EFFECTIVE ACOUSTICS

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B3/SB 2030 PROGRAMS AND TOOLS

PREDESIGN

- GUIDELINES
- SB 2030 ENERGY STANDARD

Establish project-specific performance requirements.

DESIGN

- GUIDELINES
- SB 2030 ENERGY STANDARD

Refine project-specific performance requirements.

Optimize use of resources to achieve performance requirements.

Evaluate success of design strategies through early and repeated modeling.

CONSTRUCTION

- GUIDELINES

Implement construction practices that meet performance requirements.

OPERATIONS

- GUIDELINES
- SB 2030 ENERGY STANDARD
- BENCHMARKING
- ENERGY EFFICIENT OPERATIONS
- POST-OCCUPANCY EVALUATION

Ensure project is meeting performance requirements.

B3 GUIDELINES REVISIONS

v3.0

Performance Management

Materials & Waste

projects starting Schematic Design after 7/1/2017

v3.1

Site & Water

Indoor Environmental Quality

projects starting Predesign after 1/1/2019

v3.2

Energy & Atmosphere

projects starting Predesign after 1/1/2020

LEARNING OBJECTIVES

01

Understand basic acoustical characteristics.

02

Understand the difference between raw decibel (dB) and Noise Criteria (NC) ratings.

03

Be able to perform a simple HVAC NC estimate.

04

Be able to perform a simple room reverberation analysis.

SESSION OUTLINE

- How acoustics impact health and productivity
- Trends impacting acoustics
- Acoustics basics
- B3 Acoustics Guidelines
- Acoustic calculation demos

WHY THIS MATTERS

PRODUCTIVITY & PERFORMANCE

Focus

Memory

Comprehension

Mental arithmetic

Confidentiality

Clinician accuracy

Student learning

Teacher absenteeism

HEALTH

Blood pressure

Stress

Anxiety

Sleep disorders

Patient recovery

HAPPINESS

Satisfaction

Walls too thin, I hear everything—some of which I shouldn’t hear.

Corridor doors are too high off the floor allowing sound to enter our room when we are trying to study.

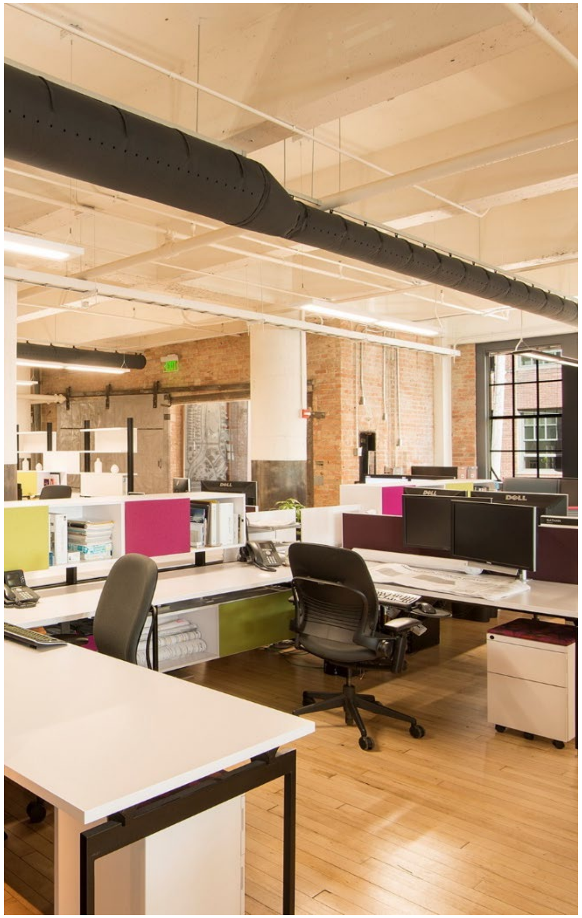
Very, very noisy place to work. [...] Obviously our needs were not too important.”

I can’t hear myself think!

DESIGN TRENDS IMPACTING ACOUSTICS

DESIGN TRENDS

Open floor plans
Higher ceilings
Exposed structure
Exposed HVAC
More hard surfaces
Less carpet



ENERGY EFFICIENCY

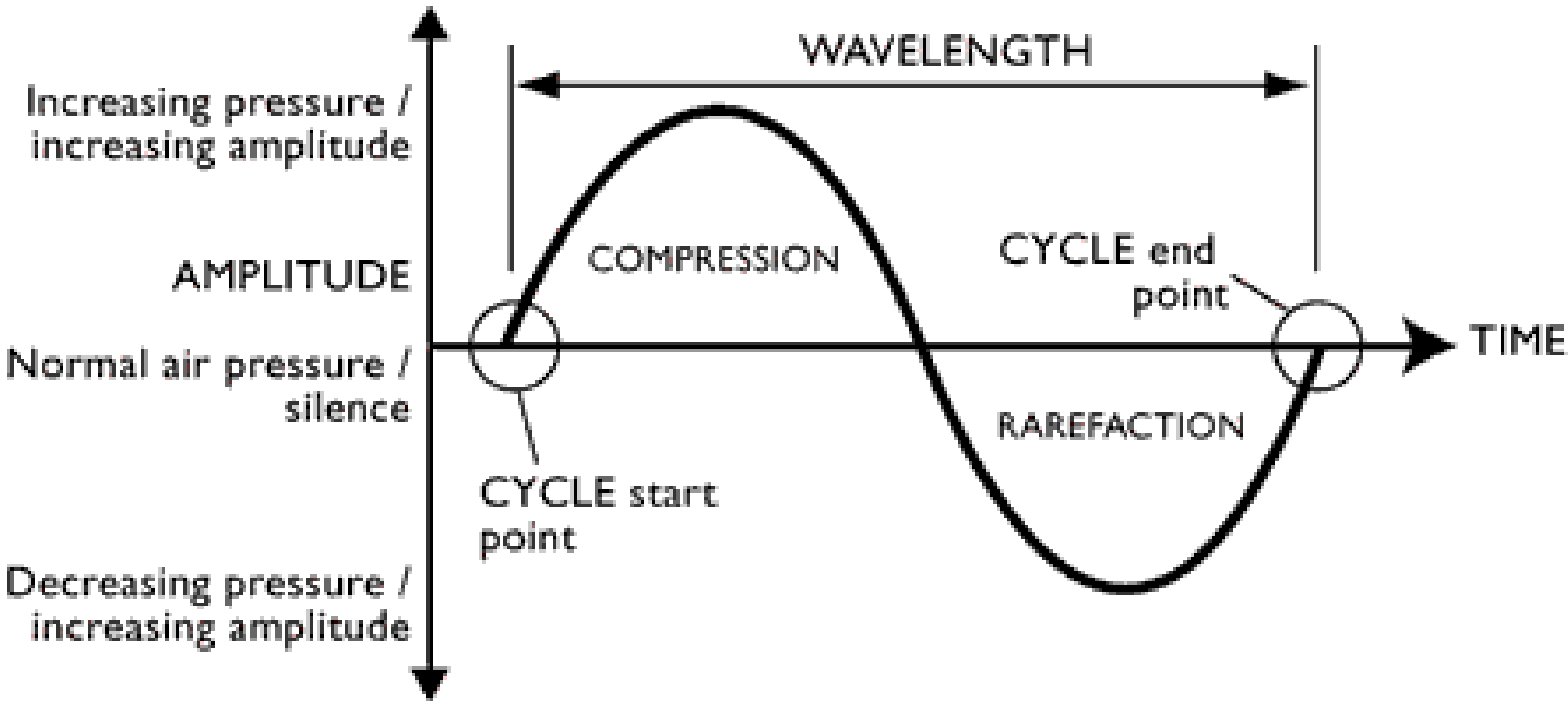
Image source: LHB

FUNDAMENTALS OF SOUND

- What is sound?
  - Audible emissions resulting from vibration of molecules within an elastic medium.
  - Generated by vibrating surface or movement of a fluid.
  - In buildings, it may be air-bourn or structure-bourn.
  - Unwanted sound is termed noise!
- Sound waves and frequency
  - Since sound is caused by vibration, we can measure the waves over time.
  - This is called the sound frequency.
  - We generally evaluate combinations of sound waves of difference frequency and amplitude (loudness).

FUNDAMENTALS OF SOUND

- Loudness: wavelength amplitude
  - 10 dB doubles



FUNDAMENTALS OF SOUND

- Pitch: wavelength frequency
  - Octave is frequency doubled

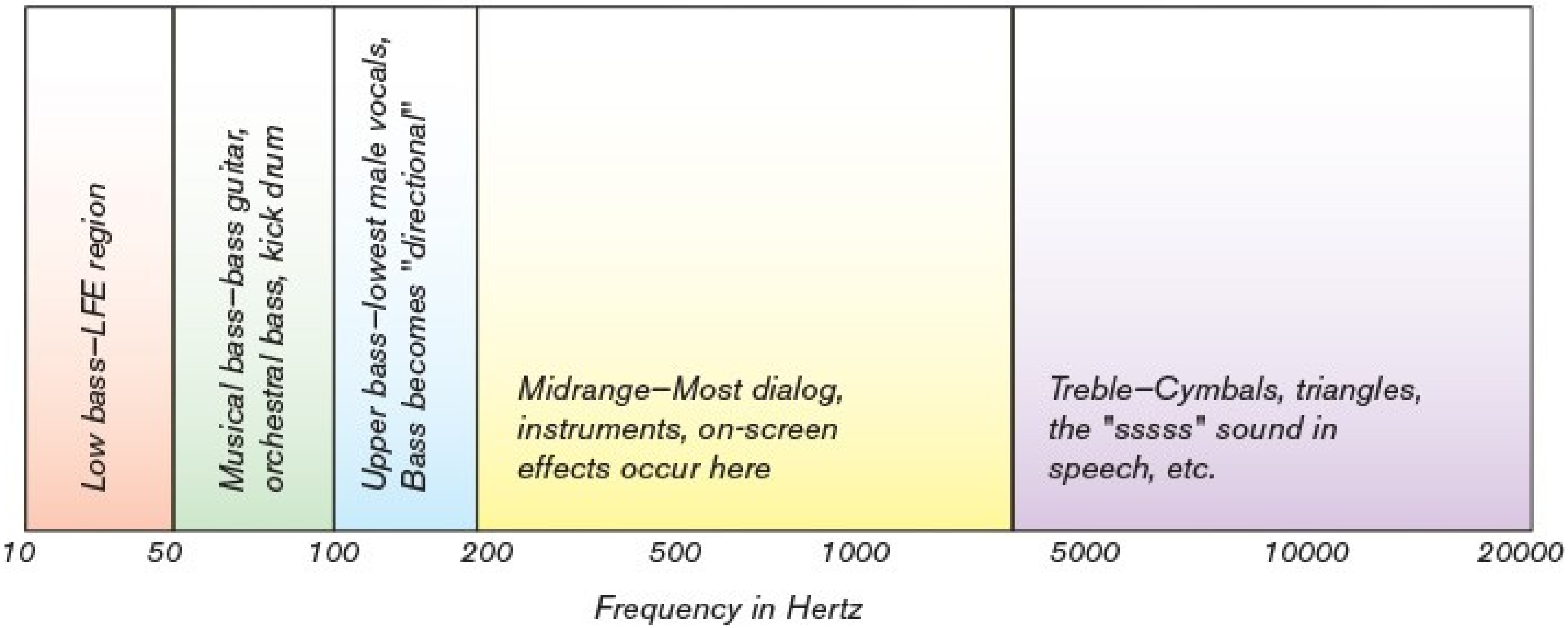
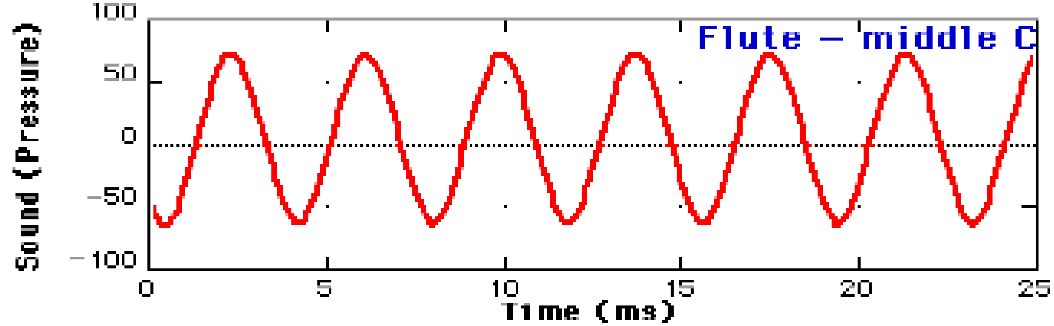
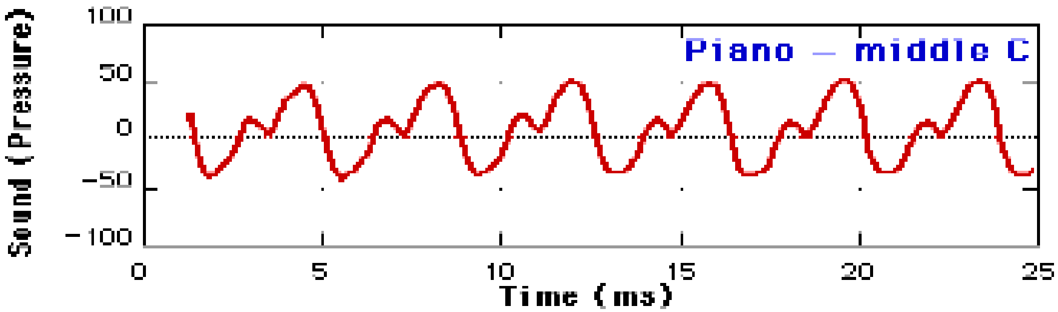


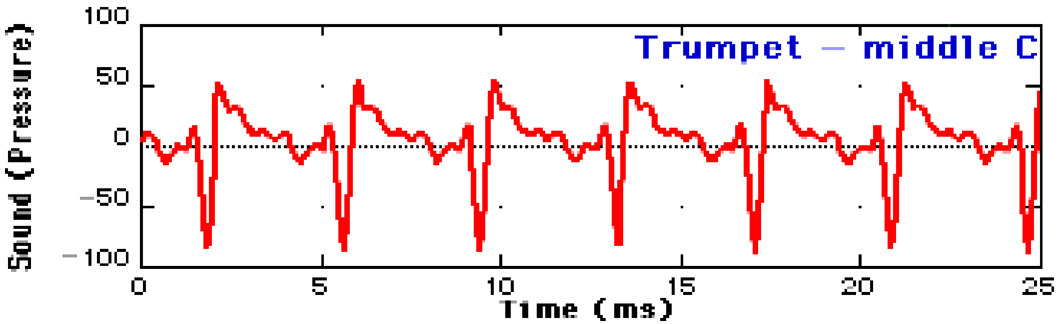
Image source: Alesis, Steve Feinstein, "Understanding Frequency Response – Why it Matters", 2016.

FUNDAMENTALS OF SOUND

- Waveform





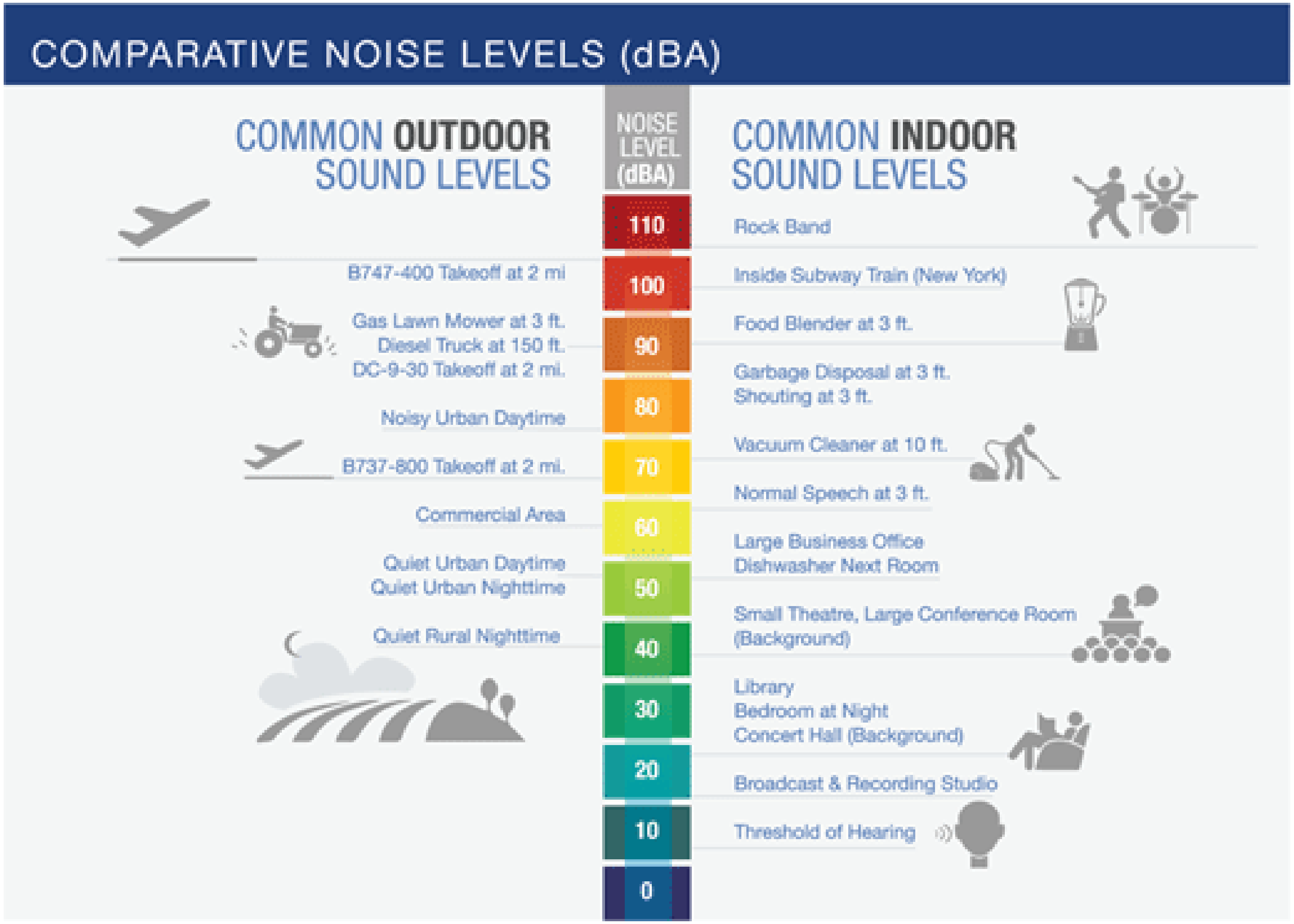


FUNDAMENTALS OF SOUND

- Sound Power
  - The acoustical energy emitted by the sound source.
  - Raw power, unaffected by the surroundings
  - It should be expressed in Watts.
- Sound Pressure
  - The intensity of the pressure disturbance at a location measured in Pascals (Pa).
- Decibels
  - A dimensionless term that creates a logarithmic scaled value from the pressure or power measured divided by a reference value.
  - Because they are logarithmic, they cannot be conventionally added.

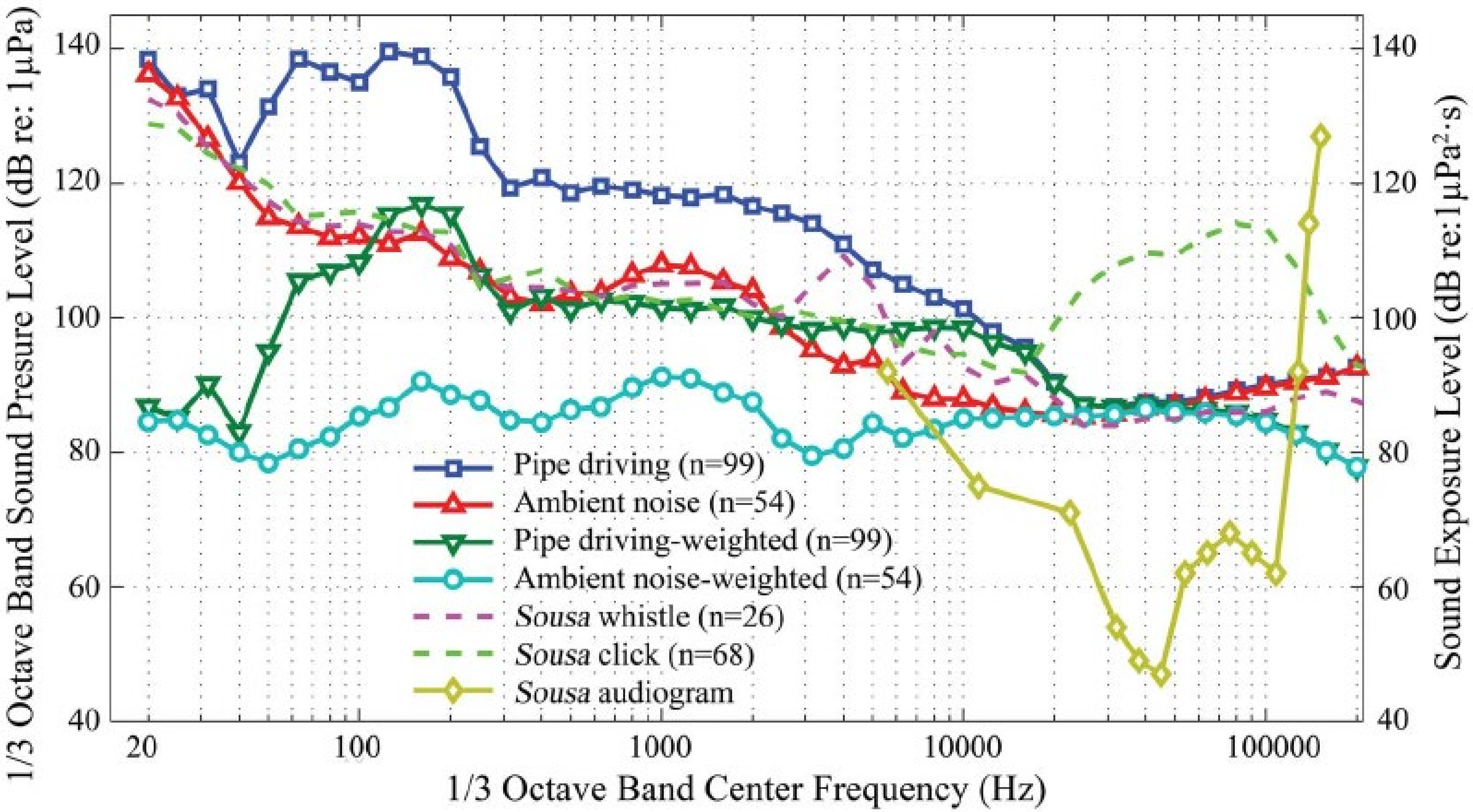
$$L = 10 \operatorname{Log}_{10}\left(\sum_{i=1}^{n} 10^{(L_i/10)} \right)$$

FUNDAMENTALS OF SOUND



Source: U.S. Department of Transportation, Federal Aviation Administration, "Fundamentals of Noise and Sound"

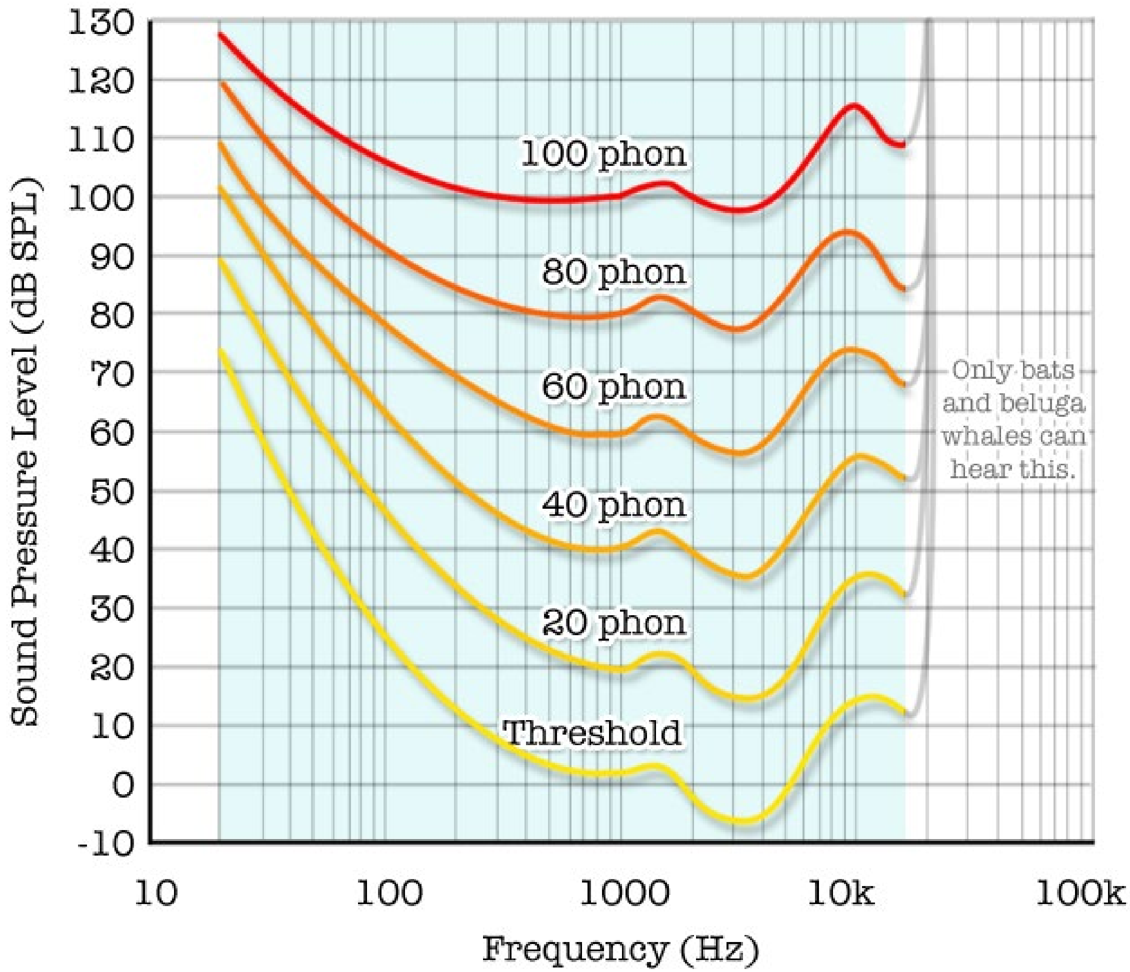
FUNDAMENTALS OF SOUND



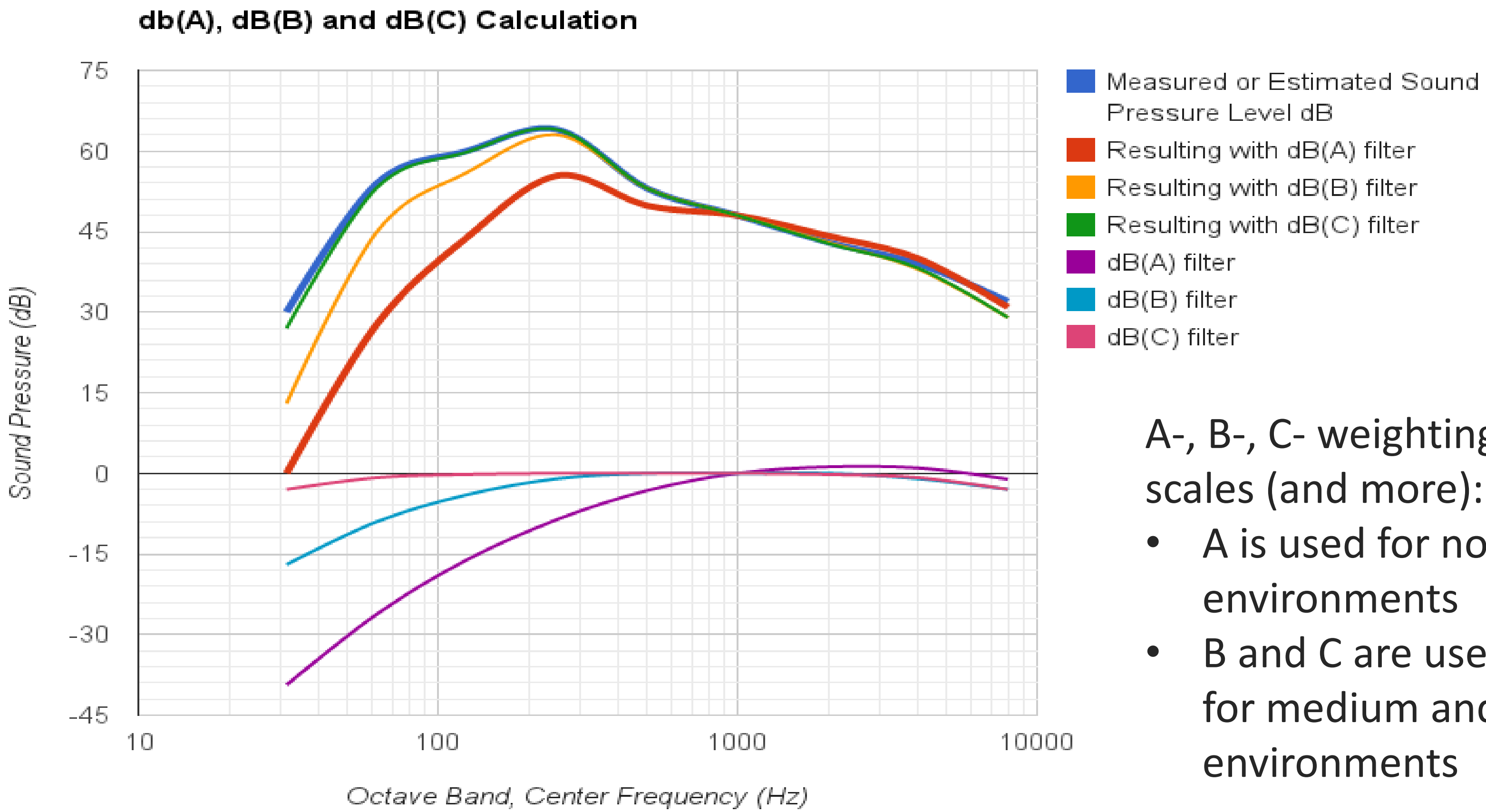
SOUND PERCEPTION

- The Ear
  - A complex biological mechanism that converts sound pressure into electrical impulses.
  - Ear design results in unequal conversion of sound pressure into impulses.
  - Is non-linear in response..
- The Brain
  - Converts the impulses into perceived sound or noise.
  - It can be tricked.
  - We don't all hear the same thing.
- Loudness contours
  - Experimentally determined equal response curves.

SOUND PERCEPTION



SOUND RATING METHODS



A-, B-, C- weightings for dB scales (and more):

- A is used for normal sound environments
- B and C are used for medium and loud environments

Source: The Engineering Toolbox

SOUND MATH

Frequency (Hz)	31.5	63	125	250	500	1kHz	2kHz	4kHz	8kHz	16kHz
A-Weighting Correction (dB)	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	-6.6
Level (dB)	70.9	78.4	83.3	87.6	87.3	93.5	93.8	97	99.9	98.2
Result (dB)	**31.5**	**52.2**	**67.2**	**79**	**84.1**	**93.5**	**95**	**98**	**98.8**	**91.6**

Now we need to take each of the resulting values and do a calculation on each one. Firstly we need to divide each value by 10 and then anti-log each value. The simplest way to do this is to use the formula 10 ^(L/10) where L is the value in each cell.

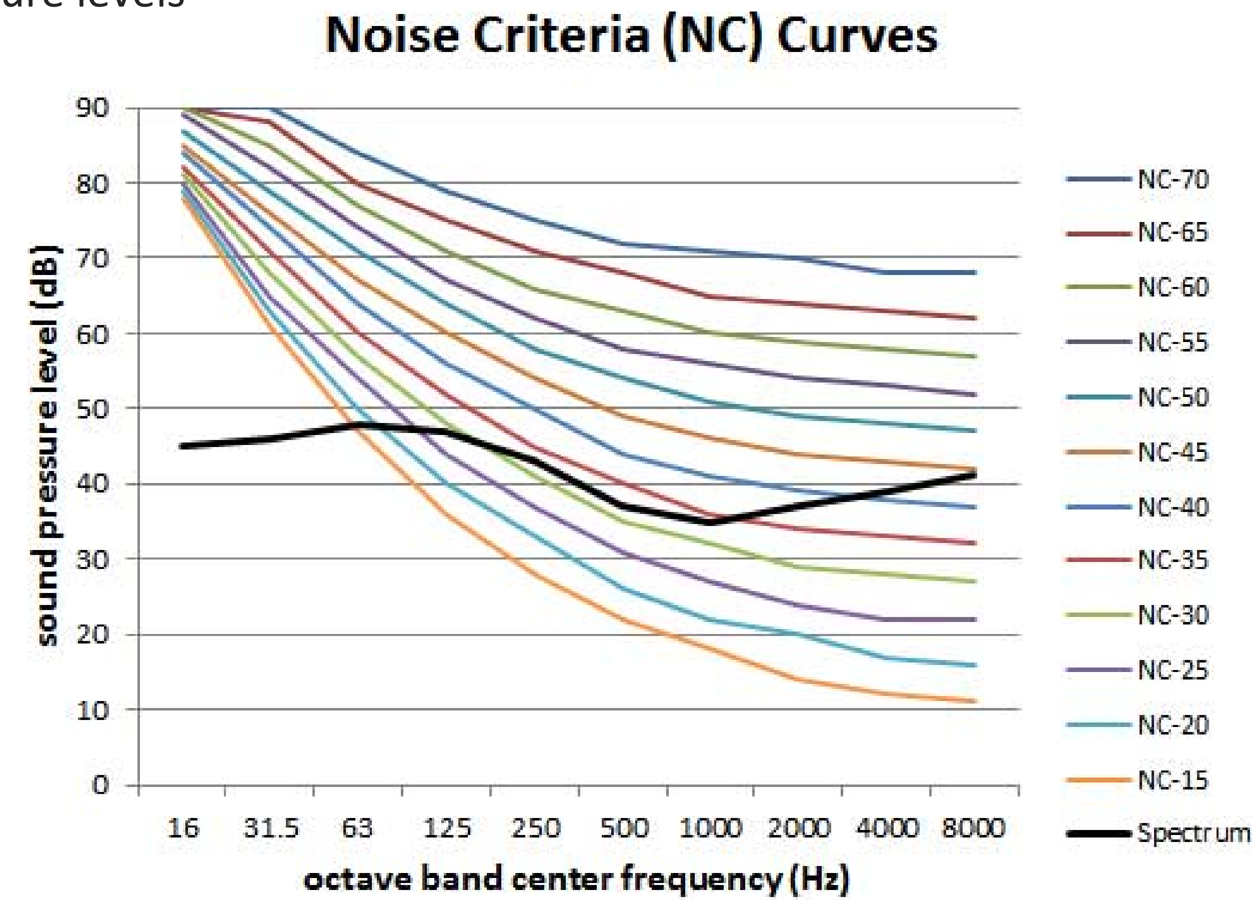
Now we add all of these values together, log this value and multiply it by 10 to give the final dB(A) value.

These steps allow us to calculate the overall dB(A) value of this noise measurement and the value that we end up with is 103.2dB(A).

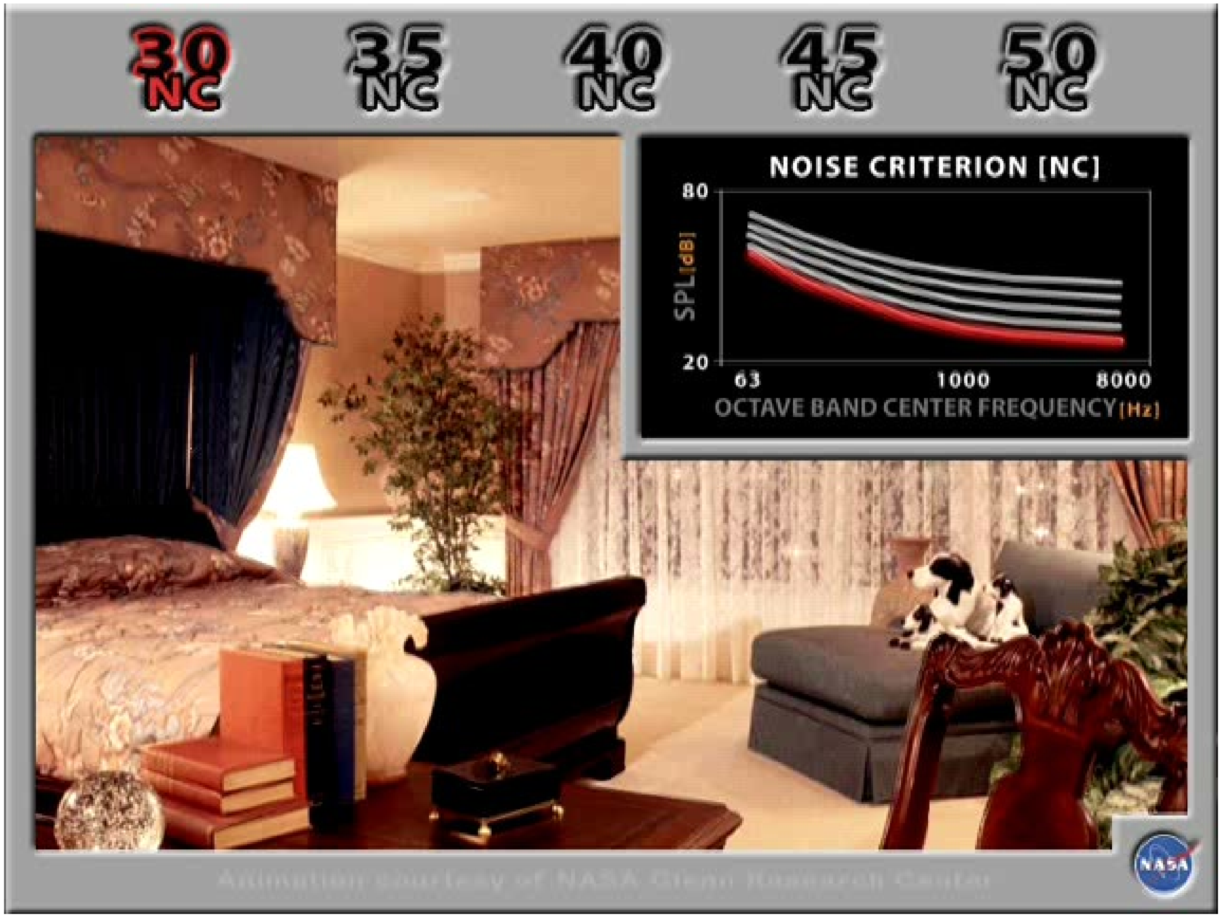
103.2 dB(A)

SOUND RATING METHODS – NOISE CRITERIA

Most common single number method used to rate indoor environments in terms of sound pressure levels



NOISE CRITERIA (NC)



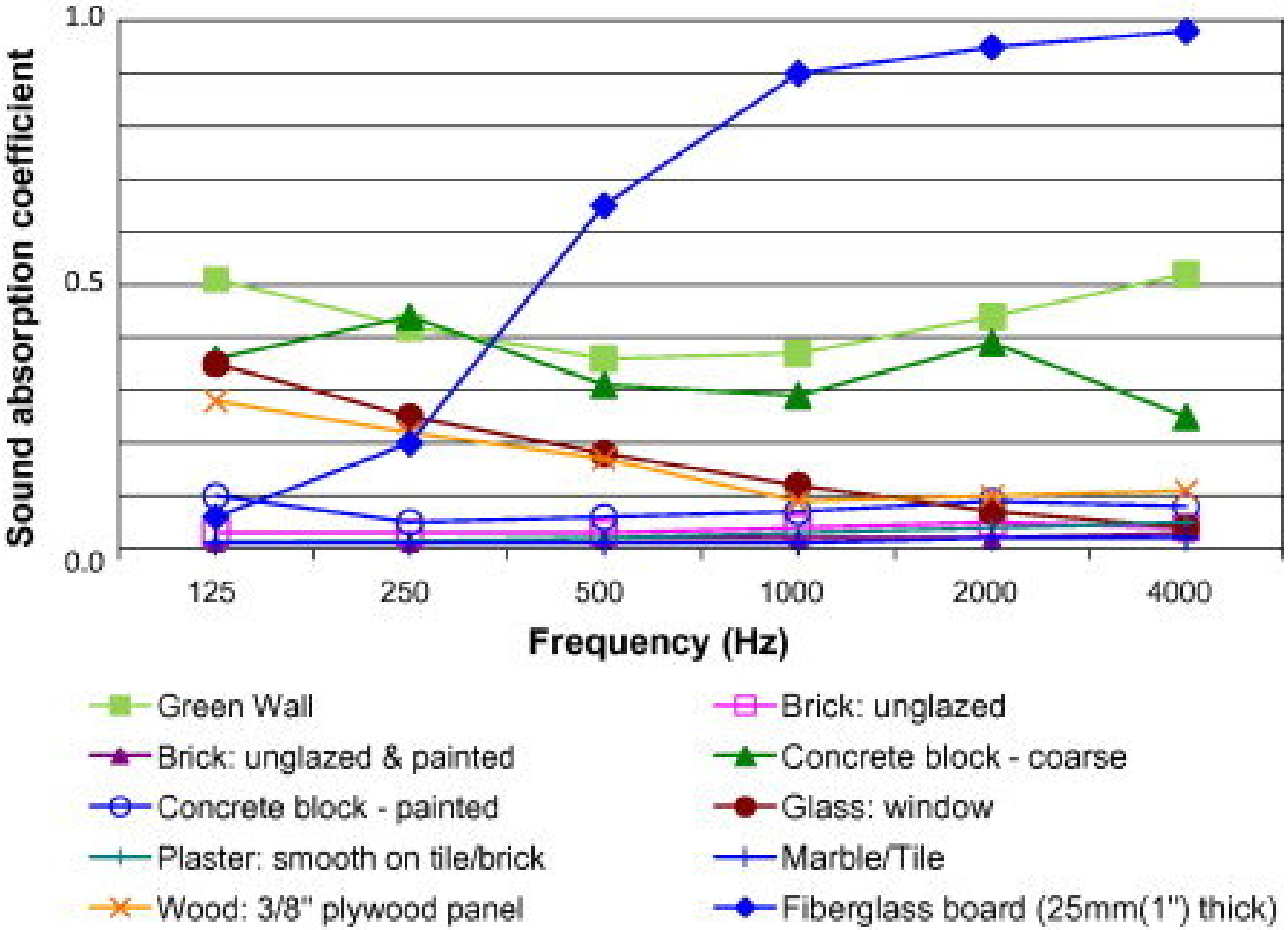
Source: NASA Glenn Research Center Acoustical Testing Laboratory, "Animated Auditory Demonstrations II".

ROOM ACOUSTICS

- Reverberation Time (RT): the amount of time for a sound to decay by 60 dB
- Sound absorption coefficients: the percentage of sound absorbed by a material
- Noise Reduction Coefficient (NRC): average material absorption

Material	Sound Absorption Coefficient						NRC
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	
Ceilings[6, 8-10][+]							
Sound-Reflecting:							
37. Concrete	0.01	0.01	0.02	0.02	0.02	0.02	0
38. Gypsum board, 1/2 in thick	0.29	0.1	0.05	0.04	0.07	0.09	0.05
39. Gypsum board, 1/2 in thick, in suspension system	0.15	0.1	0.05	0.04	0.07	0.09	0.05
40. Plaster on lath	0.14	0.1	0.06	0.05	0.04	0.03	0.05
41. Plywood, 3/8 in thick	0.28	0.22	0.17	0.09	0.1	0.11	0.15
Sound-Absorbing:							
42. Acoustical board, 3/4 in thick, in suspension system (mtg. E)	0.76	0.93	0.83	0.99	0.99	0.94	0.95
43. Shredded-wood fiberboard, 2 in thick on lay-in grid (mtg. E)	0.59	0.51	0.53	0.73	0.88	0.74	0.65
44. Thin, porous sound-absorbing material, 3/4 in thick (mtg. B)	0.1	0.6	0.8	0.82	0.78	0.6	0.75
45. Thick, porous sound-absorbing material, 2 in thick (mtg. B), or thin material with airspace behind (mtg. D)	0.38	0.6	0.78	0.8	0.78	0.7	0.75

FUNDAMENTALS OF SOUND



REVERBERATION TIME

Source: NASA Glenn Research Center Acoustical Testing Laboratory, "Animated Auditory Demonstrations II".

ACOUSTIC SEPARATION

- STC
  - Sound Transmission Class, sound reduction going through an interior wall, biased similar to dB(A)
  - Determined with an ASTM procedure measuring reduction between 125Hz-4000Hz.
- OITC
  - Outside Inside Transmission Class, sound reduction going through an exterior wall, biased similar to dB(C)
  - Determined with an ASTM procedure measuring reduction between 80Hz-4000Hz.
- IIC
  - Impact Isolation Class, measures a floor assembly’s ability to absorb impact sound – like footsteps

SOUND TRANSMISSION CLASS (STC)

Source: NASA Glenn Research Center Acoustical Testing Laboratory, *"Animated Auditory Demonstrations II"*.

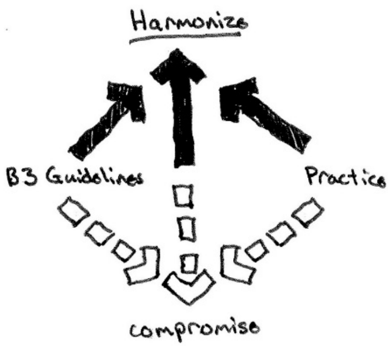
MULTIPLE ACOUSTIC CONDITIONS

Source: NASA Glenn Research Center Acoustical Testing Laboratory, "Animated Auditory Demonstrations II".

ACOUSTICS IN THE:

B3 GUIDELINES V3.1

B3 GUIDELINES – ACOUSTICS



- Lessons learned from previous version of the Acoustics Guidelines
  - Acoustics is a leading cause of dissatisfaction among occupants
  - The acoustics calculations are difficult for teams to implement
- Approach under v3.1 is to:
  - Address each negative acoustic phenomenon, in alignment with national standards and green rating systems where appropriate
  - When feasible, provide multiple compliance paths
  - Provide training

B3 GUIDELINES – ACOUSTICS

Intent: To promote productive, supportive, and comfortable acoustic environments for all occupants and to control unwanted noise.

- Block outside noise
- Minimize mechanical noise
- Limit sound transfer between spaces
- Ensure speech intelligibility and acoustic comfort

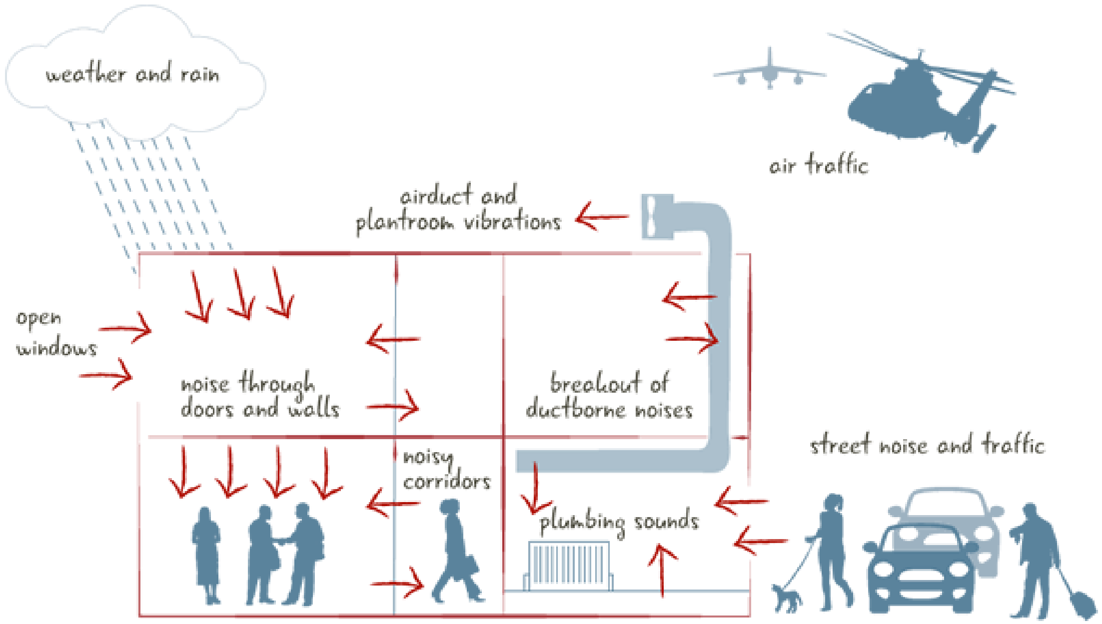


Image source: Ideas for Ears, Acoustics and Background Noise

DEFINITIONS

regularly occupied space: any space that is occupied by one or more persons for more than one hour during days the building is in use.

Examples:

Regularly Occupied	Not Regularly Occupied
Office Conference room Lobby with receptionist or security guard	Corridors Copy area Break room Lobby without receptionist or security guard

B3 GUIDELINES – ACOUSTICS

Intent	B3 Approach	Applicable spaces
Block outside noise	• Maximum measured dBA OR • OITC ratings for facades and roofs	Regularly occupied spaces
Minimize mechanical noise	• NC rating	Regularly occupied spaces*
Limit sound transfer between spaces	• STC ratings for interior walls and floor-ceiling assemblies • IIC ratings for floor-ceiling assemblies • Construction details	Regularly occupied spaces* (IIC for sleeping area/ dwelling unit)
Ensure speech intelligibility and acoustic comfort	• Reverberation time OR • Average NRC	Regularly occupied spaces*

*With different performance thresholds depending on space type

DEFINITIONS

core learning spaces: spaces for educational activities where the primary functions are teaching and learning and where good speech communication is critical to a student's academic achievement

ancillary learning spaces: spaces where good communication is important to a student's educational progress but for which the primary educational functions are informal learning, social interaction, or similar activity other than formal instruction.

Core Learning Spaces	Ancillary Learning Spaces	Not included
Classrooms Libraries Activity areas Music rooms	Corridors Cafeterias Gymnasia	Natatoria Auditoria Music performance spaces

B3 GUIDELINES – ACOUSTICS IN LEARNING SPACES

Intent	ANSI S12.60	Applicable spaces
Block outside noise	• Maximum dBA • Maximum dBC • OITC ratings for facades & roofs	Core learning spaces Ancillary learning spaces
Minimize mechanical noise	• Maximum dBA • Maximum dBC	Core learning spaces* Ancillary learning spaces
Limit sound transfer between spaces	• STC ratings for interior walls and floor-ceiling assemblies • IIC ratings for floor-ceiling assemblies • Construction details	Core learning spaces** Ancillary learning spaces (IIC only)**
Ensure speech intelligibility and acoustic comfort	• Reverberation time	Core learning spaces*

*With different performance thresholds depending on space volume

**With different thresholds depending on adjacent space type

BLOCK OUTSIDE NOISE – I.6B

Meet one of the following in regularly occupied spaces.

Requirement
Maximum measured dBA from exterior background noise: • 45 dBA
Minimum OITC ratings for facades and roofs: • 30 for typical sites • 40 for sites with identified noise risks

MINIMIZE MECHANICAL NOISE – I6.C

Meet the following in <u>regularly occupied</u> spaces.

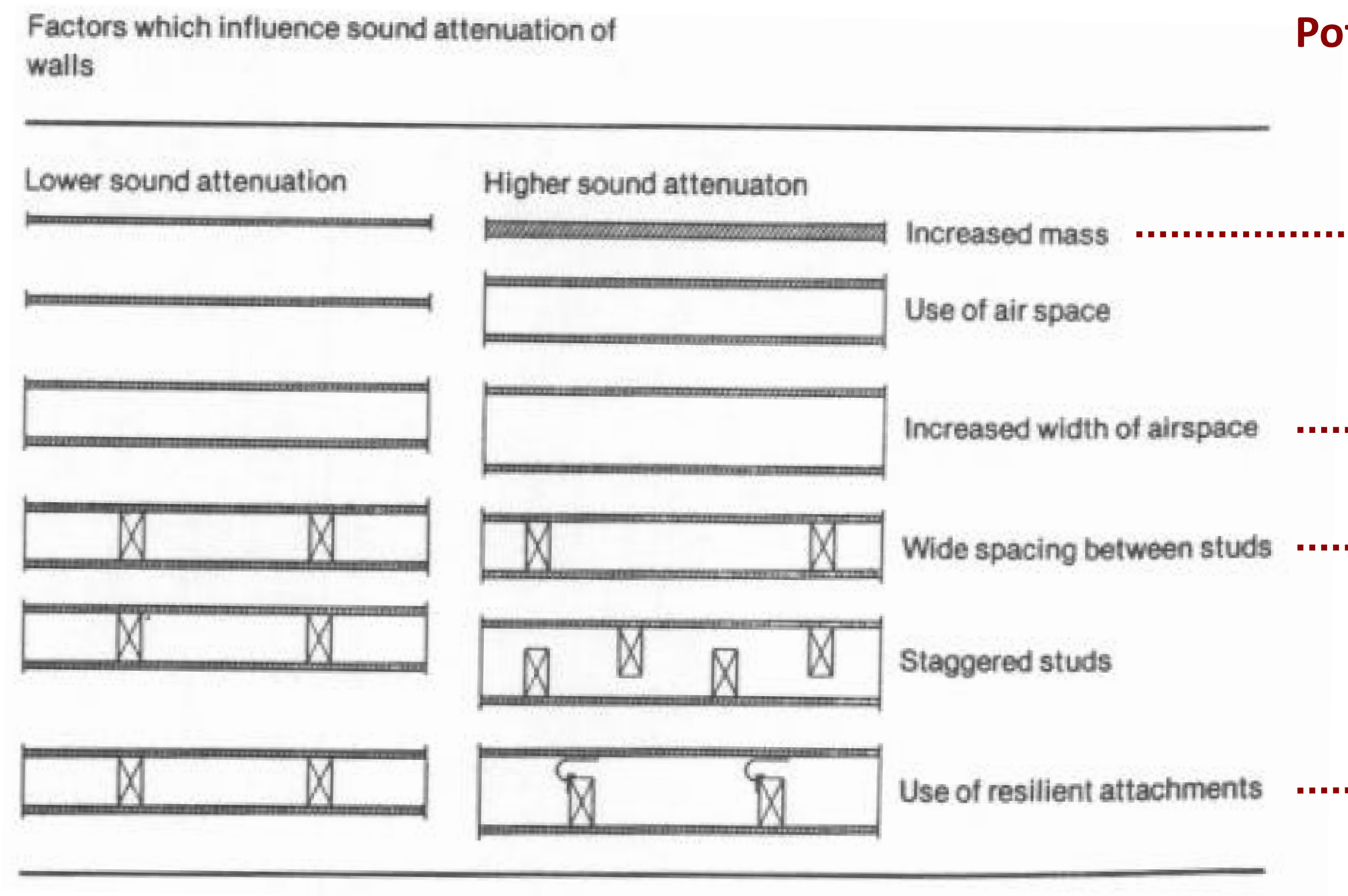
Requirement
Maximum Noise Criteria (NC) levels from air-distributed mechanical noise: • NC 45 for gymnasia, circulation spaces, lobbies, service areas, and sports facilities • NC 35 for meeting rooms, lecture halls, small offices, and conference rooms • NC 40 for all other spaces

LIMIT SOUND TRANSFER BETWEEN SPACES – I.6C

Meet all of the following in regularly occupied spaces.

Requirement
Minimum STC for wall and floor/ceiling assemblies between occupancies: • 50 or 60, based on occupancy groups
Minimum STC for wall and floor/ceiling assemblies within occupancies: • 45, 50, or 55, based on occupancy group
Construction details: • Walls continue and are sealed to bottom of floor/ceiling structure • Other penetrations are limited

LIMIT SOUND TRANSFER BETWEEN SPACES – I.6C



Potential STC increase

Increased mass: **6**

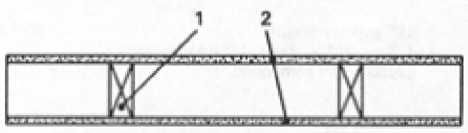
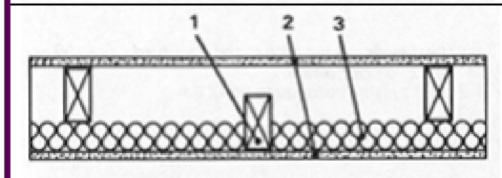
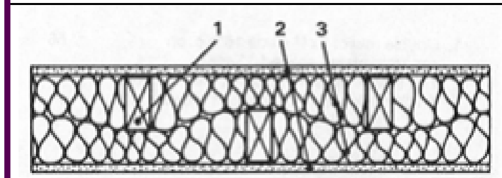
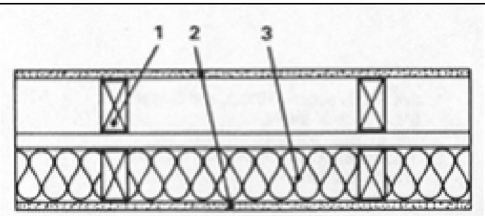
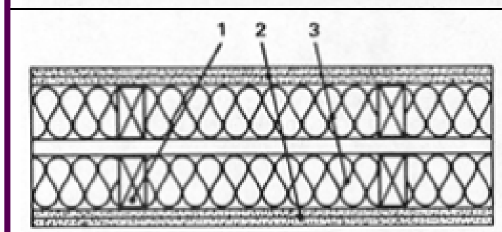
Increased width of airspace: **5**

Wide spacing between studs: **2-5**

Use of resilient attachments: **2-5**

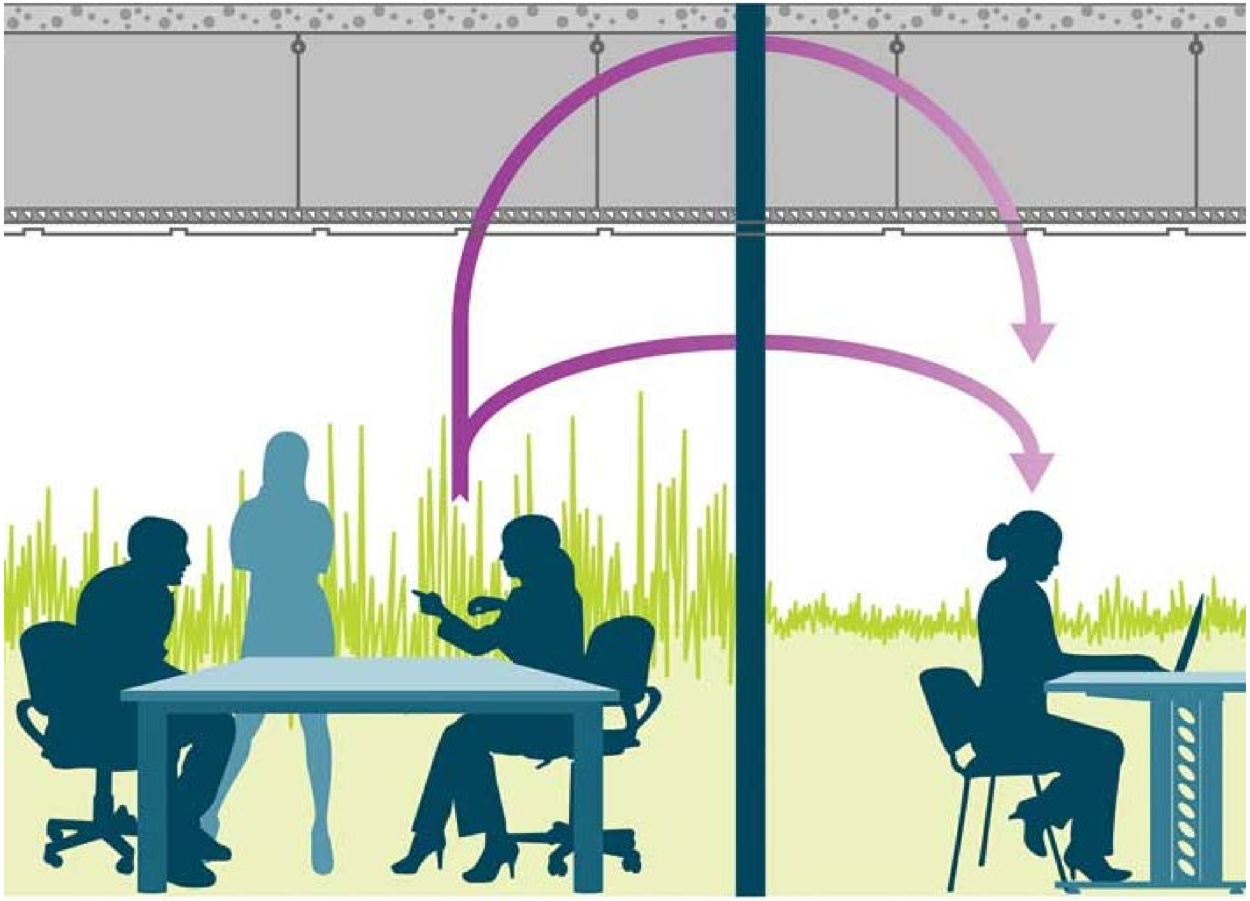
Source: U.S. Department of Housing and Urban Development, HUD Noise Guidebook, "Chapter 4 Noise Attenuation," March 2009

LIMIT SOUND TRANSFER BETWEEN SPACES – I.6C

	1. 2x4" studs, 16"o.c. 2. 3/8" gypsum board nailed to studs.	35
	1. 2x4" studs spaced 24"o.c. and staggered 12"o.c. on 2x6" plates. 2. ½" gypsum board screwed to studs. 3. 2" thick sound attenuation blanket.	46
	1. 2x4" studs spaced 16"o.c. and staggered 8"o.c. on 2x6" plates. 2. ½" gypsum board screwed 12"o.c. 3. 3 ½" thick sound attenuation blankets in both stud cavities.	51
	1. Double row of 2x4" studs 16"o.c. on separate plates spaced 1" apart. 2. ½" type X gypsum board screwed 12"o.c. 3. 3 ½" thick sound attenuation blanket.	56
	1. Double row of 2x4" studs 16.o.c. on separate plates spaced 1" apart. 2. Double row of 5/8" type X gypsum board screwed 16.o.c. 3. 3 ½" thick sound attenuation blankets in both stud cavities.	63

Source: U.S. Department of Housing and Urban Development, HUD Noise Guidebook, "Sound Transmission Class Guidance," March 2009

LIMIT SOUND TRANSFER BETWEEN SPACES – I.6C



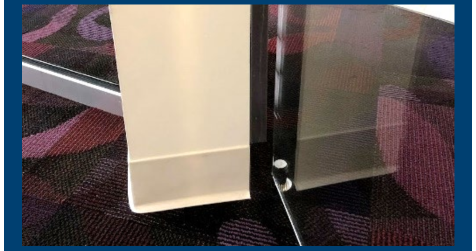


Image Sources: Acoustic Comfort UK, Wikipedia, ElectricianTalk.com, LHB

LIMIT SOUND TRANSFER BETWEEN SPACES – I.6C

Meet <u>all</u> of the following in <u>mechanical rooms</u>.

Requirement
Minimum STC for wall and floor/ceiling assemblies: • 50 or 60, depending on equipment noise
Construction details: • Walls continue and are sealed to bottom of floor/ceiling structure • Other penetrations are limited • Isolate mechanical equipment to limit structure-borne sound and vibration transmission • Isolate plumbing equipment to prevent noise transmission

LIMIT SOUND TRANSFER BETWEEN SPACES – I.6C

Meet the following in <u>sleeping areas and dwelling units.</u>

Requirement
Minimum IIC of floor/ceiling assemblies: • 50

ENSURE SPEECH INTELLIGIBILITY – I.6C

Meet <u>one</u> of the following in <u>regularly occupied spaces</u>.*

Requirement
Reverberation time in the 500Hz, 1000Hz, and 2000Hz octave bands: • 0.2 - 0.7 seconds • 0.2 - 0.8 seconds for open offices
Minimum average area-weighted NRC of all interior surfaces: • 0.45 • 0.35 for spaces less than 30,000cf • 0.30 for open offices

*except concert halls or other music performance auditoria, laboratory spaces, aquatic facilities, and gymnasia

ENSURE SPEECH INTELLIGIBILITY – I.6D

Meet <u>all</u> of the following in <u>spaces intended for gatherings of 15+ people where audible communications is integral to the use of the space</u>.*

Requirement
Include audio-induction loops to provide an electromagnetic signal for hearing aids and cochlear implants if a permanent audio amplification system is present in the space.
Maximum background noise: • Per ANSI S12.60
Reverberation times: • Per ANSI S12.60

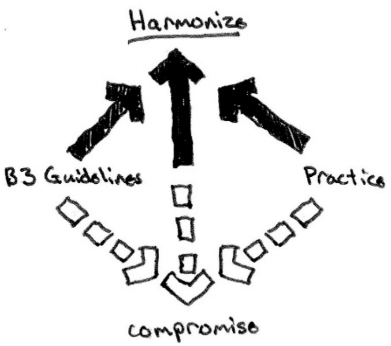
*coordinated with Minnesota Statute §16C.054 to ensure adequate acoustic conditions of gathering spaces and accommodation for hard-of-hearing

ENSURE SPEECH PRIVACY – I.6E

Meet the following in <u>spaces that are not compliant with I6.A, I6.B, or I6.C</u> or <u>that need additional sound privacy</u> or <u>that may hinder productivity due to being too quiet.</u>

Requirement
Sound masking system: • Broad spectrum • 45 dBA maximum

QUESTIONS



- What team members are involved in meeting these Guidelines? Are additional team members needed?
- What should I be thinking about during each stage of the design process?
- What are acoustical solutions to consider?
- What are the cost implications?

WHO IS INVOLVED?

Key:
Significant responsibility
Some responsibility

	Architect	Interior Designer	Mechanical Engineer	Electrical or A/V	Acoustician	Contractor
I.6A Effective acoustics for learning spaces	Significant	Some	Significant	Some	Some	Significant
I.6B Exterior-source noise control	Significant				Significant	Significant
I.6C Mechanical noise (NC)			Significant	Some	Some	
I.6C STC ratings of walls and floor-ceiling assemblies	Significant			Some	Some	Significant
I.6C IIC ratings of floor-ceiling assemblies	Significant				Some	Significant
I.6C Construction details	Significant					Significant
I.6C Mechanical equipment isolation			Significant			Some
I.6C Room acoustics (reverberation time/NRC)	Significant	Significant			Some	
I.6D Effective acoustics for gathering spaces	Significant	Some	Significant	Significant	Some	Significant
I.6E Sound masking				Significant		

PREDESIGN

Space	Area	Occupancy Group	Minimum STC between occupancies	Minimum STC within occupancy	Minimum IIC of floor-ceiling above	Maximum Exterior Noise	Minimum OITC	Maximum Interior Noise	Reverb Time	Audio-Induction Loop?
		A			40	40dBA/60dBC		40dBA/60dBC		
		A			40	40dBA/60dBC		40dBA/60dBC		
		A	60	55		45 dBA	30-40	40 NC	0.2-0.7	
		A	60	55		45 dBA	30-40	40 NC	0.2-0.7	
		B	50	45		45 dBA	30-40	40 NC	0.2-0.7	
		B	50	45		45 dBA	30-40	35 NC	0.2-0.7	
		B	50	45		45 dBA	30-40	35 NC	0.2-0.7	
		B	50	45		45 dBA	30-40	45 NC	0.2-0.7	
		R	50	45		45 dBA	30-40	40 NC	0.2-0.7	
		A	60	55		45 dBA	30-40	45 NC	0.2-0.7	
		A	60	55		45 dBA	30-40	40 NC	0.2-0.7	X
		A	45-60		45	35dBA/55dBC	30-50	35dBA/55dBC	≤0.6	X
			50-60							
IT/Electrical	148									
Recycle & Receiving	200									
Janitor	180									
Circulation	6,598									

Determine which guidelines are applicable.

- Which spaces are regularly-occupied?
- Are there learning spaces?
- Are there gathering spaces for 15 or more people?
- Are there sleeping areas or dwelling units?
- Are there shared walls between different occupancy groups?

Image source: LHB

PREDESIGN

Space	Area	Regularly Occupied	Core Learning	Ancillary Learning	Gathering Space	Occupancy Group	Minimum STC between occupancies	Minimum STC within occupancy	Minimum IIC of floor-ceiling above	Maximum Exterior Noise	Minimum OITC	Maximum Interior Noise	Reverb Time	Audio-Induction Loop?
Museum/Gallery														
Exhibit	4,984			X		A			40	40dBA/60dBC		40dBA/60dBC		
Gallery	733			X		A			40	40dBA/60dBC		40dBA/60dBC		
Museum Work Area	300	X				A	60	55		45 dBA	30-40	40 NC	0.2-0.7	
Museum Workshop	500	X				A	60	55		45 dBA	30-40	40 NC	0.2-0.7	
Collection Storage	4,000													
Administrative														
Open Office	528	X				B	50	45		45 dBA	30-40	40 NC	0.2-0.7	
Private Office	840	X				B	50	45		45 dBA	30-40	35 NC	0.2-0.7	
Conf Room	600	X				B	50	45		45 dBA	30-40	35 NC	0.2-0.7	
Reception	-	X				B	50	45		45 dBA	30-40	45 NC	0.2-0.7	
Workroom/storage	434													
Kitchen/Break Area	1,000													
File Storage	72													
Supply Storage	72													
Retail														
Retail	1,541	X				R	50	45		45 dBA	30-40	40 NC	0.2-0.7	
Retail Storage	150													
Program														
Reception	100	X				A	60	55		45 dBA	30-40	45 NC	0.2-0.7	
Auditorium	1,200	X			X	A	60	55		45 dBA	30-40	40 NC	0.2-0.7	X
Classroom	1,125		X		X	A	45-60		45	35dBA/55dBC	30-50	35dBA/55dBC	≤0.6	X
Aviary	837													
Green Room	120													
Mews	600													
Mew Circulation	1,000													
Program Support														
Eagle Care	472													
Cleaning Room	70													
Food Prep	200													
Workroom	200													
Storage	104													
Facilities														
Mechanical	2,691						50-60							
Restrooms	2,006													
IT/Electrical	148													
Recycle & Receiving	200													
Janitor	180													
Circulation	6,598													

Image source: LHB

PREDESIGN

Select which pathway to use for exterior-noise:

- Measured background noise
- OITC ratings: Does the site have a high-noise risk?
    - Check airport map
    - Measure site noise (24 hours)

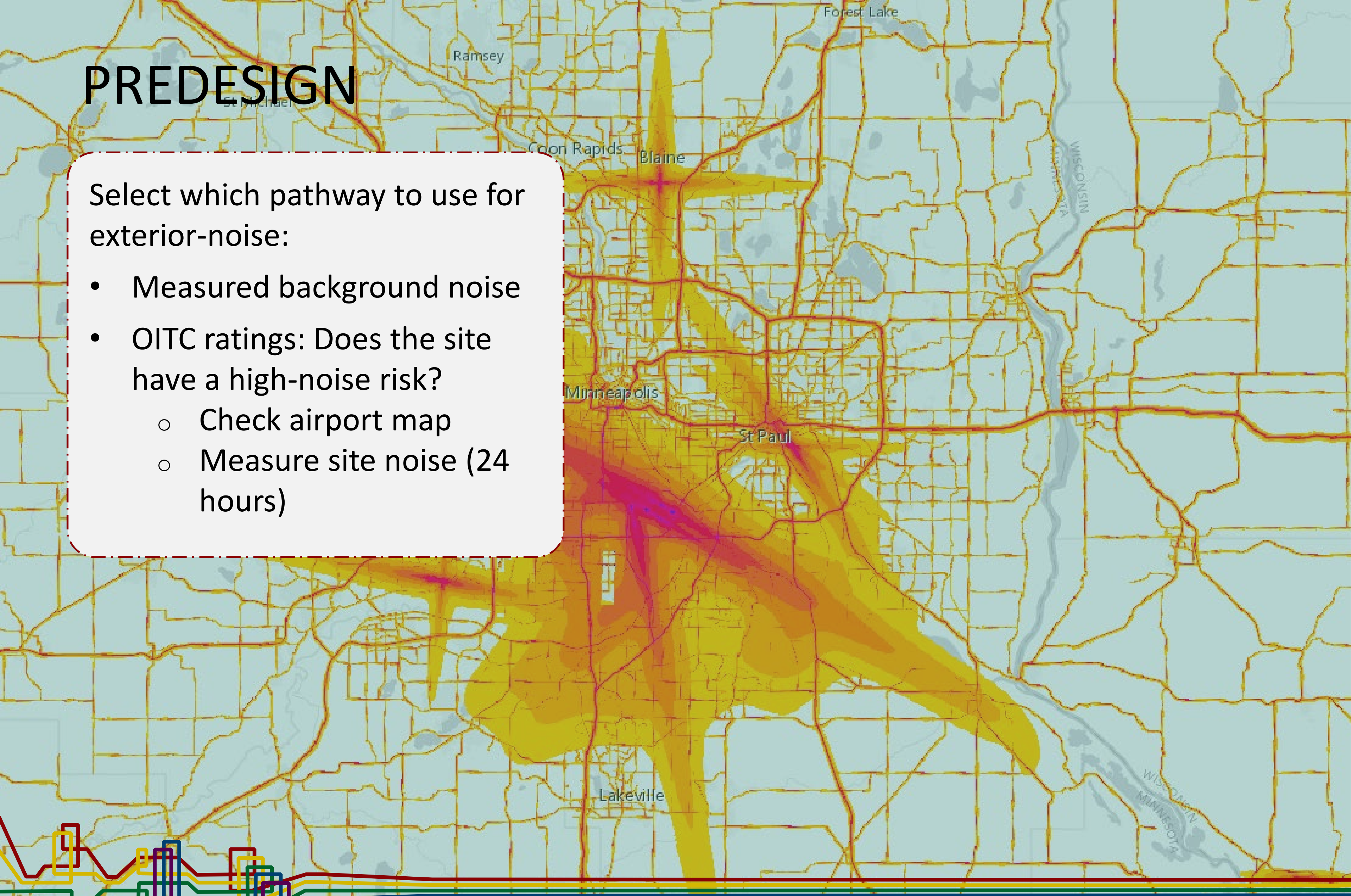


Image source: Bureau of Transportation Statistics, U.S. Department of Transportation, "National Transportation Noise Map,"
https://maps.bts.dot.gov/arcgis/apps/webappviewer/index.html?id=a303ff5924c9474790464cc0e9d5c9fb

PREDESIGN

Assign responsibility and budget adequate time and fee for:

- Site noise monitoring
- OITC determination
- NC calculations
- STC determination
- Reverberation time or NRC calculations
- Audio-induction design

Determine the scope – if any – for an acoustic consultant.

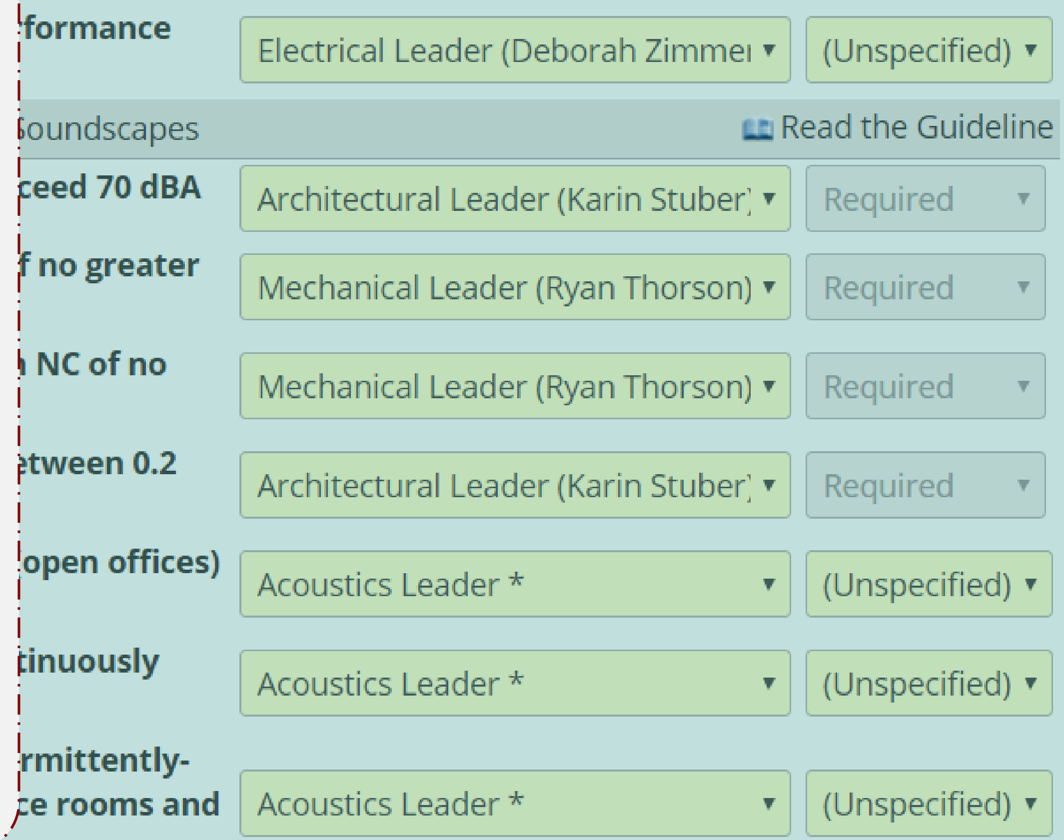


Image source: B3 Guidelines Tracking Tool

SPACE LAYOUT

Consider:

- Acoustic programming
- Location of internal and external noise sources – including MEP
- Room volume
- Presence/absence of walls that can be used as acoustic barriers

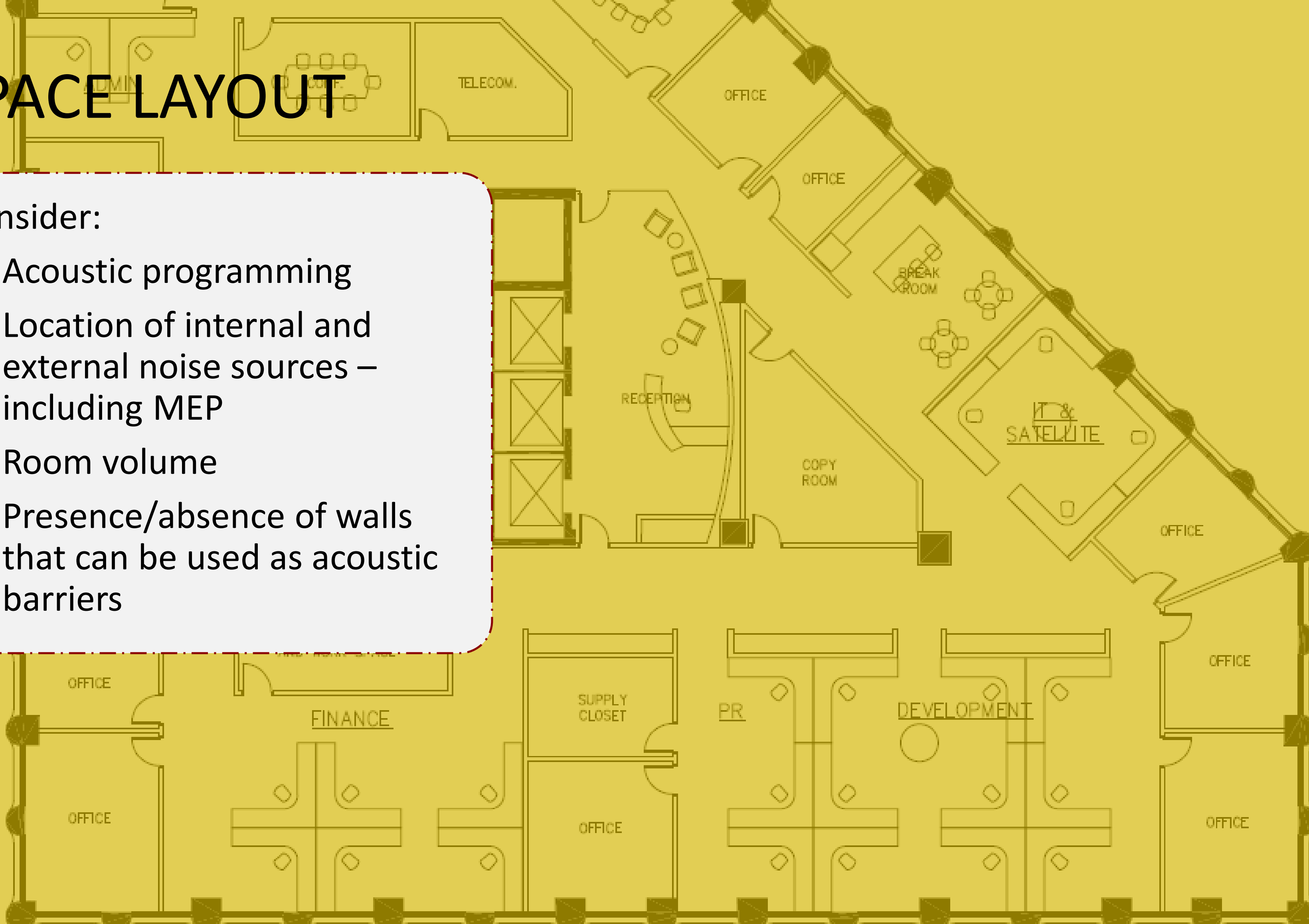


Image source: LHB

ENVELOPE DESIGN

Consider:

- Exterior noise levels
- OITC of wall and roof assemblies
- Synergies and conflicts with energy efficiency, moisture control, and daylighting requirements

Photo of Lake Superior College Health Services, LHB.

INTERIOR DESIGN AND ASSEMBLIES

Consider:

- Noise reduction coefficients (NRC) of interior materials
- Ceiling height and design
- STC ratings of walls and floor-ceiling assemblies
- IIC ratings of floor-ceiling assemblies

Photo of Nine Mile Creek Watershed District Center, LHB.

MECHANICAL DESIGN

Consider:

- Location of sound producing equipment
- Selection! More efficient equipment is often quieter!
- Do the design conditions match those used for rating?
- Isolation requirements
- Distribution design

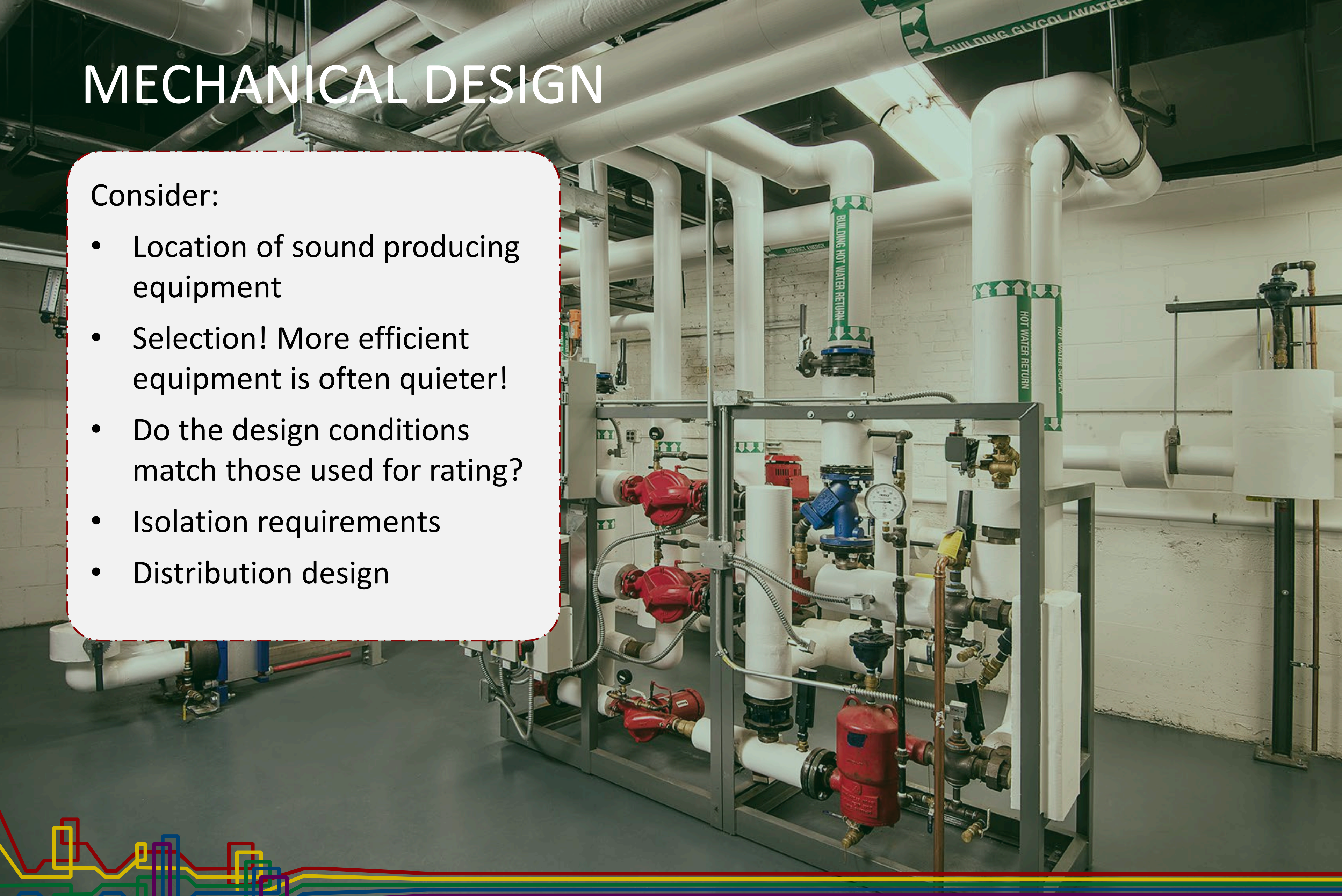
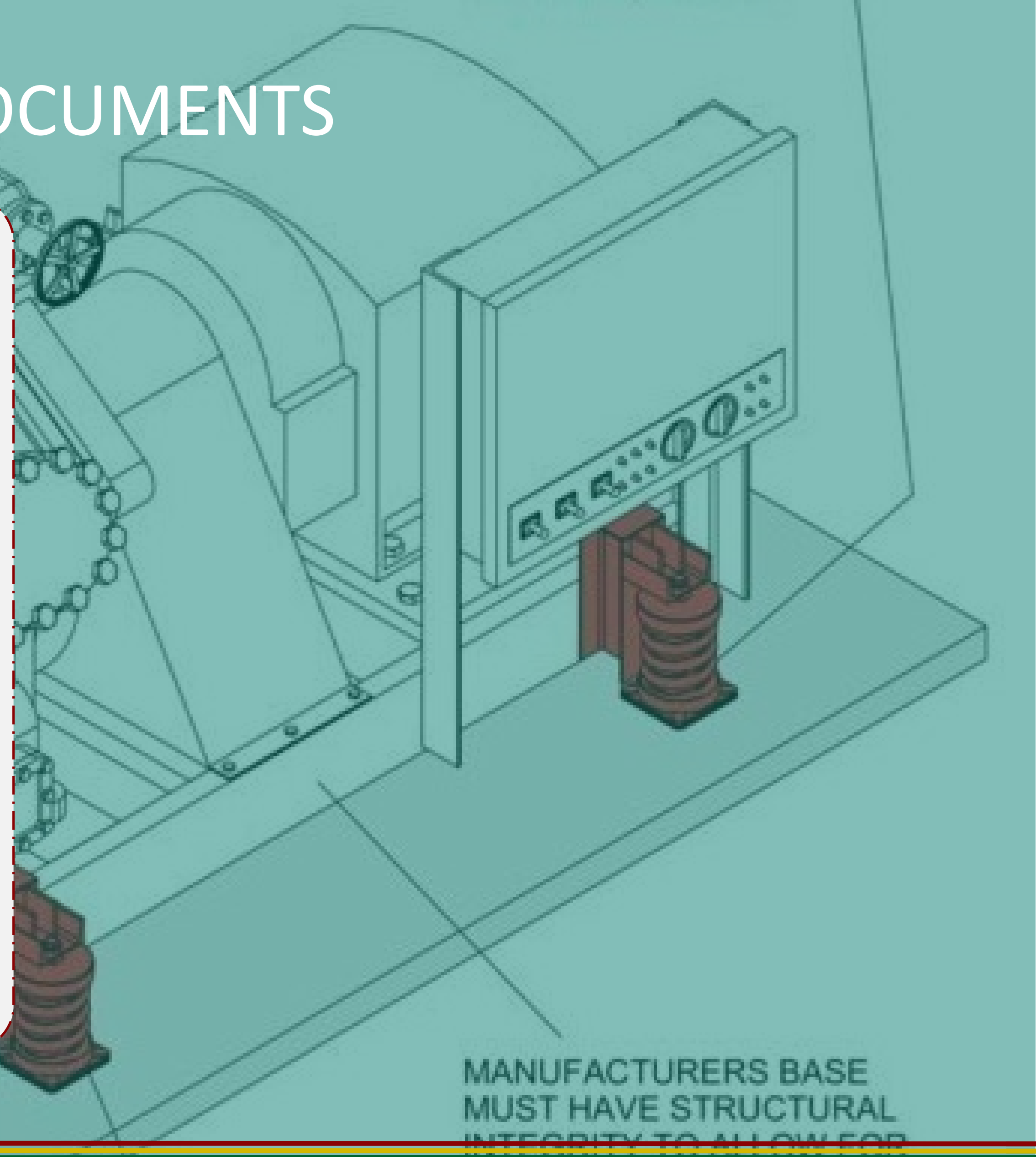


Photo of District Energy St. Paul's Jemne Building, LHB.

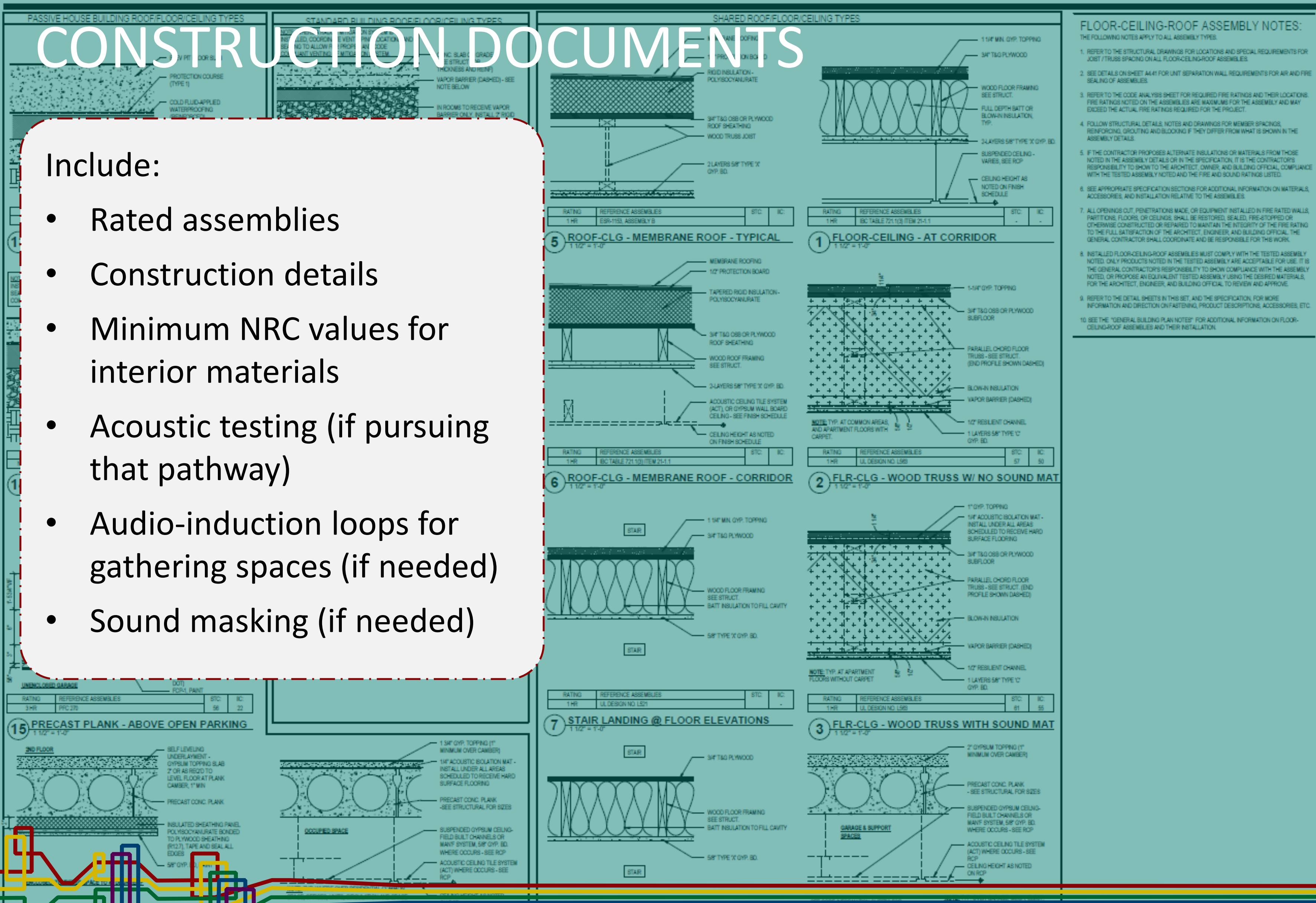
CONSTRUCTION DOCUMENTS

Include:

- Maximum sound levels for mechanical equipment
- HVAC insulation density
- HVAC sound "kits" specification
- Sound wall coordination
- Sufficient room for sound attenuators if required
- Proper sound isolator specification
- Sound control roof curb detailing



CONSTRUCTION DOCUMENTS



Include:

- Rated assemblies
- Construction details
- Minimum NRC values for interior materials
- Acoustic testing (if pursuing that pathway)
- Audio-induction loops for gathering spaces (if needed)
- Sound masking (if needed)

Image credit: LHB.

CONSTRUCTION

- Review substitution requests and submittals to ensure NRC ratings, equipment noise levels.
- Confirm that the specified construction practices are being used for acoustically-rated assemblies

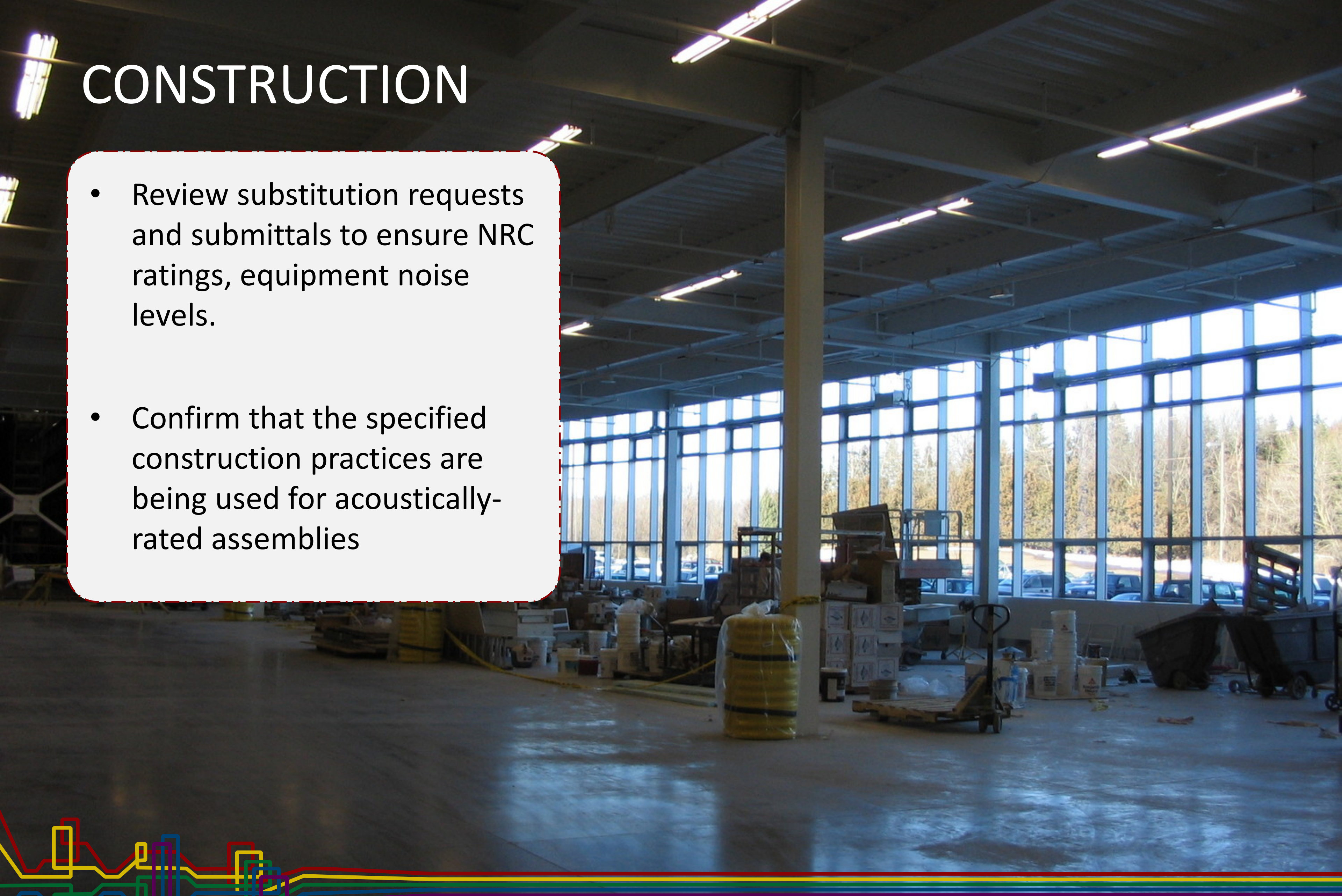


Photo of Quality Bicycle Products, LHB.

DOCUMENTATION REQUIREMENTS

Predesign

- Identification of whether the project is in a high-risk outdoor noise environment

Design & Final Design

- OITC rating of building enclosure
- STC ratings of rated wall types and floor-ceiling assemblies
- Reverberation time and noise criteria by room
- Audio-induction loop design description

Closeout

Verification that installed condition meets requirements for:

- Learning space acoustics
- OITC ratings
- STC ratings
- Reverberation times
- Audio-induction loops

QUESTIONS?

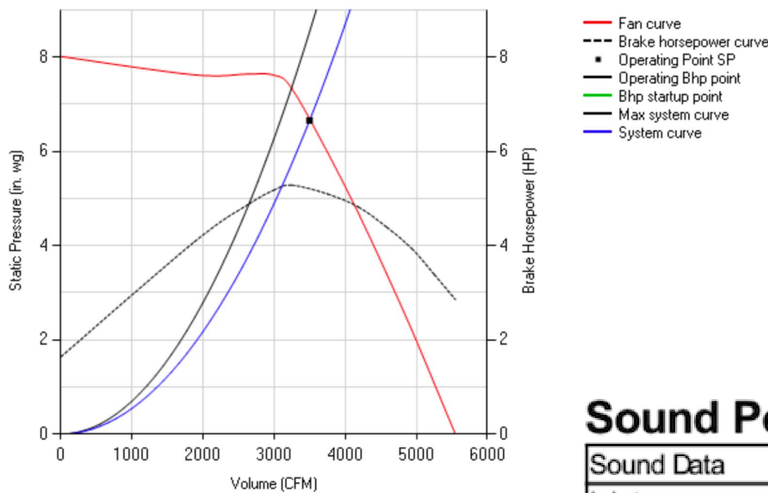
NOISE CRITERIA DEMO

Fan Curve

AHU-1 Supply Fan

APM-15-4-90-II-75

Volume Per Fan (CFM)	3,500	Total Volume (CFM)	7,000	Drive Loss (%)	-
External SP (In. wg)	1.00	Total SP (In. wg)	6.66	Static Efficiency (%)	70.63
Elevation (ft.)	0	Brake Horsepower (bhp)	10.38	Fan Manufacturer	Greenheck
Airstream Temp. (F)	68.0	Fan RPM	3320	Fan Size (In.)	15
Motor Horsepower (hp)	15.0	Max Class RPM	3525		

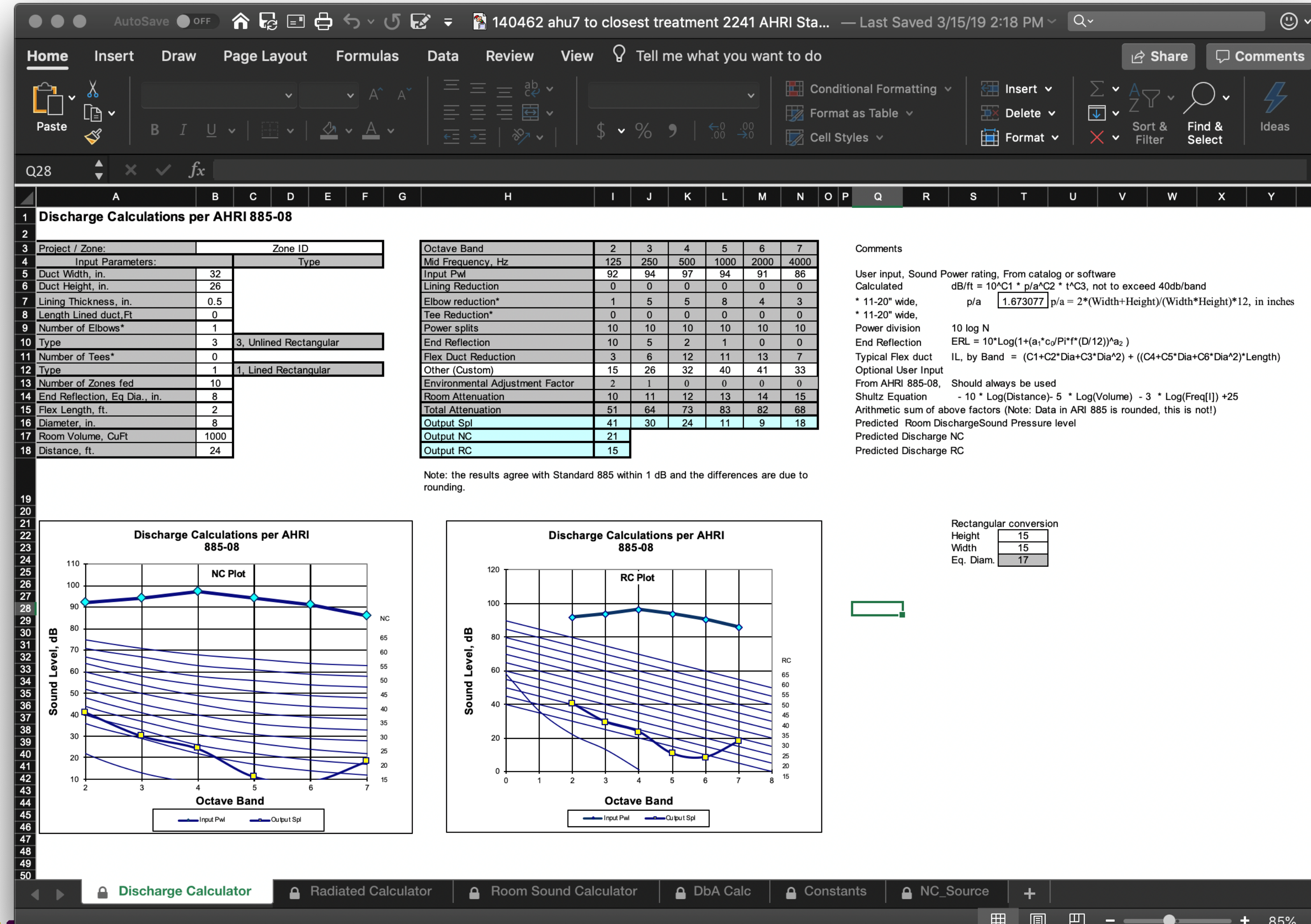


Sound Power by Octave Band

Sound Data	62.5	125	250	500	1000	2000	4000	8000	LwA	dBA
Inlet	91	93	86	91	84	82	80	78	91	83
Outlet	91	90	89	93	91	89	87	83	96	88

Fan arrays display sound data for the array.

NOISE CRITERIA DEMO



Discharge Calculations per AHRI 885-08

Project / Zone:	Zone ID	
Input Parameters:		Type
Duct Width, in.	32	
Duct Height, in.	26	
Lining Thickness, in.	0.5	
Length Lined duct,Ft	0	
Number of Elbows*	1	
Type	3	3, Unlined Rectangular
Number of Tees*	0	
Type	1	1, Lined Rectangular
Number of Zones fed	10	
End Reflection, Eq Dia., in.	8	
Flex Length, ft.	2	
Diameter, in.	8	
Room Volume, CuFt	1000	
Distance, ft.	24	

Octave Band	2	3	4	5	6	7
Mid Frequency, Hz	125	250	500	1000	2000	4000
Input Pwl	92	94	97	94	91	86
Lining Reduction	0	0	0	0	0	0
Elbow reduction*	1	5	5	8	4	3
Tee Reduction*	0	0	0	0	0	0
Power splits	10	10	10	10	10	10
End Reflection	10	5	2	1	0	0
Flex Duct Reduction	3	6	12	11	13	7
Other (Custom)	15	26	32	40	41	33
Environmental Adjustment Factor	2	1	0	0	0	0
Room Attenuation	10	11	12	13	14	15
Total Attenuation	51	64	73	83	82	68
Output Spl	41	30	24	11	9	18
Output NC	21					
Output RC	15					

Note: the results agree with Standard 885 within 1 dB and the differences are due to rounding.

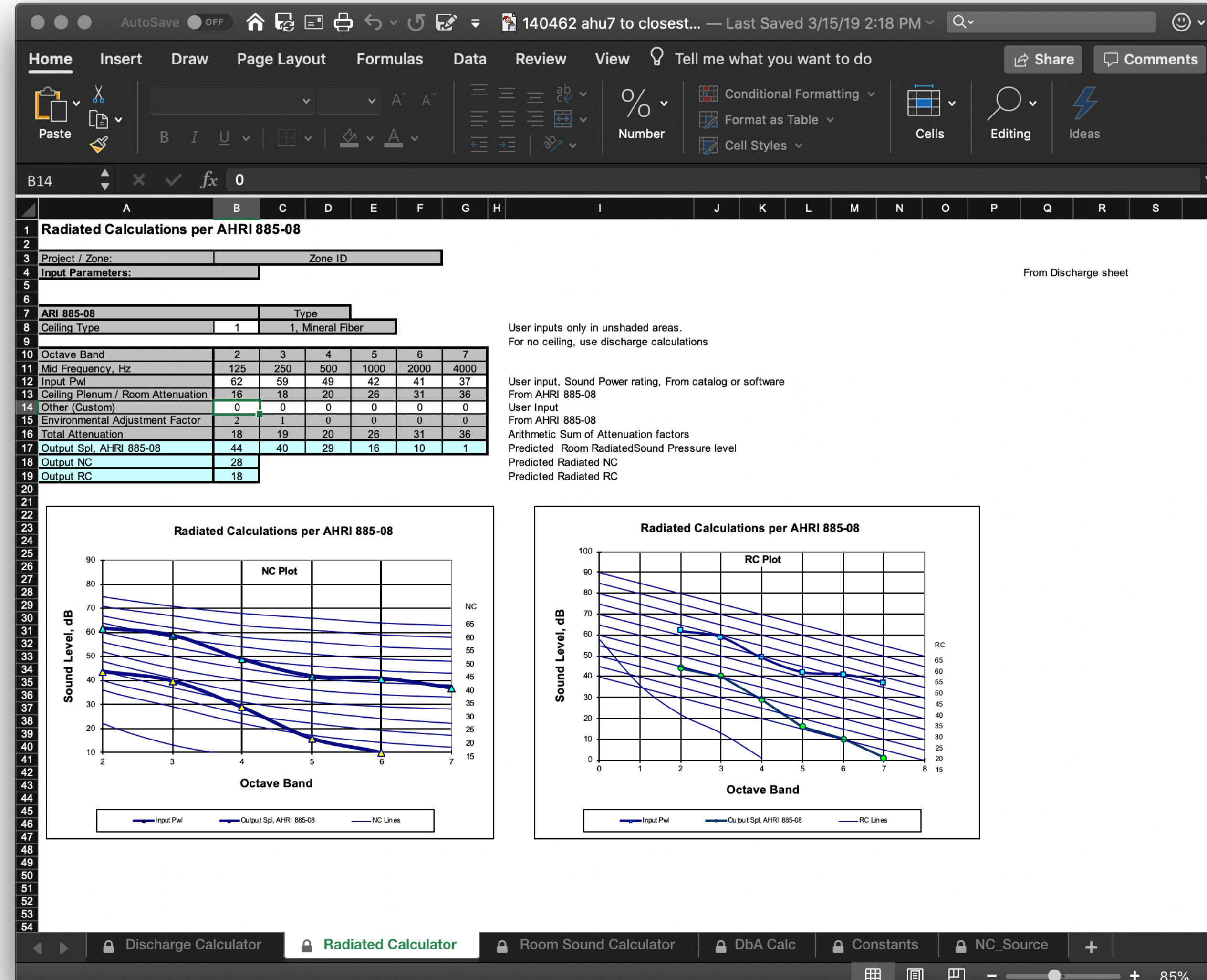
Comments

User input, Sound Power rating, From catalog or software
Calculated dB/ft = 10^C1 * p/a^C2 * t^C3, not to exceed 40db/band
* 11-20" wide, p/a 1.673077 p/a = 2*(Width+Height)/(Width*Height)*12, in inches
* 11-20" wide,
Power division 10 log N
End Reflection ERL = 10*Log(1+(a1*c0/Pi*f*(D/12))^a2)
Typical Flex duct IL, by Band = (C1+C2*Dia+C3*Dia^2) + ((C4+C5*Dia+C6*Dia^2)*Length)
Optional User Input
From AHRI 885-08, Should always be used
Shultz Equation - 10 * Log(Distance)- 5 * Log(Volume) - 3 * Log(Freq[I]) +25
Arithmetic sum of above factors (Note: Data in ARI 885 is rounded, this is not!)
Predicted Room DischargeSound Pressure level
Predicted Discharge NC
Predicted Discharge RC

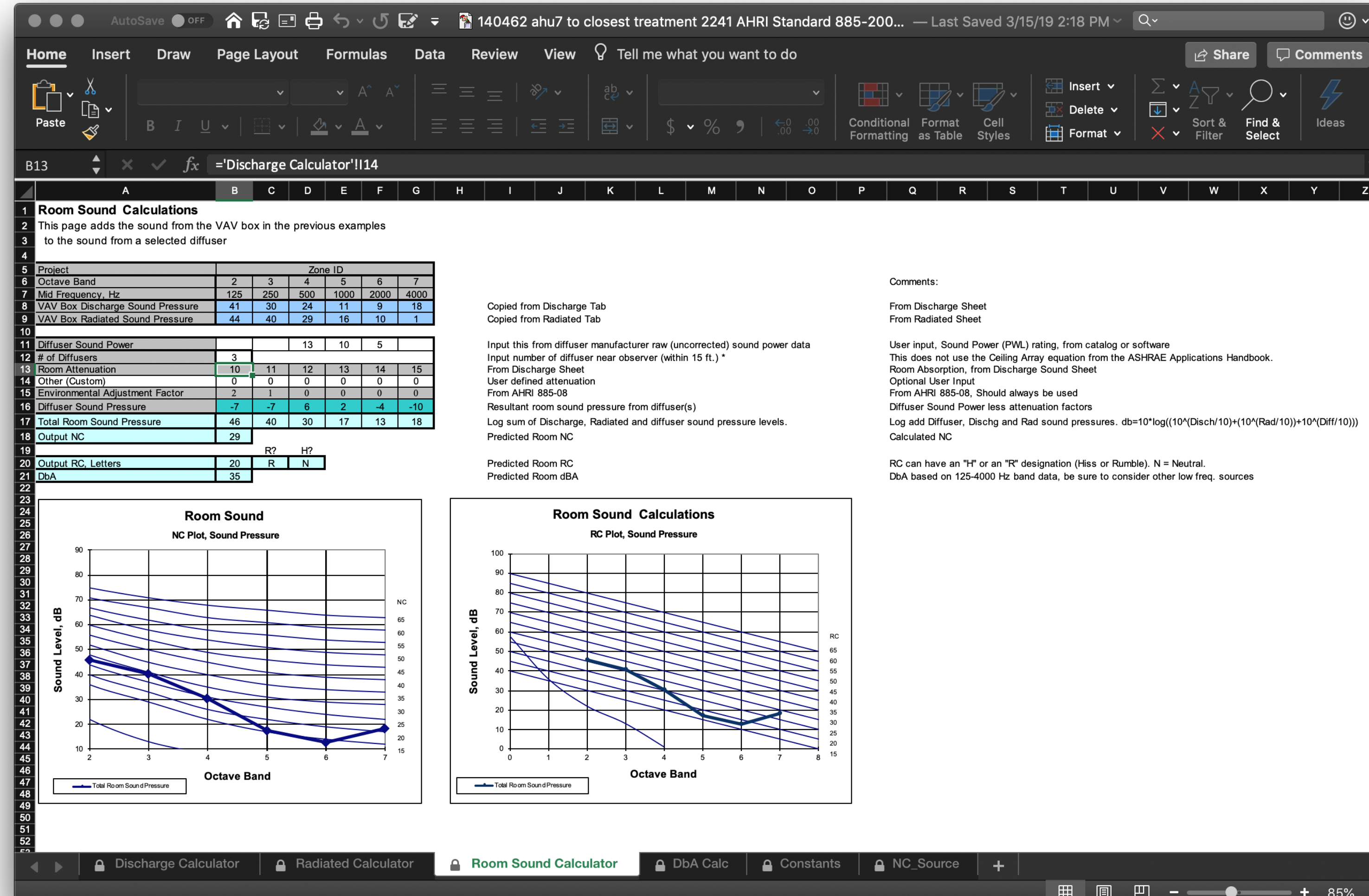
Rectangular conversion

Height	15
Width	15
Eq. Diam.	17

NOISE CRITERIA DEMO



NOISE CRITERIA DEMO

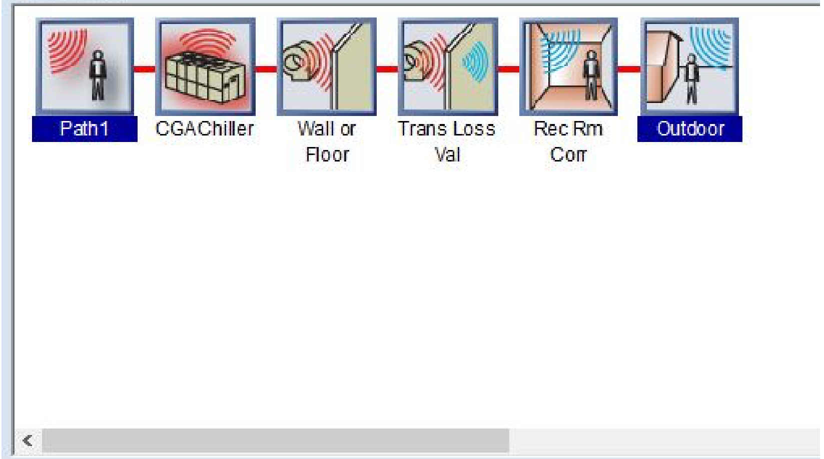


Room Sound Calculations

This page adds the sound from the VAV box in the previous examples
to the sound from a selected diffuser

Project	Zone ID							Comments:
Octave Band	2	3	4	5	6	7		
Mid Frequency, Hz	125	250	500	1000	2000	4000		
VAV Box Discharge Sound Pressure	41	30	24	11	9	18	Copied from Discharge Tab	From Discharge Sheet
VAV Box Radiated Sound Pressure	44	40	29	16	10	1	Copied from Radiated Tab	From Radiated Sheet
Diffuser Sound Power			13	10	5		Input this from diffuser manufacturer raw (uncorrected) sound power data	User input, Sound Power (PWL) rating, from catalog or software
# of Diffusers	3						Input number of diffuser near observer (within 15 ft.) *	This does not use the Ceiling Array equation from the ASHRAE Applications Handbook.
Room Attenuation	10	11	12	13	14	15	From Discharge Sheet	Room Absorption, from Discharge Sound Sheet
Other (Custom)	0	0	0	0	0	0	User defined attenuation	Optional User Input
Environmental Adjustment Factor	2	1	0	0	0	0	From AHRI 885-08	From AHRI 885-08, Should always be used
Diffuser Sound Pressure	-7	-7	6	2	-4	-10	Resultant room sound pressure from diffuser(s)	Diffuser Sound Power less attenuation factors
Total Room Sound Pressure	46	40	30	17	13	18	Log sum of Discharge, Radiated and diffuser sound pressure levels.	Log add Diffuser, Dischg and Rad sound pressures. db=10*log((10^(Disch/10)+(10^(Rad/10))+10^(Diff/10)))
Output NC	29						Predicted Room NC	Calculated NC
		R?	H?					
Output RC, Letters	20	R	N				Predicted Room RC	RC can have an "H" or an "R" designation (Hiss or Rumble). N = Neutral.
DbA	35						Predicted Room dBA	DbA based on 125-4000 Hz band data, be sure to consider other low freq. sources

NOISE CRITERIA DEMO

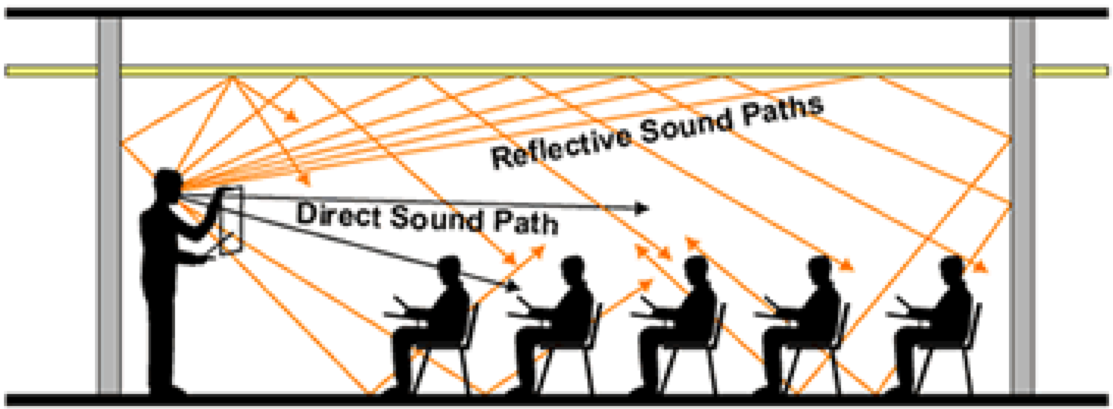


Sum View

Path Table View - path1

Octave Bands (Hz)	63	125	250	500	1K	2K	4K	Comments
CGA Chiller	90	93	89	86	84	79	75	
Wall or Floor	11	11	11	8	8	8	6	
SubSum	101	104	100	94	92	87	81	
Trans Loss Val	-24	-28	-33	-36	-39	-40	-40	
Rec Rm Corr	-7	-7	-6	-7	-8	-8	-8	
Outdoor	-32	-32	-32	-32	-32	-32	-32	
Sum	38	37	29	19	13	7	5	
Ratings	NC 16		RC 13(R)			25 dBA		

REVERBERATION TIME DEMO



B3 Requirements for Learning Spaces:

- ≤0.6 seconds for core learning spaces less than 10,000 cf
- ≤0.7 seconds for core learning spaces 10, 000 cf – 20,000 cf
- No requirement for core learning spaces greater than 20,000 cf or ancillary learning spaces

B3 Requirements for Other Spaces:

- 0.2-0.8 seconds for open office
- 0.2-0.7 seconds for other regularly-occupied spaces
- OR meet NRC thresholds

(in 500, 1000, and 2000 Hz octave bands)

Image Source: Acoustical Surfaces, Inc.

REVERBERATION TIME DEMO

REVERBERATION TIME RESOURCES

Online tools

- Sound absorption coefficients for common materials
- Reverberation time calculators for simple room shapes

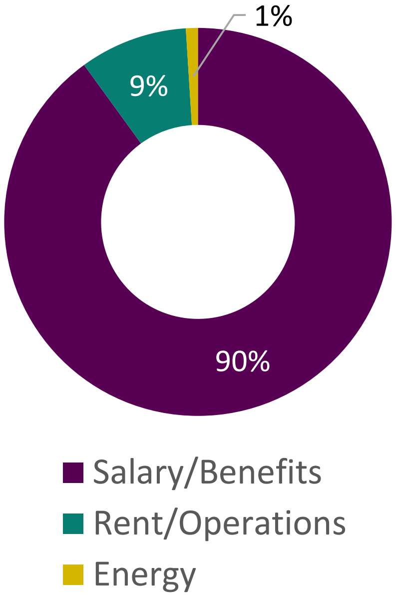
Manufacturers

- Sound absorption coefficients by octave band
- Reverberation time calculators
- Customized reverberation time calculations
- Advice on acoustic solutions

Acoustic consultant

- Customized reverberation time calculations
- Third-party advice on acoustic solutions

WHAT ARE THE COST IMPLICATIONS?



- Acoustic testing
- Acoustic consultant
- Quiet mechanical equipment
- Sound attenuation in mechanical design
- Acoustic wall, roof and floor-ceiling assemblies
- Audio-induction loops
- Sound masking system

QUESTIONS?

www.b3mn.org

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