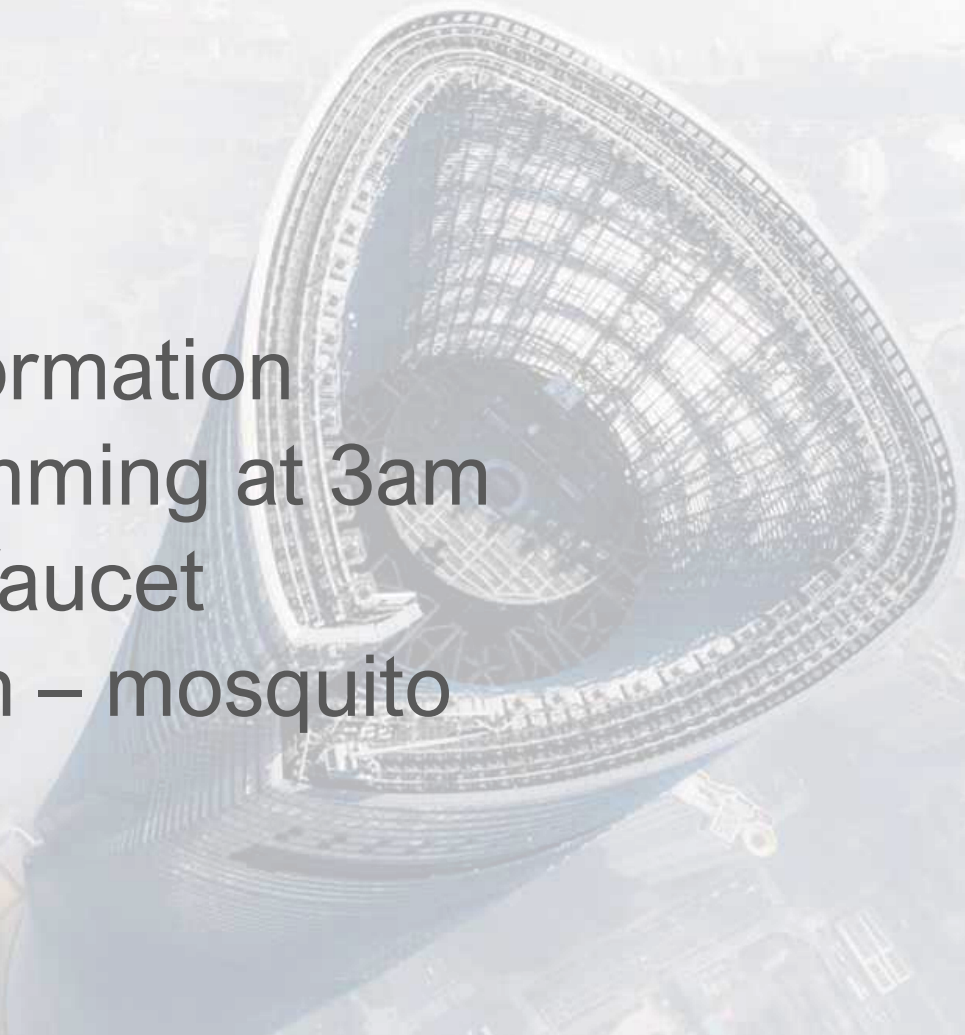
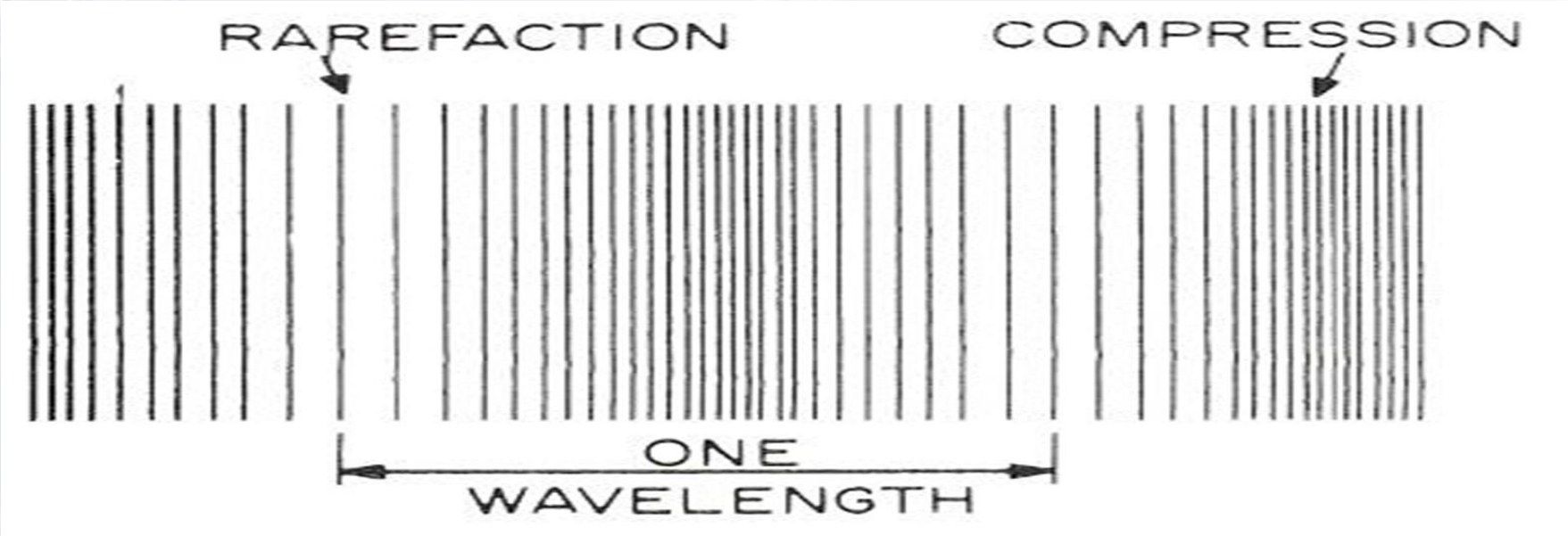
Acoustic Fundamentals

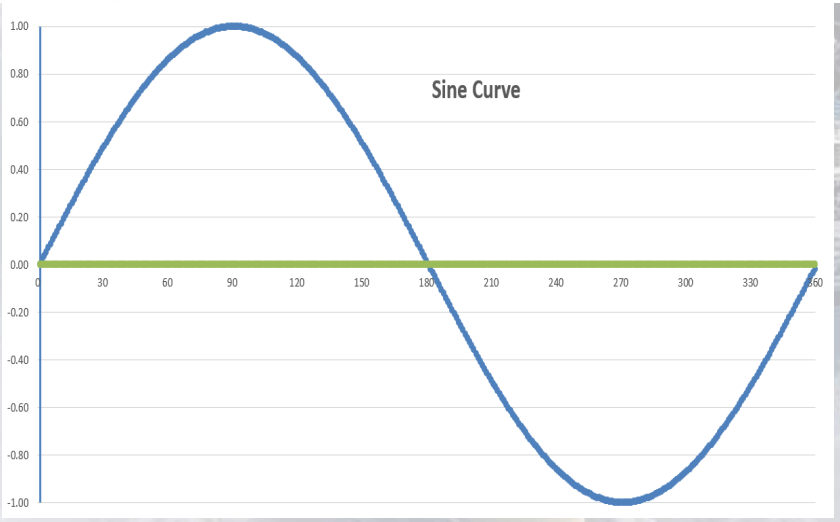
Acoustic Fundamentals

- Noise = Unwanted Sound
  - Too Loud
  - Pure Tones
  - Unwanted or illegal information
  - Wrong time – door slamming at 3am
  - Unpleasant – dripping faucet
  - Unpleasant connotation – mosquito



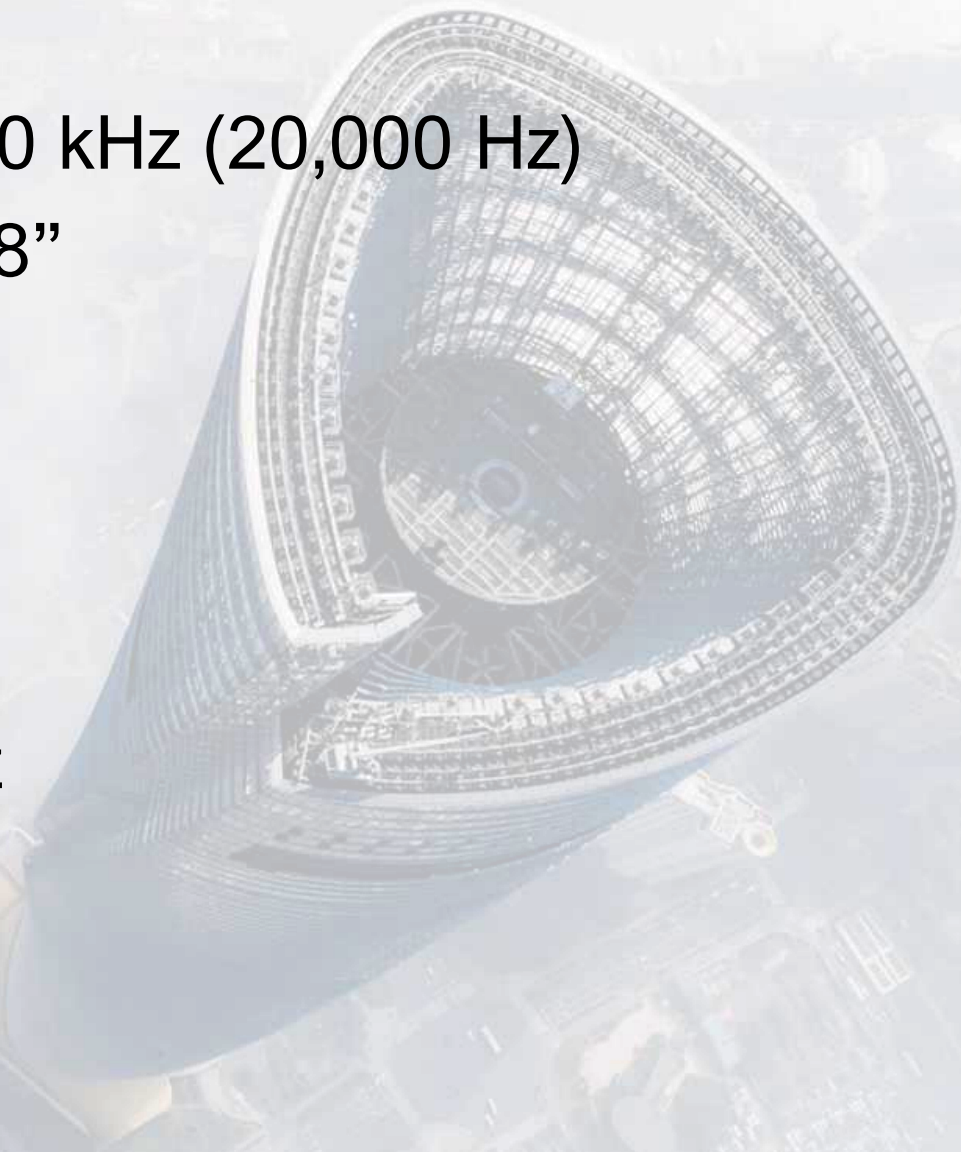
Compression - Rarefraction





Frequency

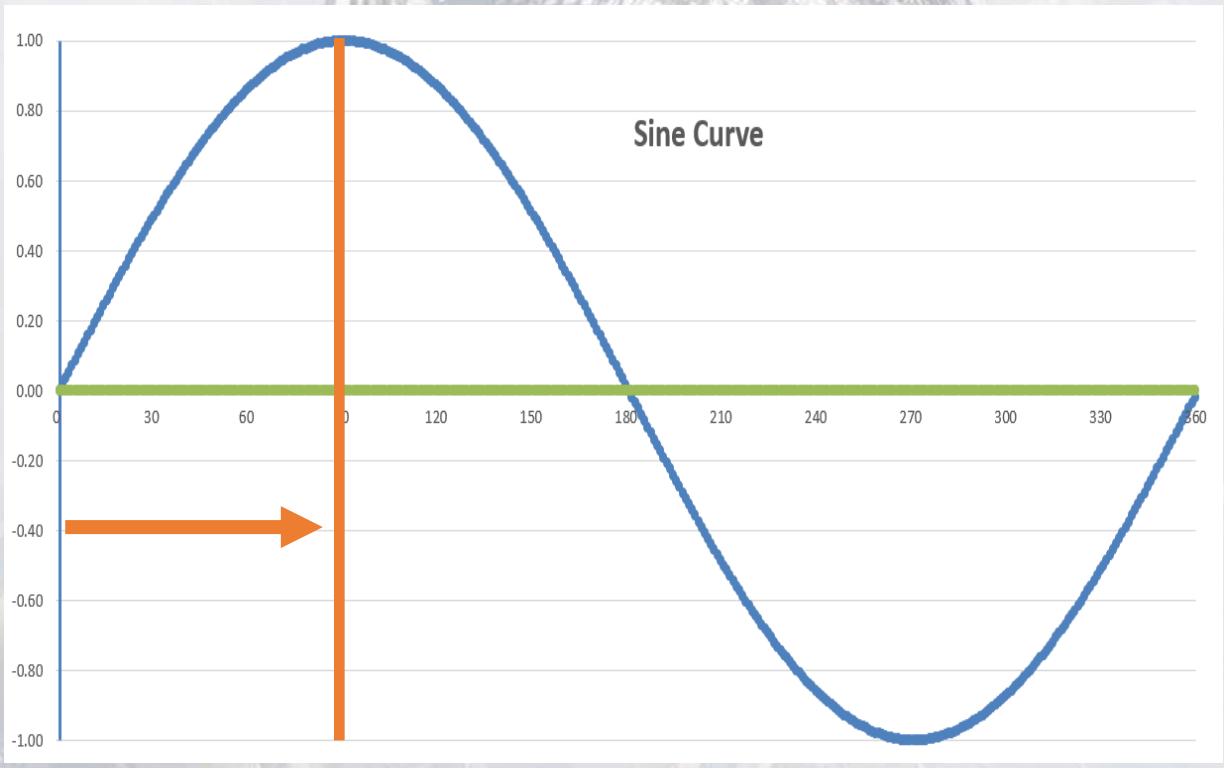
- Audible Range ~ 16 Hz – 20 kHz (20,000 Hz)
- Audible Length ~ 68 ft – 5/8”
- 1,000 Hz ~ 1.1 feet
- Speech ~ 500 – 5,000 Hz
  - 2 to 0.2 feet
- Middle C = 262 Hz
- Grand Piano 28 – 4,186 Hz



Octave Bands

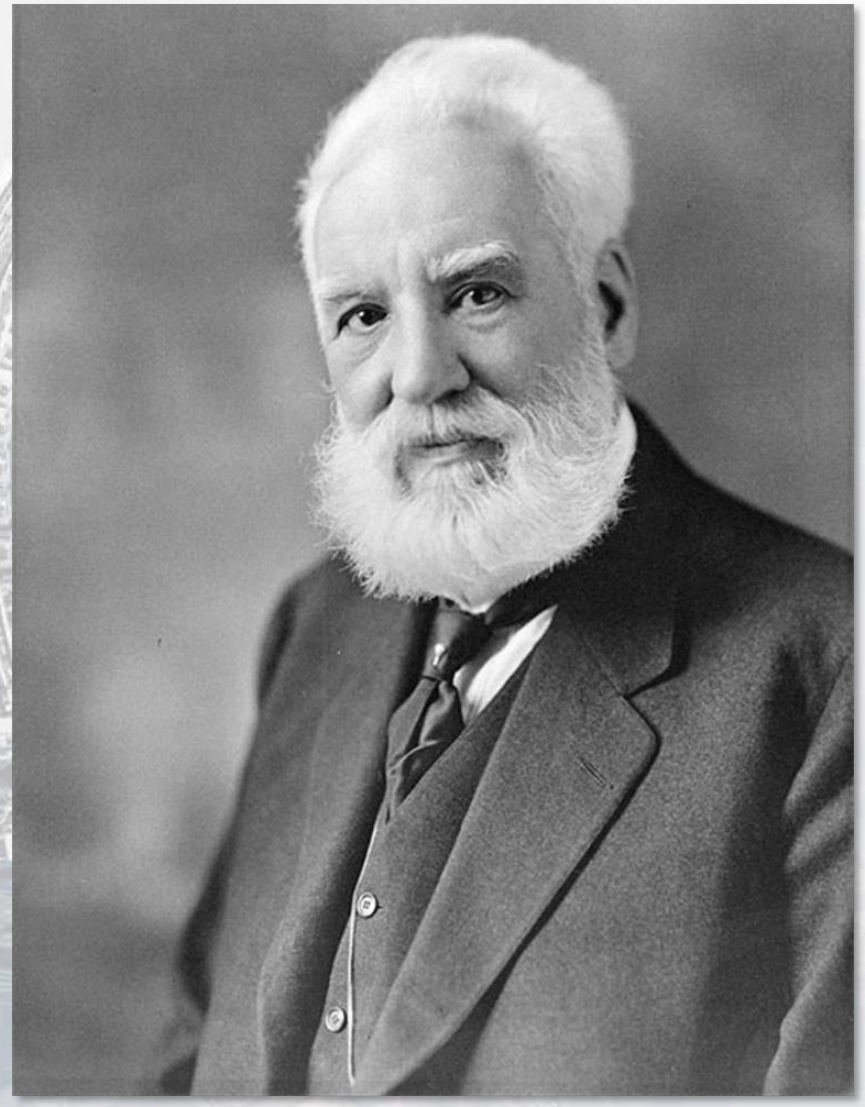
Band No.	--	--	1	2	3	4	5	6	7	8
Center Frequency (Hz)	16	31.5	63	125	250	500	1,000	2,000	4,000	8,000
Wavelength of Center Frequency (feet)	71.4	36.3	18.3	9.1	4.6	2.3	1.1	6.9”	3.4”	1.7”
Range (Hz)	11.2 to 22.4	22.4 to 45	45 to 90	90 to 180	180 to 355	355 to 710	710 to 1400	1,400 to 2,800	2,800 to 5,600	5,600 to 11,200

- Rule of Thumb:
  - Absorptive media should be >1/4 wavelength deep if mounted to a solid surface
- Suspended Ceilings



Decibels

- Used to handle large ranges
- Decibel is a ratio, not a quantity
- Alexander Graham **B**ell
- dB or dBA (weighted or not)!
  - dB = total noise level
  - dBA = human perception of volume



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Volume Range

- Humans hear volume over huge ranges:
  - 140 dB (120 starts pain region)
  - Accuracy of ~ +/- 3 dB
  - Imagine a scale that weighs small ants (1 milligram) and the largest (110,000 ton) aircraft carriers. The dB helps us comprehend this range.
  - Cry in your cubicle 🤦 😢

Sound Power & Pressure

- Lw = SwL = Sound Power = energy
  - This is the total sound emitted by a source
  - Analogy to lighting = Lumens
    - I digress: Speaker efficiency depends on box volume and whether it is a ported speaker, at least in low frequencies. Dispersion depends on tweeter size (smaller = better).
- Lp = SpL = Sound Pressure
  - This is the pressure your ears feel
  - 0 dB is audible (barely, if you are young)
  - Negative numbers are inaudible, but exist
  - Analogy to lighting = Foot Candles

Image Courtesy of Klipsch

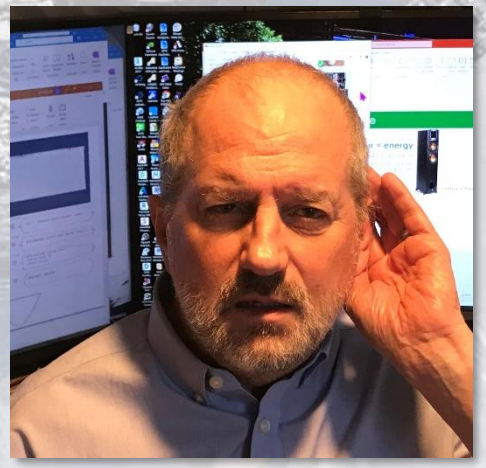

Image courtesy of IMEG Corp.

Weighting

- **dB(A) aka dBA is the most common one-number acoustic value**
  - dBA resembles 40 phon curve
  - OSHA uses dBA
- **dB(B) is for louder sounds**
  - Resembles the 80 Phon contour
  - Never used
- **dB(C) is for even louder sounds**
  - dBC is nearly unweighted
  - C and “flat” are often the same on meters
- **Ear is more linear at louder sound levels**

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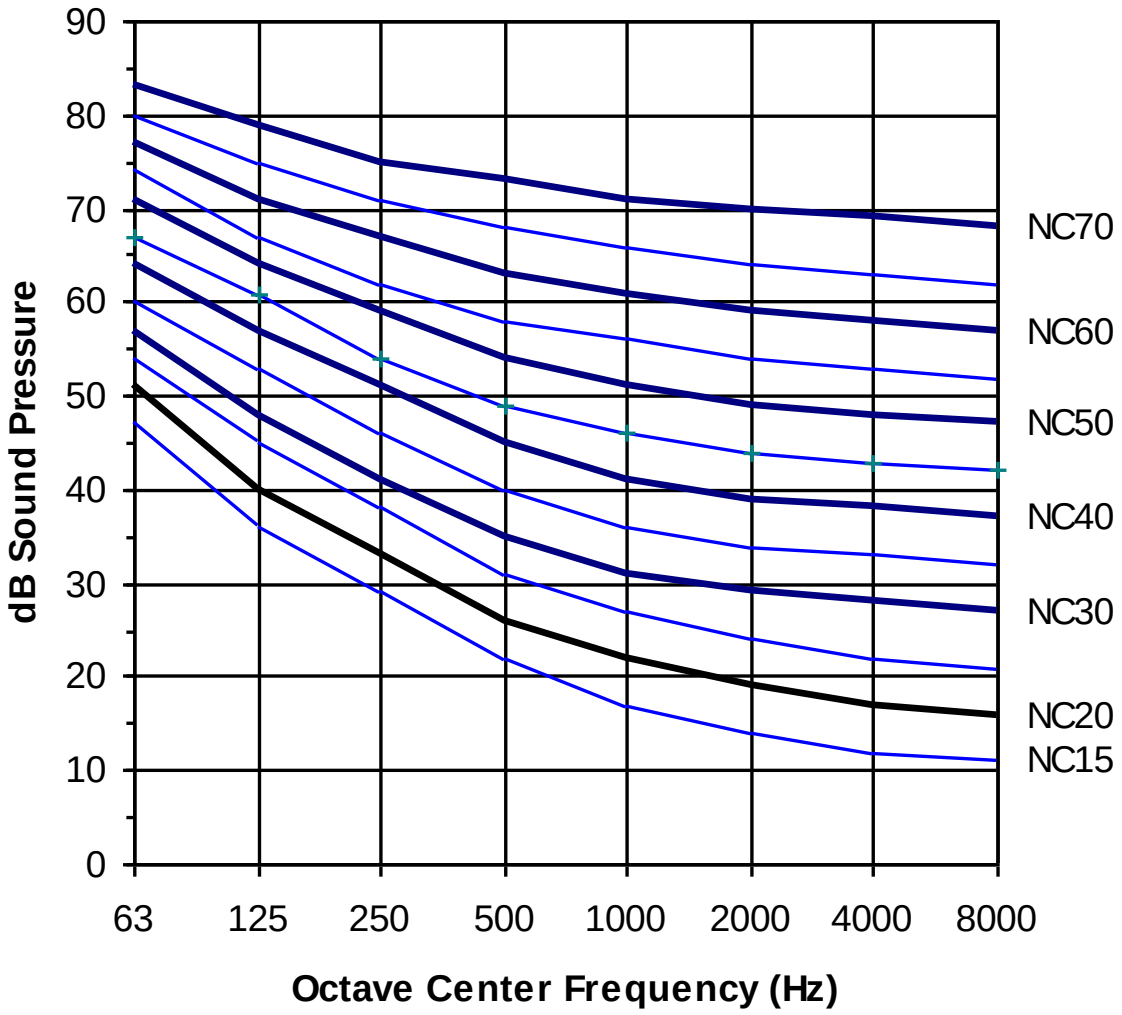
NC Curves

- Intended to measure annoyance
- Worst case determines rating



Noise Criteria (NC) Curves

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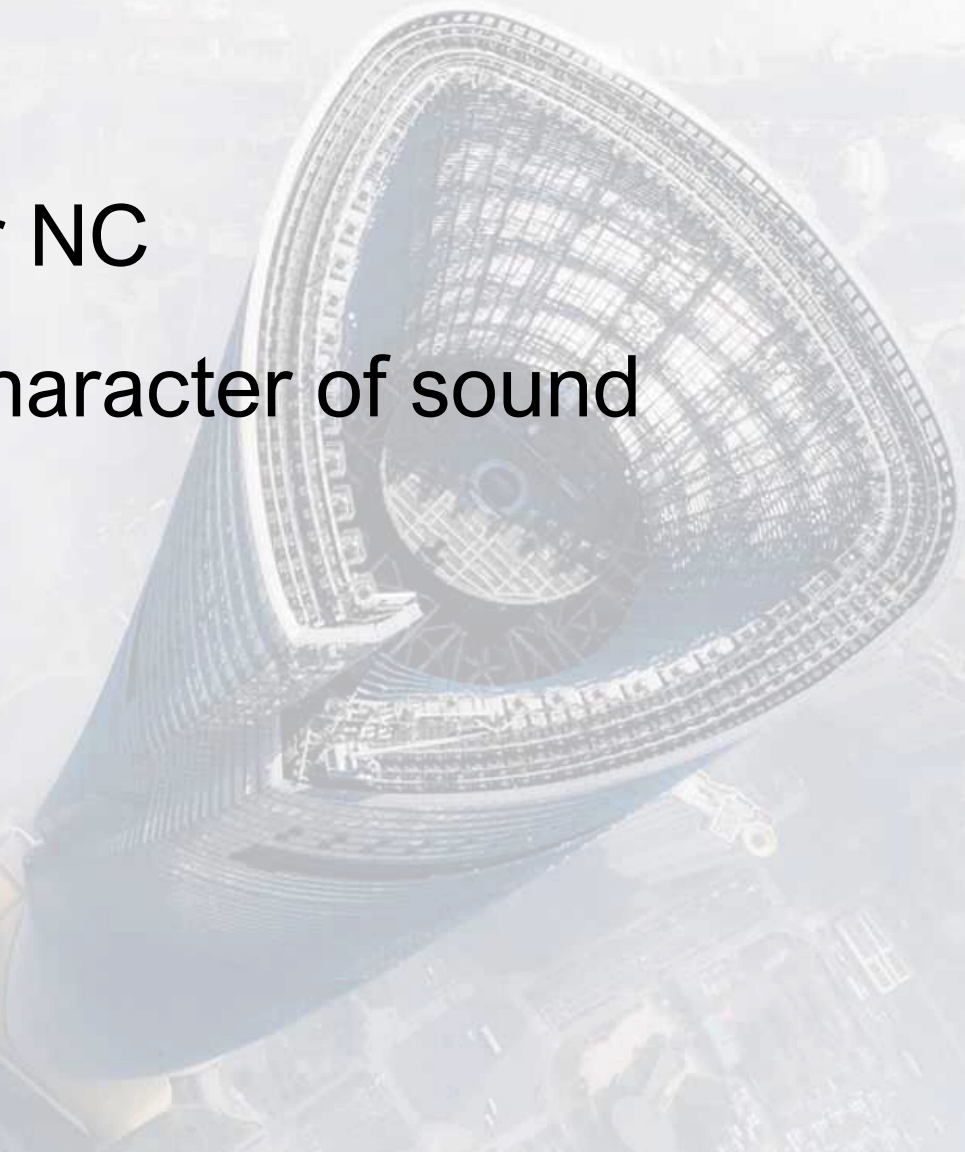
RC (Room Criteria)

- Developed by ASHRAE
- Not as common as dBA or NC
- Gives information about character of sound
  - RC-35R = Rumble
  - RC-35H = Hiss



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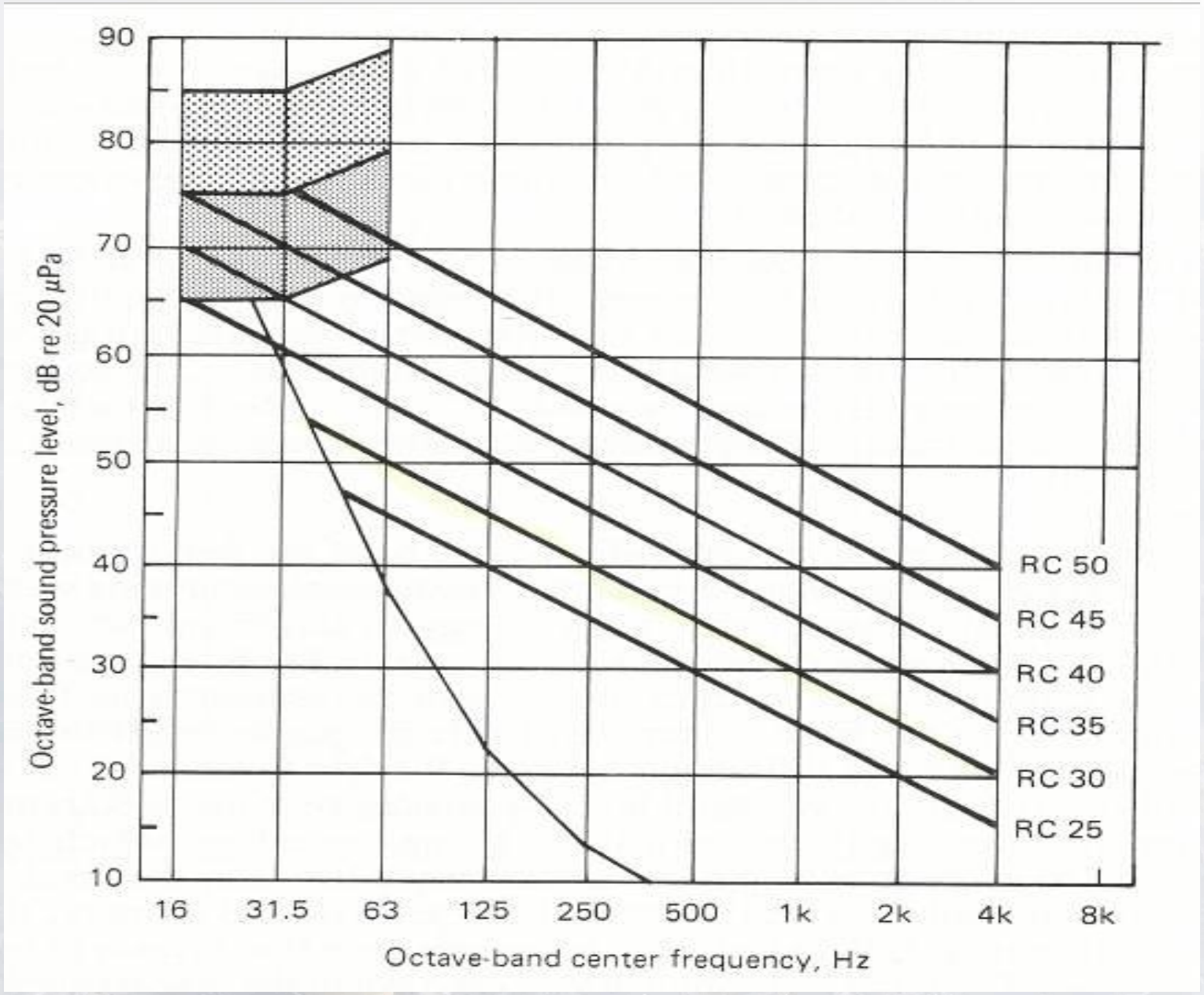
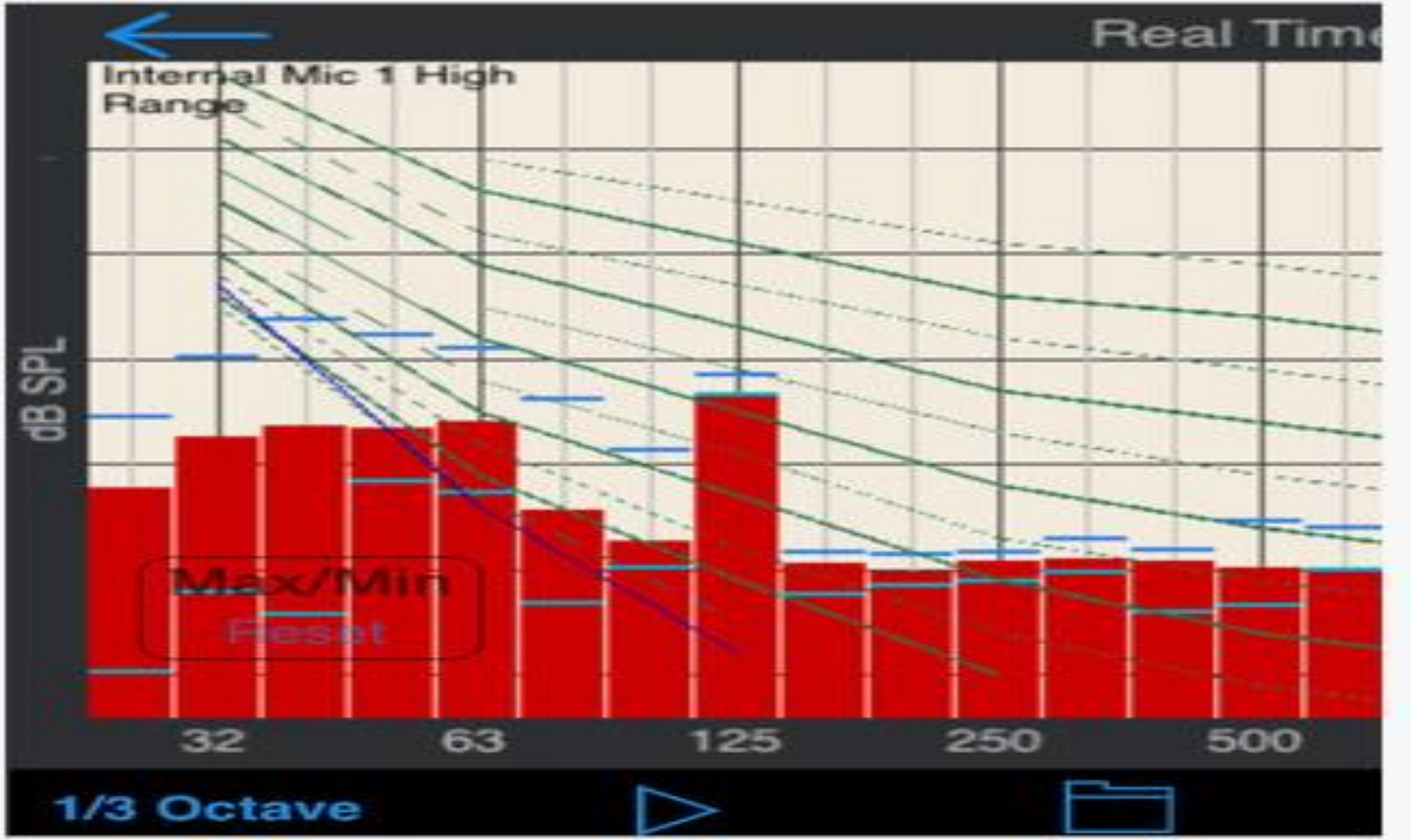
RC Curves


90
80
70
60
50
40
30
20
10
Octave-band sound pressure level, dB re 20 μPa
16
31.5
63
125
250
500
1k
2k
4k
8k
Octave-band center frequency, Hz
RC 50
RC 45
RC 40
RC 35
RC 30
RC 25

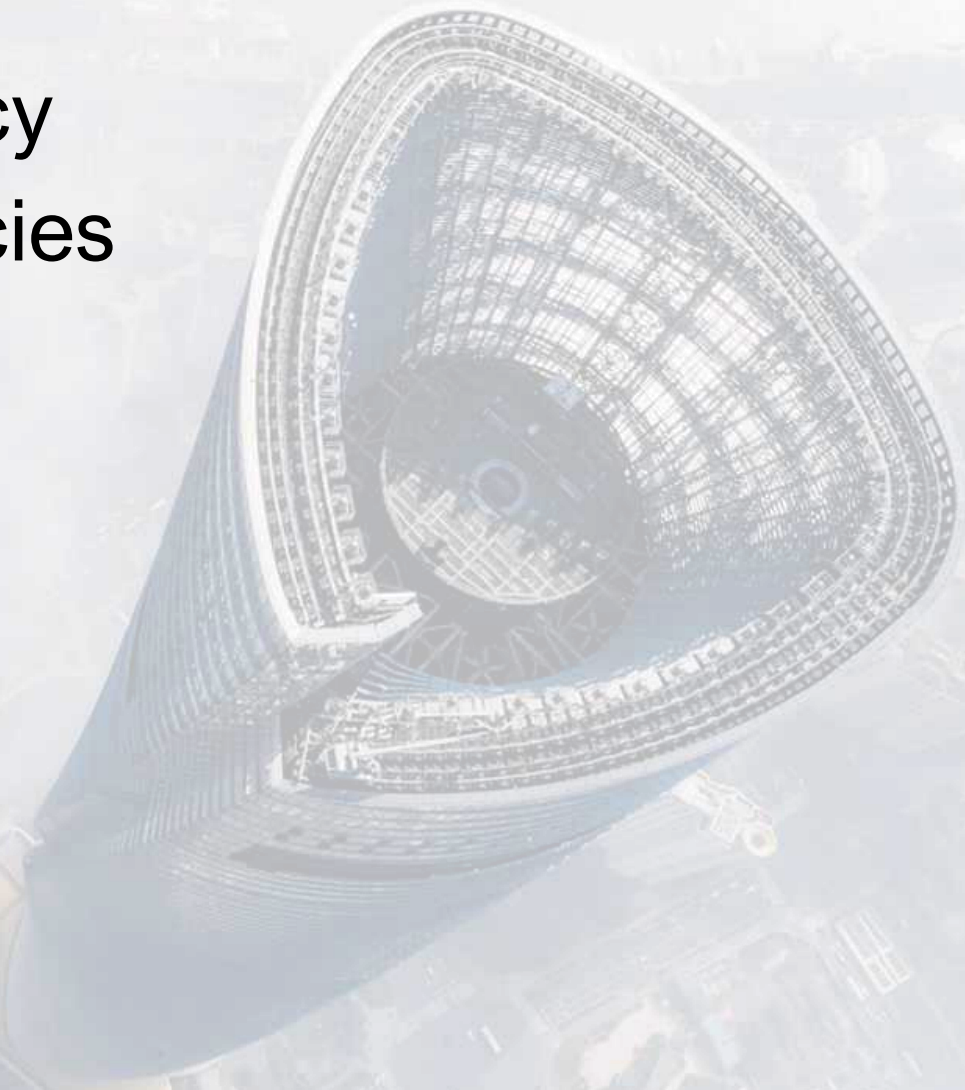
Phone Apps


Real Time
Internal Mic 1 High Range
dB SPL
Max/Min
Reset
32
63
125
250
500
1/3 Octave

Human Perception of Sound

Psychoacoustics

- Octave = double frequency
- Preferred center frequencies
  - 31.5 Hz
  - 63 Hz
  - 125 Hz
  - 250 Hz
  - 500 Hz
  - 1K, 2K, 4K, 8K
  - 16K



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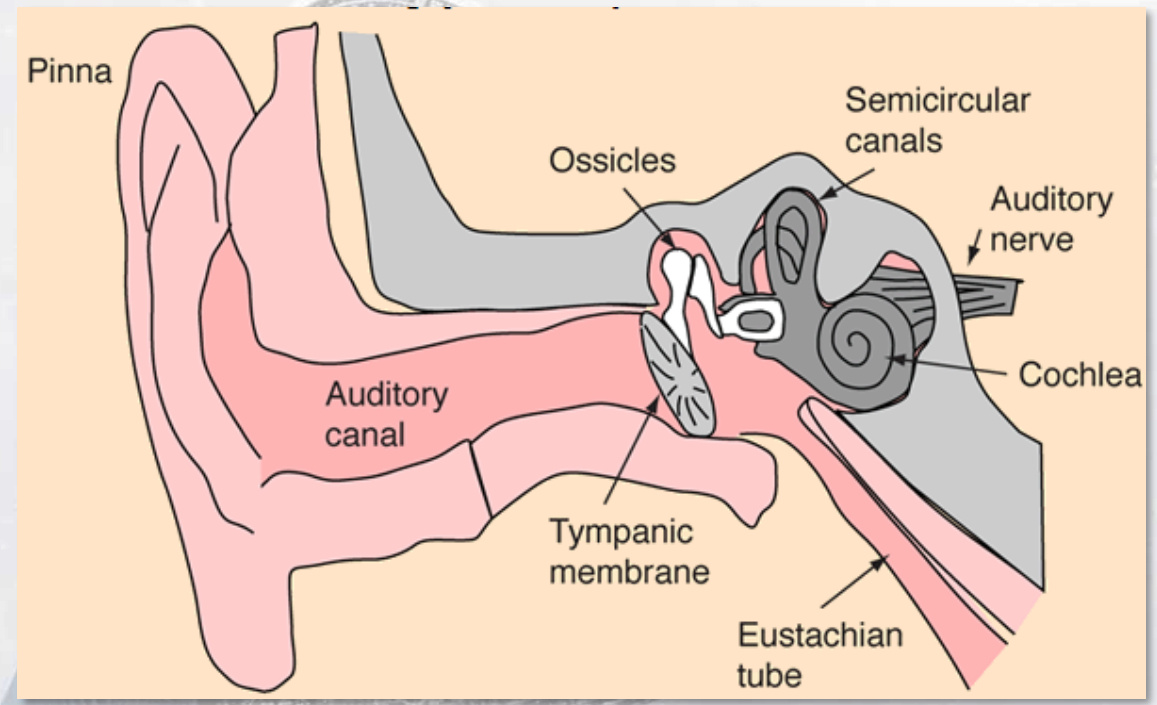
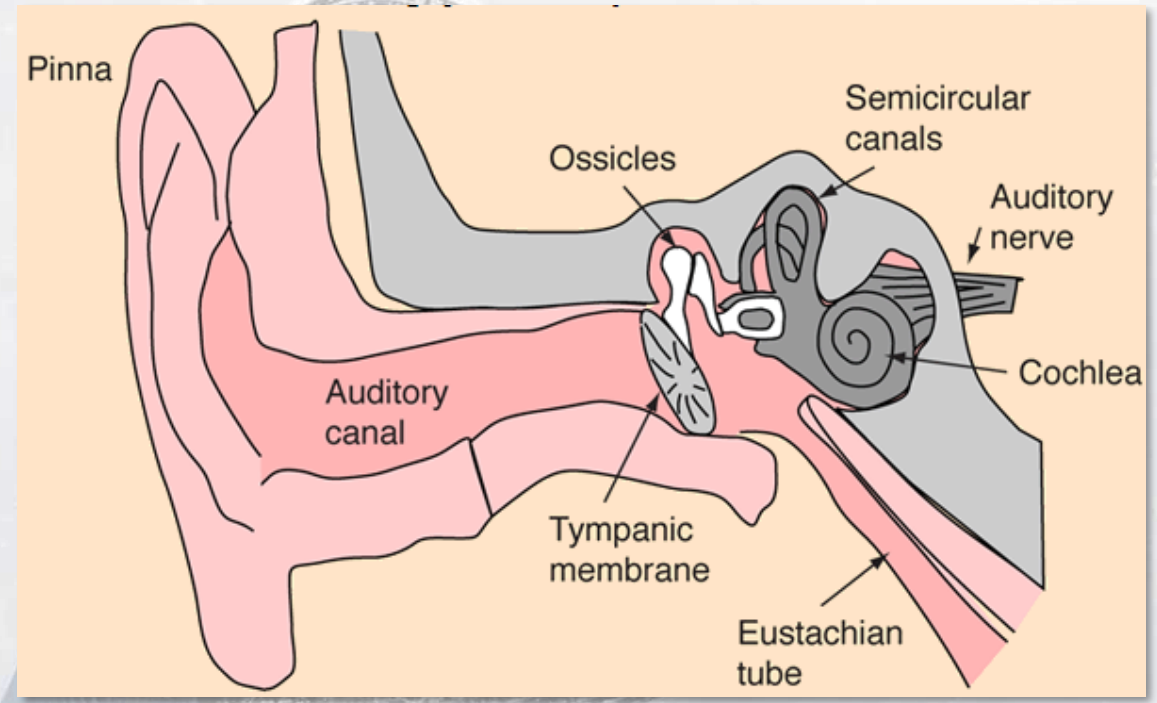
Psychoacoustics 2

- Hearing loss is either:
  - Conductivity – mechanical failure
    - All can be repaired
  - Sensory-Neuro – electrical failure
    - Sensory-Neuro is more common
    - Sensory-Neuro is irreparable



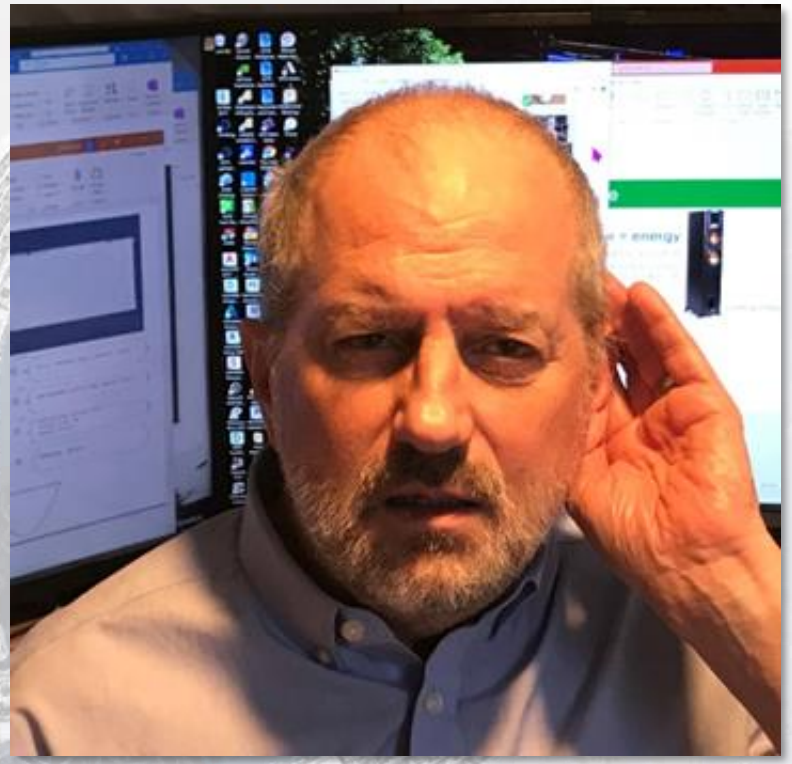
Psychoacoustics 3

- Hearing loss is either:
  - Conductivity – mechanical failure
    - All can be repaired
  - Sensory-Neuro – electrical failure
    - Sensory-Neuro is more common
    - Sensory-Neuro is irreparable
  - IMO this clearly demonstrates the superiority of mechanical engineers



Psychoacoustics 4

- As we age, men lose hearing faster than women
- Especially in high frequencies
- Most speech information is in high frequencies (consonants)
- Women have higher frequency voices
  - Does this mean that most of the useful information is from women?🤔



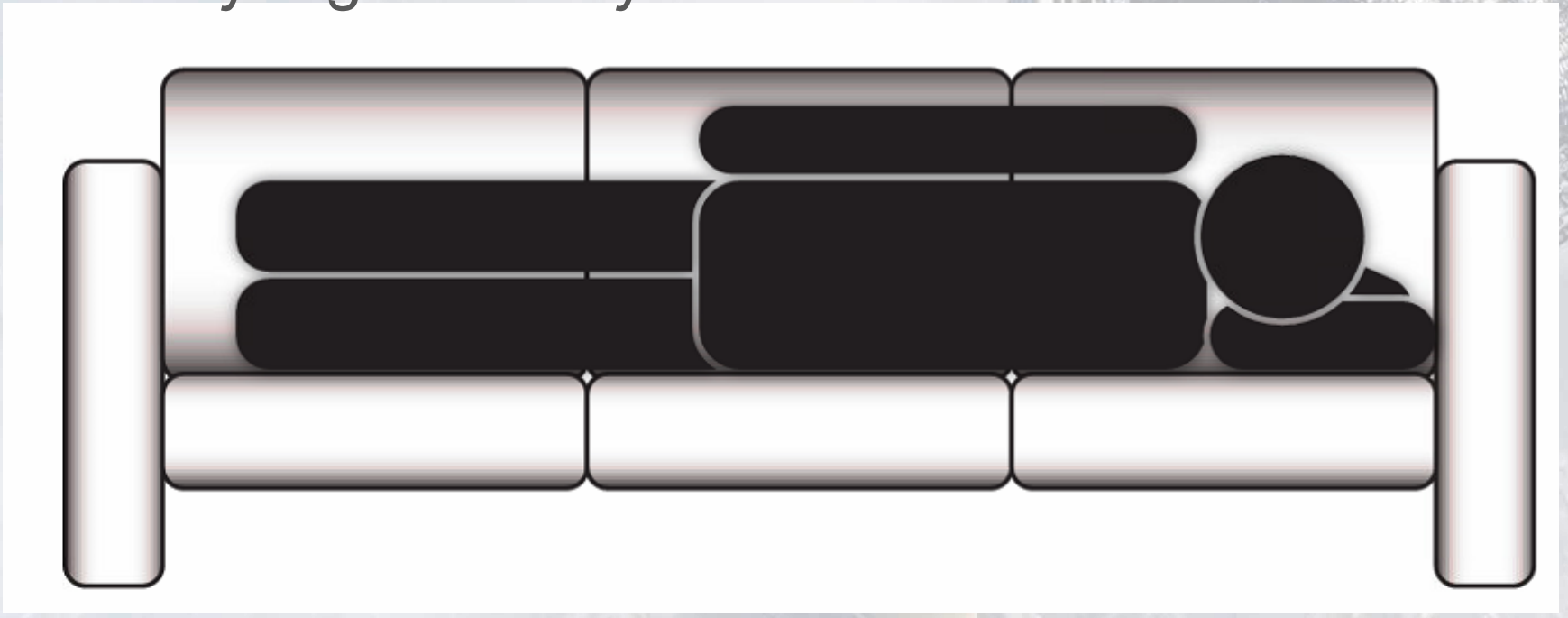
Honey, I can barely hear you. And all I do hear sounds like Charlie Brown's teacher.

Psychoacoustics 5

- Hyperacusis = poor ability to accommodate large volume ranges
  - Affects noise design for restaurants with the elderly & young
- Sense of direction (localization) is mostly from phase and directional effects

Psychoacoustics 5

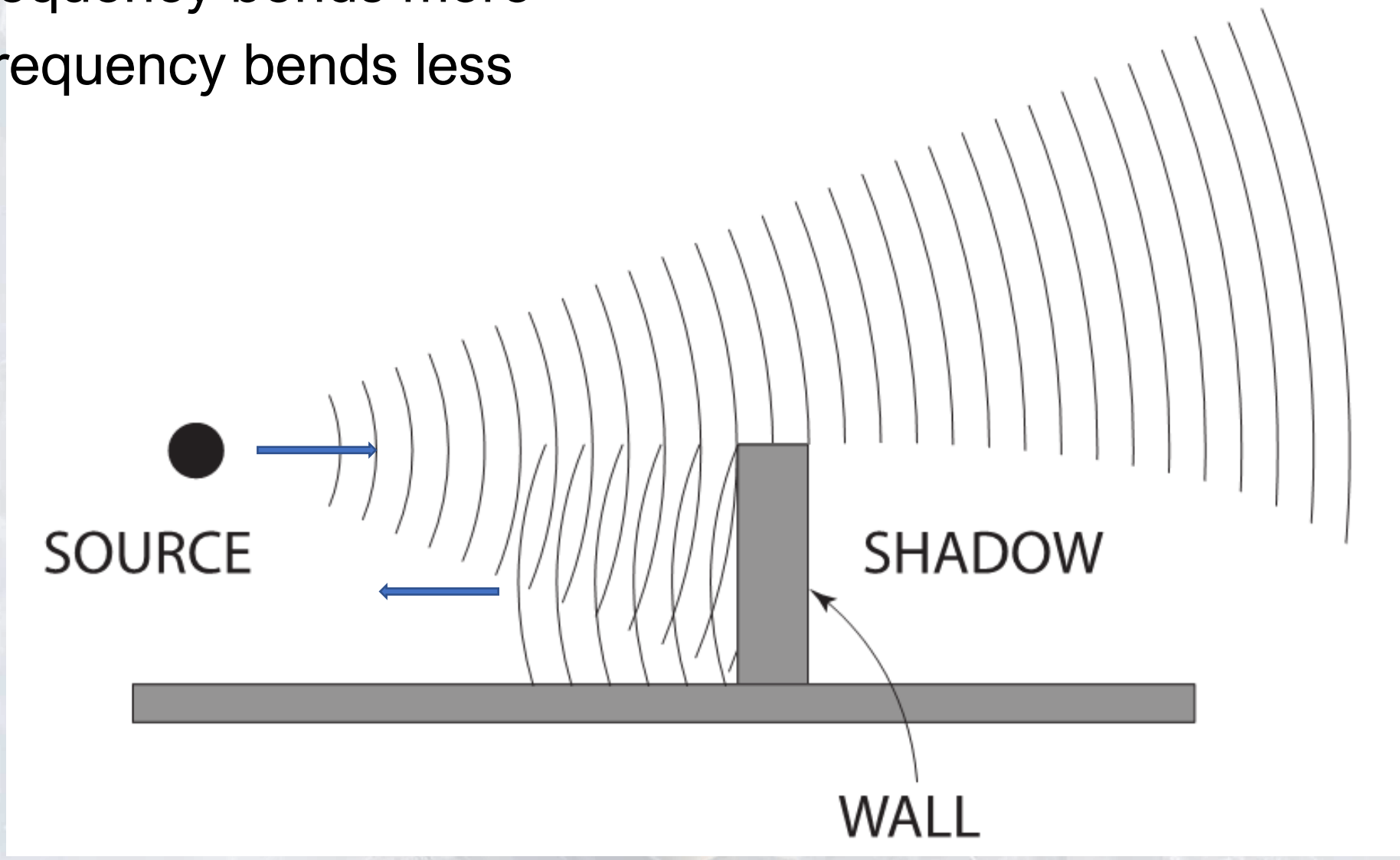
- Sense of direction (localization) is mostly from phase and directional effects
  - Concert hall design key design factor
  - Vertical symmetry – Dolby
  - I don’t yet grok Dolby Atmos



Outdoor Noise

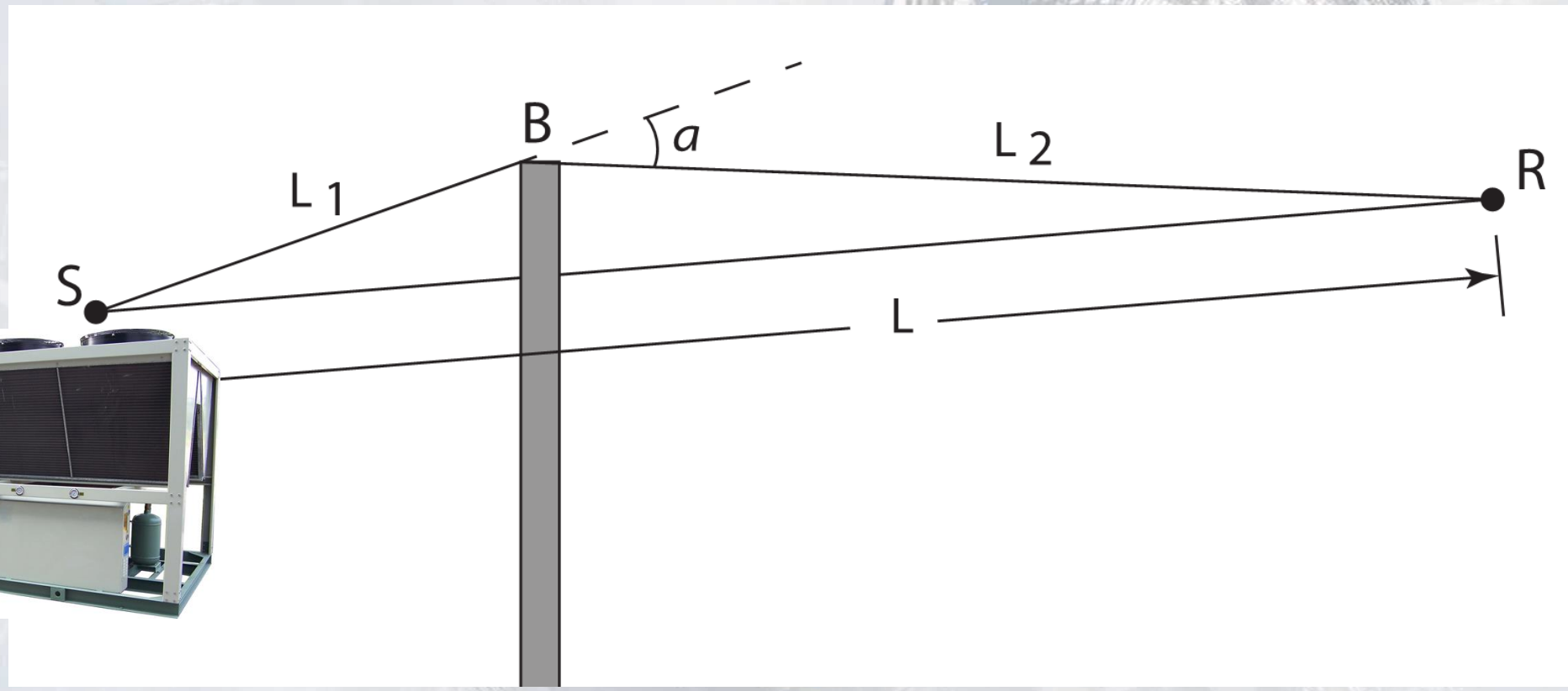
Outdoor Shadowing

- Low frequency bends more
- High frequency bends less



Outdoor Barrier Effect

- Barriers – Be close, be high
  - Noise reduction depends on extra distance divided by wavelength
  - Goal. Set unit close to the barrier!
  - Interstates



Illinois Title 35 Emergency Generator

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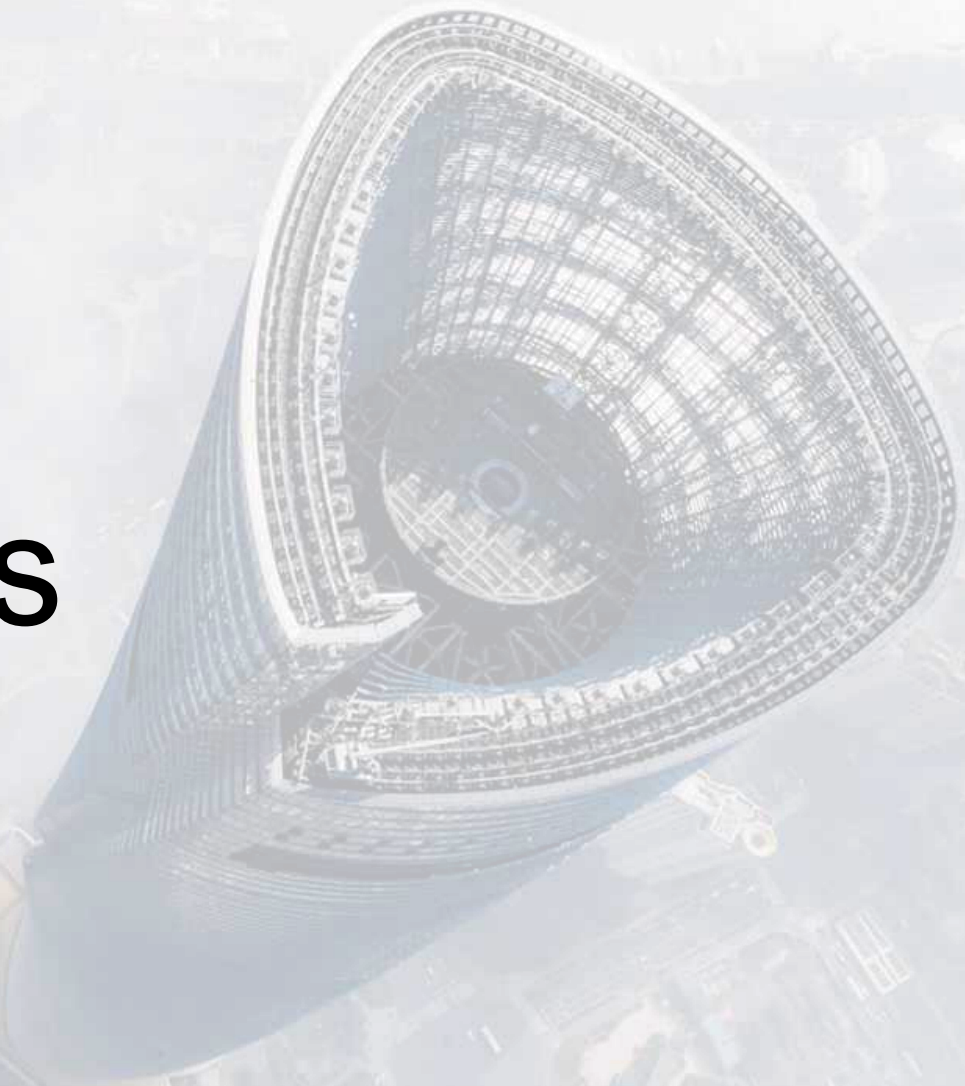
Room Acoustics



Reverberation Time (RT60)

- Important in larger auditoriums, classrooms
- Decay rate measured in seconds (RT60)
- Excess reflection reduces speech intelligibility (echo)
- Cited by LEED and ANSI 12.60 for fundamentals
- Longer = good for organ not speech
- Shorter = higher speech intelligibility

Flanking Paths and Gaps

- Door undercuts are #1 problem
  - 1% leak is a 20-30 dB leak, (4-8 times louder)
  - Gasketing doors is cheap
- STC-20 door in STC60 wall = STC 25; common mechanical room problem!
- Even small leaks are very bad, especially for quiet rooms
- A STC-60 wall with 1% gaps is really ~STC-30
- Back-to-back receptacles
- Hospital headwalls

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Glass STC

- Thicker is better
- More panes increase STC in General
- Large gaps increase STC
  - Best = 2”
- Laminated glass increases STC (like a car windshield)
- Two different pane thicknesses are better than two identical
- Acoustic glass can be exterior or interior

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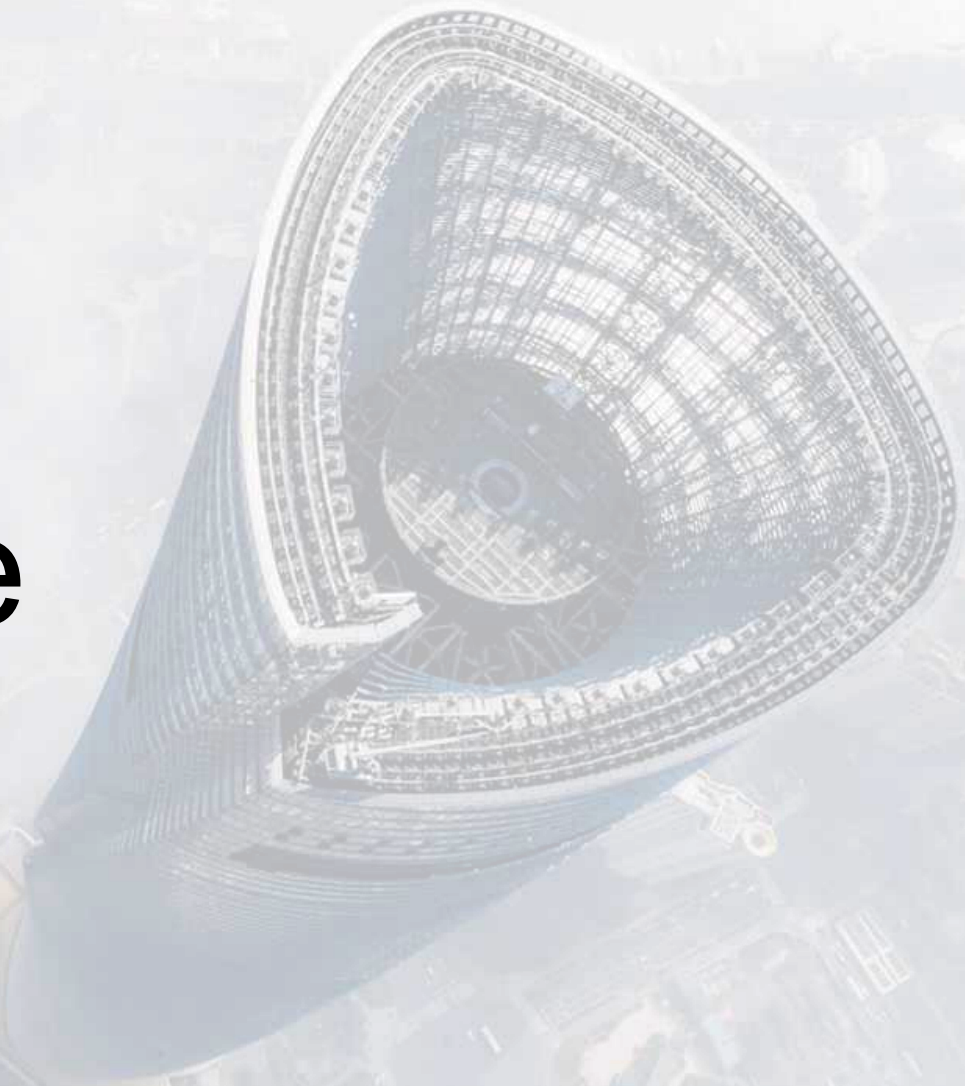
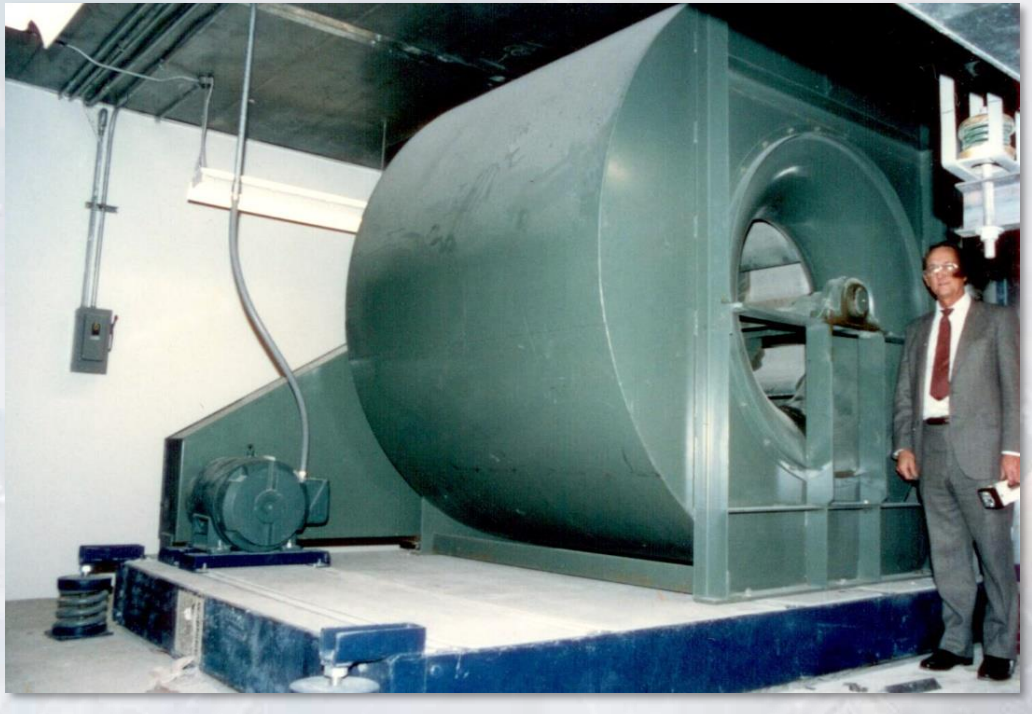
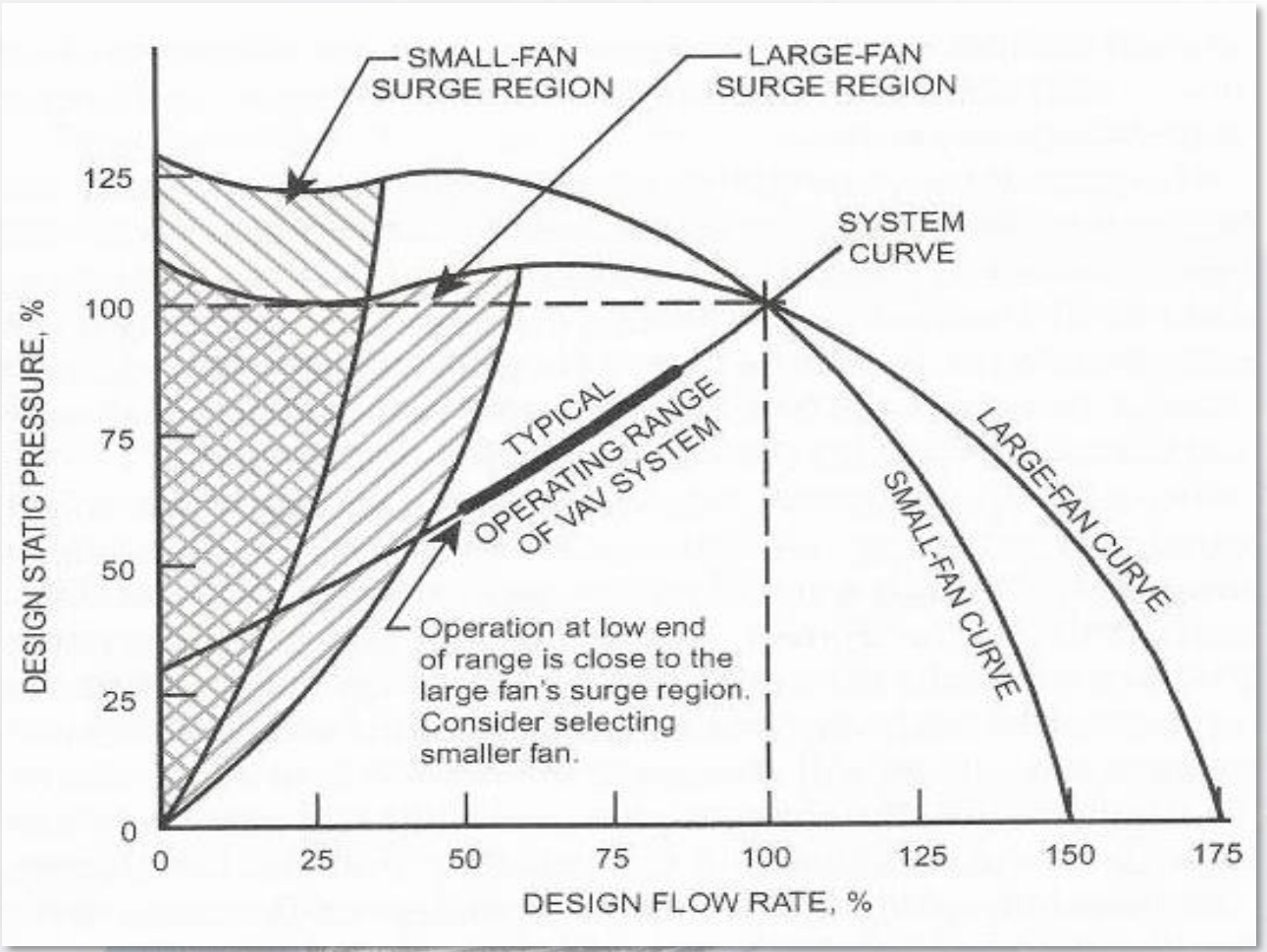
Fan & Air Noise



Fan Surge

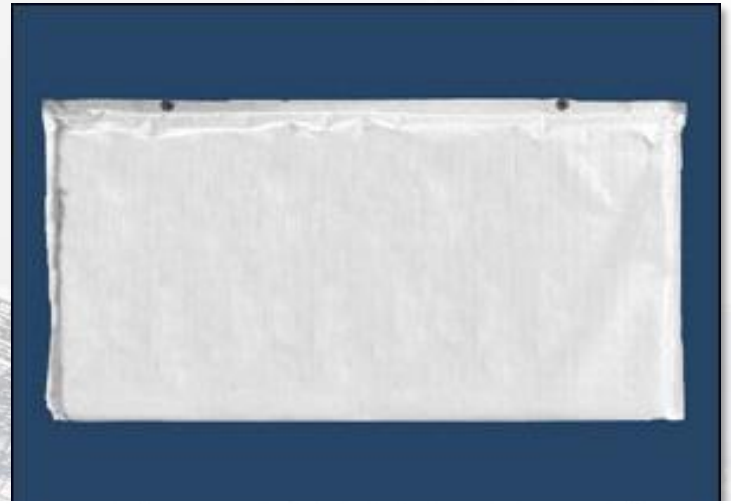
- Big Fan
- 70,000 CFM
- Iowa Public TV

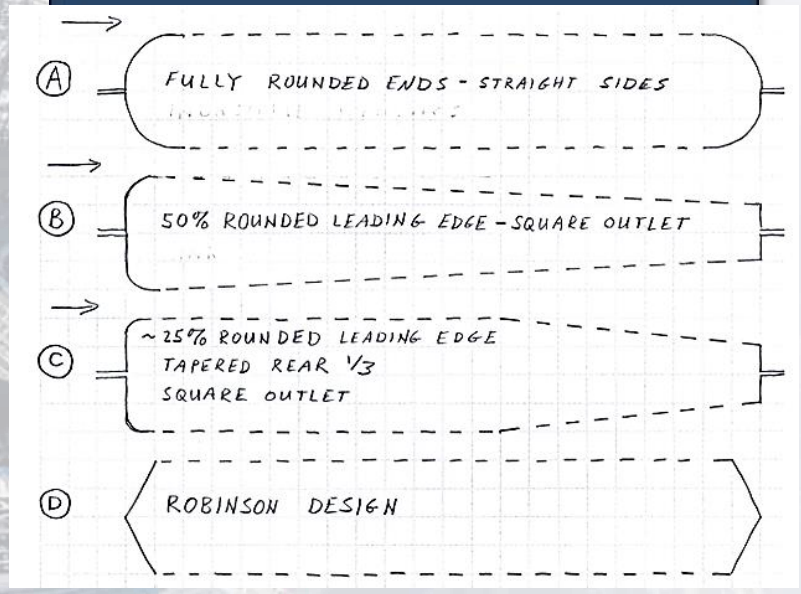


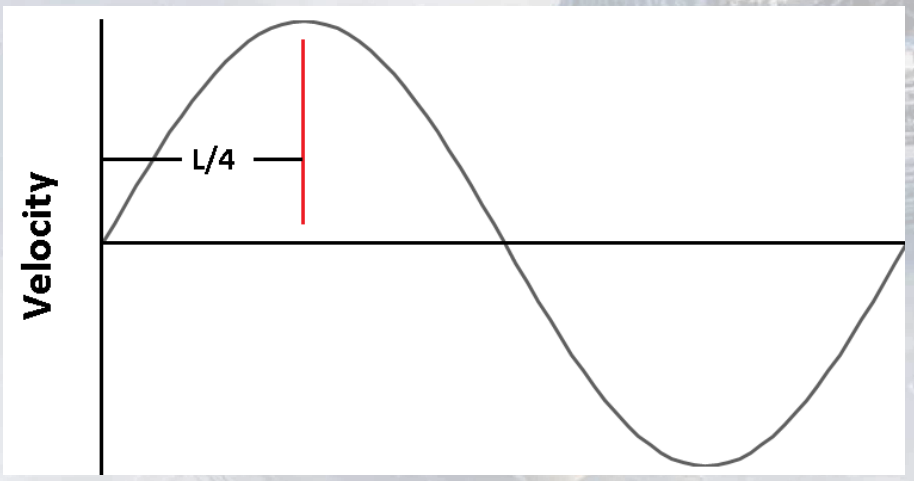


Dissipative Absorption

- Dissipative Absorption
  - Friction converts noise to heat
  - Typically, fibrous materials
  - Should be ~1/4 wavelength deep or held away from rigid surfaces
  - May need covering for:
    - Cleanliness
    - Durability
    - Vapor barrier





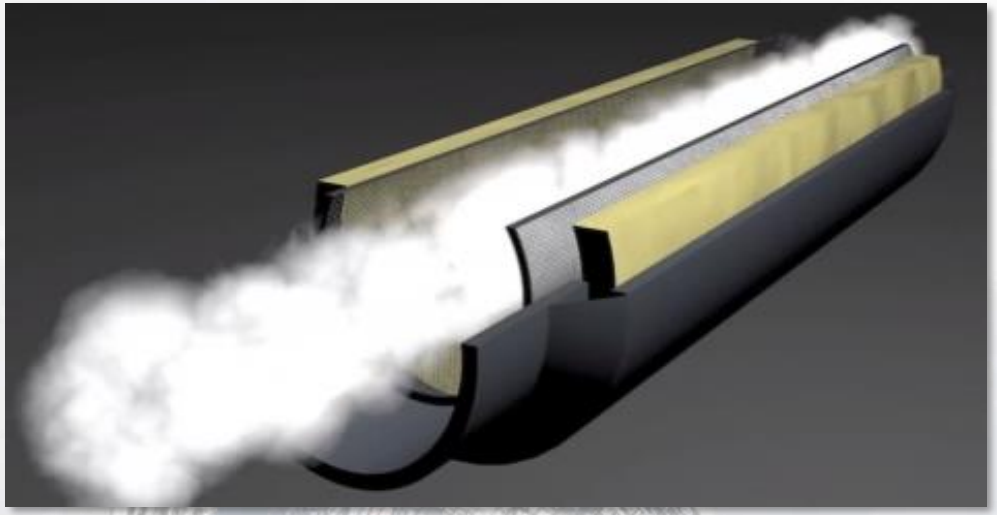


Reactive Absorption

- Reactive Absorption
  - Tuned frequencies
  - Very narrow band if not dampened
  - Best for narrow frequencies
  - Vehicle mufflers
  - Perforated panels – small holes
  - Can’t equal absorptive performance
  - Gypsum board - Transformers

Reactive Absorption

- Mufflers

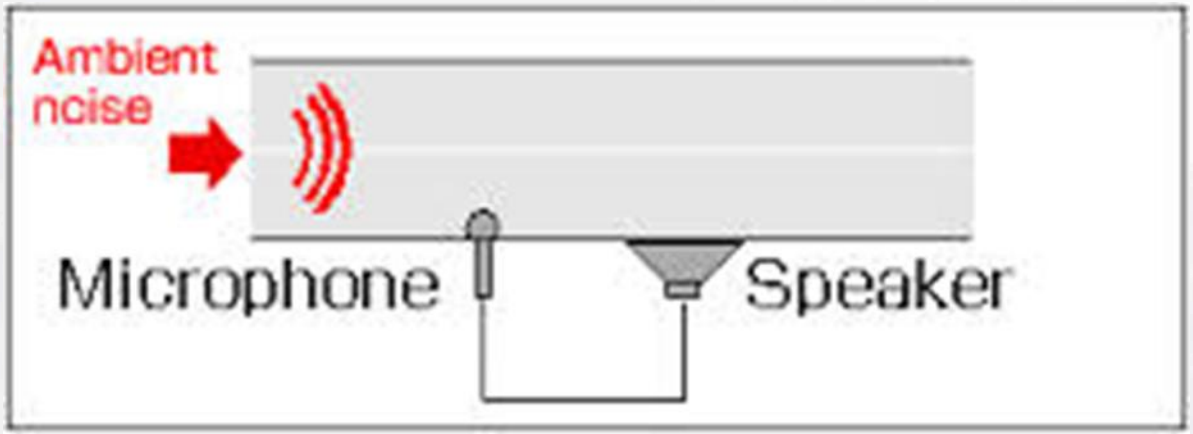


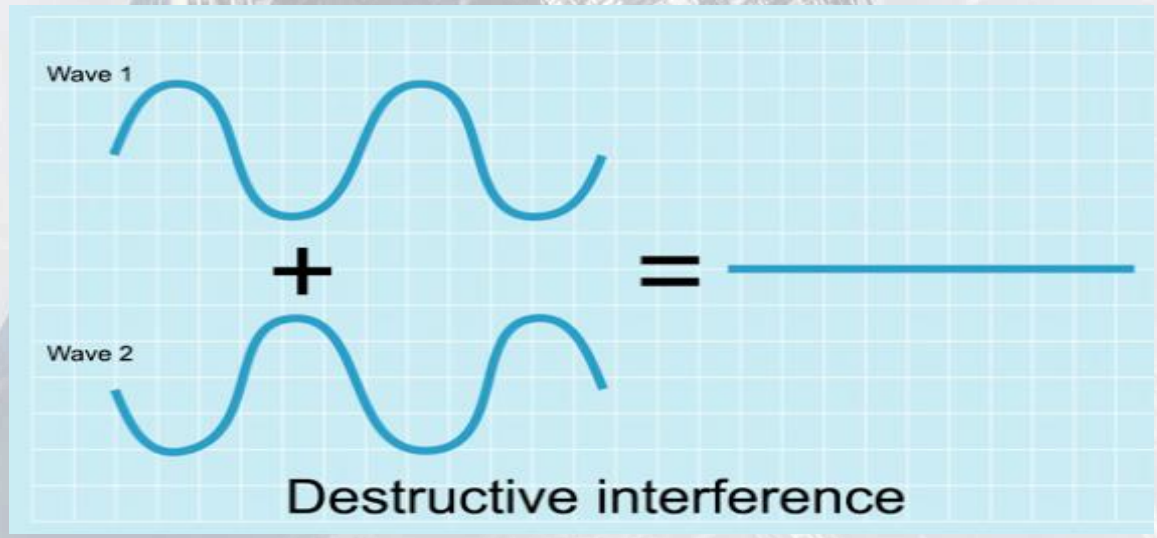
Dissipative (“packed”) muffler

Reactive muffler

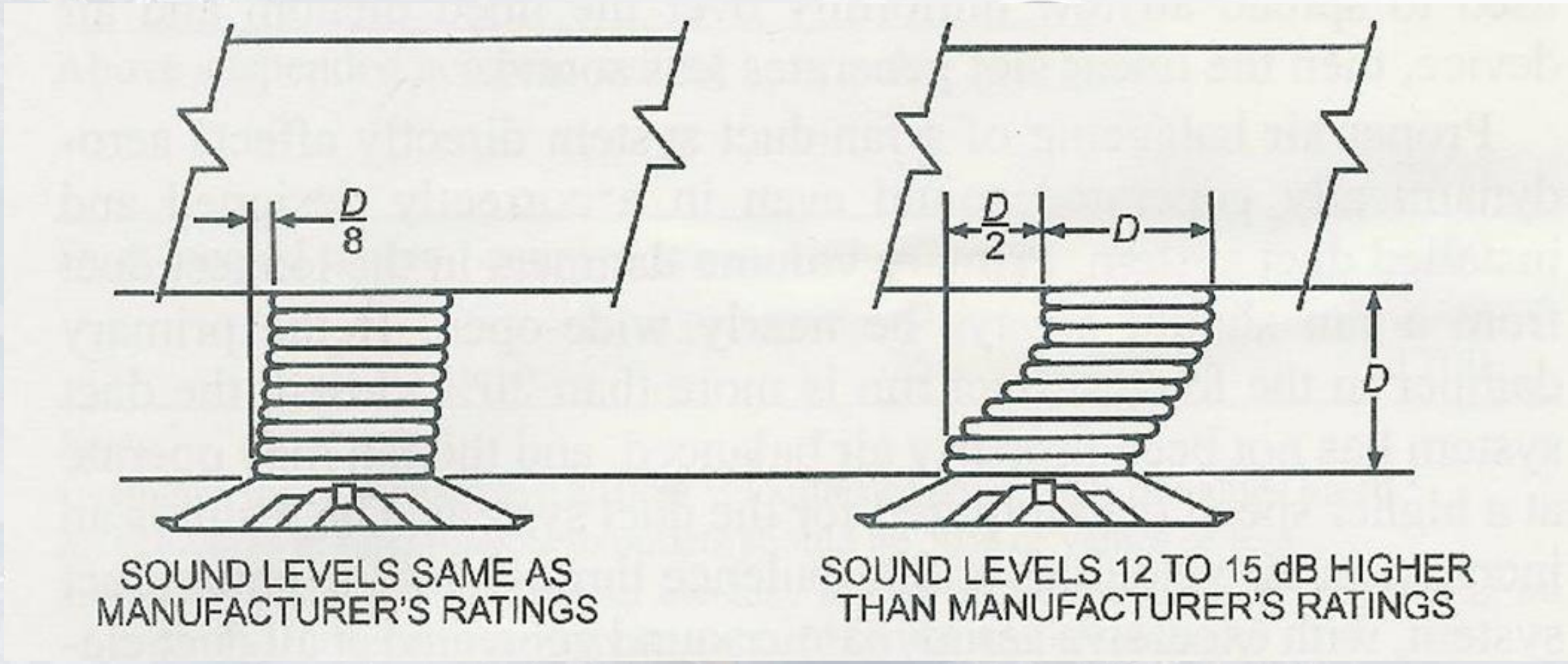
Active Absorption

- Active
  - Measure and counter noise
  - Needs to be a controlled situation
  - Digisonix was the last manufacturer I know of
  - Works best at low frequencies
  - Absorptive silencers were cheaper, except maybe at very low frequencies

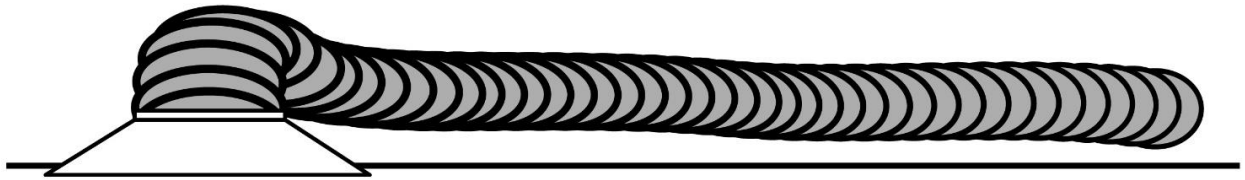




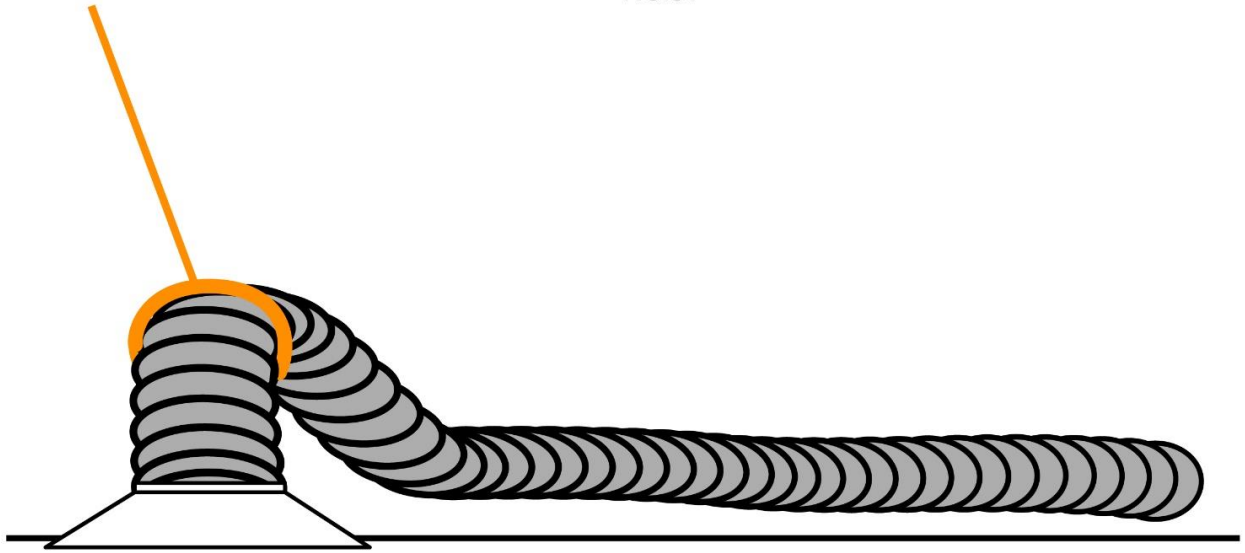
Alignment of Flex Duct



Be a Hero!



NOISY



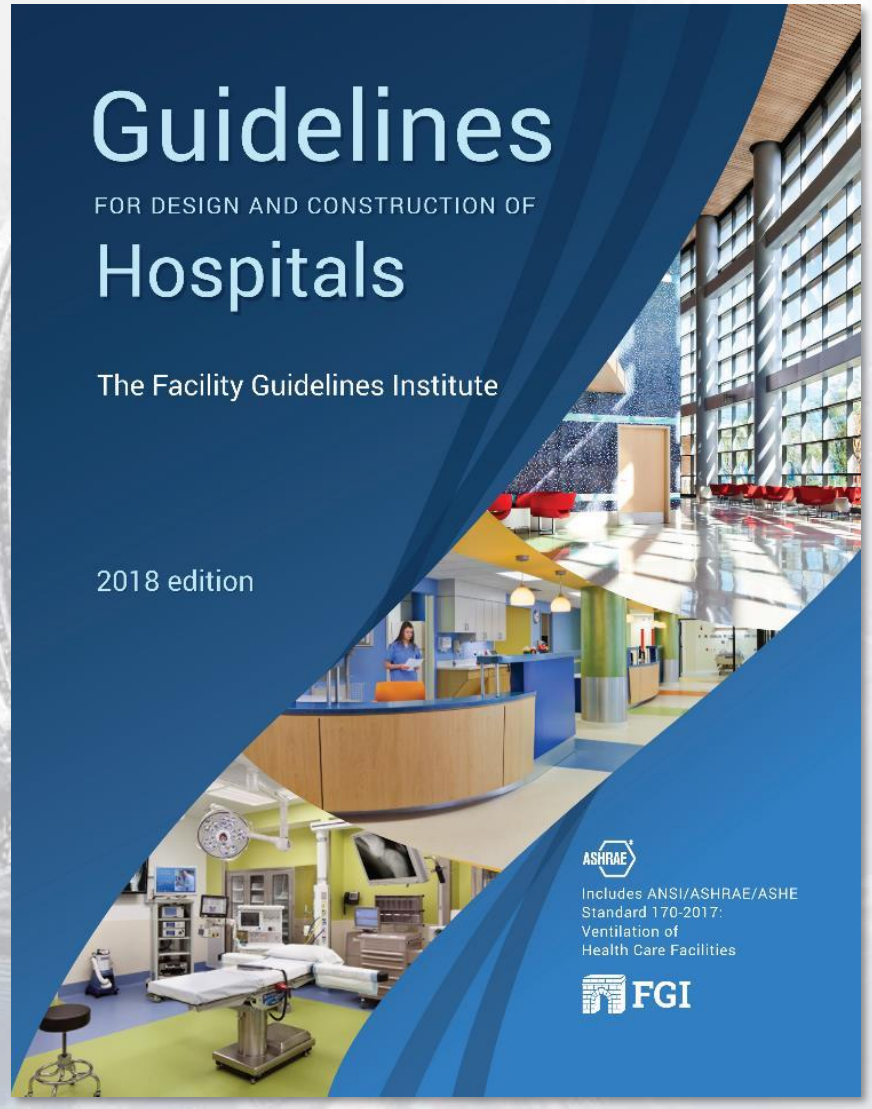
QUIET

Healthcare

FGI & HCAHPS – Why Do I Care?

FGI – Facility Guidelines Institute

- Too long to cover in detail
  - Code in some states (e.g., Iowa)
  - Always good advice for patient satisfaction
  - Strict about acoustics
  - Acoustical categories
    - Site Exterior Noise – Difficult in cities
    - Speech Privacy - HIPPA
    - Room Sound Absorption (NRC)
    - Room Noise Levels (NC, HVAC, ambient)
    - Isolation Between Rooms (STC)
    - Vibration (floor moving-structural)
  - Now 3 volumes



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Laws

- **OSHA for employees**
  - 80 dBA = have a plan!
  - 85 dBA for 8 hours limit
  - 90 dBA-4 hours, 95 for 2, 100 for 1, 105 for 30 minutes, etc.
- **Illinois Title 35**
  - By octaves, not dBA – need special meter
  - Measured at property line
  - Varies with land use combinations
  - Very restrictive ~ 35 dBA equivalent for Class A land at night
- **State or local noise ordinances**
  - Madison = 65 dBA to residential
  - Carmel = 70 dBA for 20 minutes, Leq-A

Hospital Consumer Assessment of Healthcare Providers and Systems

- Quarterly standardized assessment, by adult inpatients, of their perception of total quality of care

- Compare Hospitals - http://www.medicare.gov/hospitalcompare
  - Patients may go elsewhere
  - Reimbursement varies based on HCAHPS scores

Facility Testing

- Rooms where patients sleep
  - Affects HCAHPS
- ORs – minimize mistakes
- Teaching rooms
- Site survey

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Resources

- **AMCA International:** *www.amca.org*
- **AMCA Online Educational Module - Basics of Acoustics:** *https://www.amca.org/educate/#online-education-portal* *(Available on AMCA Learning Platform; registration & fee required)*
- **Related AMCA Webinar Recordings:** *www.amca.org/webinar* *(Available for free)*
  - > *Impact of Duct Fitting Selection; March 21, 2021*
  - > *Understanding and Reducing Air System Noise; February 10, 2021*
  - > *Environmental Noise Due to Fans and Equipment; September 30, 2020*
  - > *AND MANY MORE TOPICS!*

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Q & A

Survey QR Code:

Thank you for your time!

*To receive PDH credit for today's educational session, you **must** complete the online evaluation, which will be sent to you via email within 7 days of this program.*

*PDH credits and participation certificates will be issued electronically **within 30 days**, once all attendance records are checked and the completed online evaluations are received.*

Attendees will receive an email at the address provided on your 2022 AHR Expo registration, listing the total credit hours awarded and a link to a printable certificate of completion.

If you have any questions, please contact Lisa Cherney, Education Manager, at AMCA International (lcherney@amca.org).

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If you are interested in a presentation for your firm, please Email me.

If you want a lot of acoustics, I can train for >4 hours!

Jeff Boldt
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