Learning a Vocabulary For Acoustics Fundamentals

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Everyone experiences acoustics. It can be exhilarating for music and is traditionally recognized as a need for performing arts venues. However, with architectural styles trending to more open rooms, hard surfaces, expanded daylighting and exposed HVAC ducts, acoustics design has become more important in the architecture/engineering/construction (A/E/C) design community. This column will review how acoustical design has become fundamental for the A/E/C industry and offer a simple vocabulary of basic acoustic terms. A second column in the January *ASHRAE Journal* will focus on architectural acoustics with practical application of these principles for your clients.

Acoustics is fundamental for speech intelligibility in any collaborative or shared environment with any size room that must sound clear. Acoustic design is also a basic need for hospitality or multifamily construction where noisy restaurants and recreation venues with bass music can annoy patrons, sleepers or neighbors.

Quality acoustic design efforts can provide a "sense of place" and increase acoustic comfort in the built environment. Design for this can be predicted and planned early in the design process. For example, a library and open offices need quiet environments and speech privacy. A loud, reverberant, open classroom needs speech intelligibility with properly located acoustic materials. In health-care settings, the patient wants to understand what their doctor says, but not have the person in the next exam room also understand it.

Acoustic issues that are not assessed during design can become the cause of discomfort and stress. Poor acoustic design may cause people to stop paying attention or be distracted. Youth in a learning environment and the elderly with hearing loss are affected readily. Lack of acoustic review can allow destructive noise such as noise from a poorly placed chiller to cause excessive noise at the property line or inside the building it serves. Poor acoustical design lowers quality of life, increases stress or distraction and taxes the ability to learn and listen.

For mechanical engineers, acoustics might seem a more distant friend or even a foe during their design process. The study of acoustics considers the subjective human response to sound, and this can be perplexing. This subjectivity can be vague with a limited or

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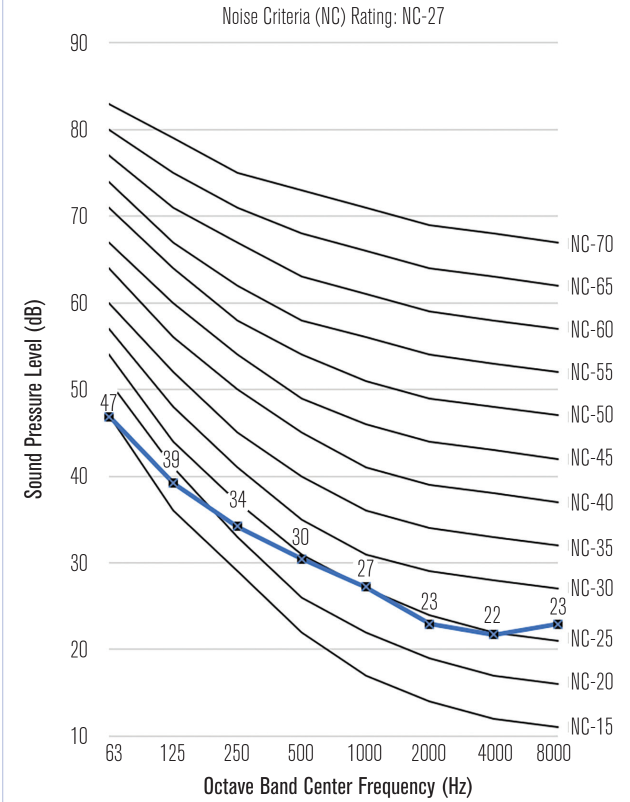
misunderstood vocabulary of acoustics. This includes the definition of noise itself, defined as "sound that is unwanted."

Acoustics is, therefore, challenging to the A/E/C community because its terminology can be confusing. This is exacerbated by the acoustical industry where a wealth of terms seem to change regularly. Product marketing further touts more limited prescriptive solutions that can add confusion for product selection. Therefore, it is becoming the norm for the A/E industry to incorporate an acoustical engineer to sort out and apply acoustic terms for noise abatement and acoustic comfort.

A basic acoustic vocabulary is the starting point. Acoustic fundamentals can be grouped into a simple list and can be illustrated by the ANSI/ASA S12.60 standard. That standard was an early effort to summarize acoustics for classrooms into a simple design exercise. That standard was subsequently extended into LEED® acoustic fundamentals. This improved acoustical awareness in the A/E field. Now acoustic fundamentals are regularly addressed by the A/E industry. This is particularly true for mechanical designers where the *2017 ASHRAE Handbook—Fundamentals,* Chapter 8, and 2019 ASHRAE *Handbook—HVAC Applications*, Chapter 49, review the fundamentals of noise and vibration control. These chapters are good guidelines.

The simplest list of acoustic design starts with four significant fundamentals that are almost always considered for any type of project. The acoustic metrics are noise criteria (NC), room reverberation (RT60), sound transmission class (STC), and impact insulation class (IIC).

FIGURE 1 NC graph for a quiet church or performing arts hall defined by the highest octave band value above the NC line as noted.



Noise Criteria (NC)

It all starts with relative quiet, and noise criteria (NC) is our first important metric in the tool box (*Figure 1*). NC is a target noise level for listening, learning and acoustic comfort. NC is a curve that defines a collection of upper limits by octave bands, such that if mechanical equipment has a tonal peak above the curve in any frequency, it will be noticeable and thus irritating because it is not "smoothed" into relative background noise levels consistent with the neighboring frequencies.

Improper NC selection may also impact the ability for a youth to hear low-level vowels or speech consonants that define intelligibility and allow focus. An appropriate NC level can improve learning and preserve the ability to understand a foreign dialect. NC is not dBA (the decibel). dBA calculates noise levels in each octave and is a measure of perceived sound level weighted for human hearing. NC predicts perceived noise annoyance.

The NC value of any space predicts how annoying the space is perceived to be. It is best if measured by a quality calibrated instrument. Phone apps might work for very rough estimates, and not for code compliance. Phone app platforms are not calibrated for low-frequency nor quiet noise readings. A quiet worship space must provide the ability to hear low-level speech consonants or soft music to be considered contemplative even under audience ambient noise. An open office space can have higher background noise, but must not have noise so high that conversations can't be understood.

Recommended and typical NC values for design can be:

- NC-20: commercial broadcast studio/music performance space;
- NC-25: worship/music facility venues/collaborative speech in large rooms;
- NC-30: quiet executive offices/lecture spaces/small conference room;
- NC-35 to 37: highest-level noise for classrooms (ANSI S12.60);

- NC-40: moderately noisy office;
- NC-45: noisy office; and
- NC-50: very noisy office or a noisy cafeteria.

Room Reverberation (RT60)

Room reverberation is also referred to as RT60 (*Figure 2* and *Figure 3*). RT60 is an acronym for reverberation time. It is the time after the sound source ceases until the sound pressure level is reduced by 60 dB. This is a very short time (in seconds) where a single fast impulse within a room dies off to quiescence. The time from onset to quiescence is measured by 60 decibels. An example is a burst balloon in a room. The fast "pop" attenuates to the NC background noise level in the space.

The RT60 metric can have a positive or negative influence. For music it is positive, and longer times are desirable, e.g., organ music. Short reverberation time improves speech intelligibility. Nearby room reflection helps amplify the speaker's voice without reducing intelligibility. But as the RT60 time increases with longer room reflection over larger distances, intelligibility degrades because reflected noises are interpreted as echoes, not part of the original message. Reverberance is easily heard in remote conference calls as a boxy or "roomy" sound where a "sense of that place" can be identified by the listener almost intuitively.

Long reverberation times in which speech clarity is required can be a challenge and should be watched carefully. When RT60 is out of the preferred target range, the acoustical engineer should work with the architect to add absorptive materials and diffusion elements that adjust RT60 for the programming needs of the space until speech is clear. Treatments are usually associated with surface area balanced with a selection of absorption values that maintain the right frequency spectrum.

Rooms under approximately one second RT60 might be considered appropriate for speech. Longer RT60 times are good for music. A professional design should have an acoustician involved for planning and calculations.

Sound Transmission Class (STC)

A third fundamental is used for simple barriers, sound transmission class (STC). This metric is widely used but often also misused. It is a lab-tested curve fit metric on a chart representing frequency range and sound level for barriers leading to privacy. It regards how humans hear and is limited to speech frequencies. The STC

FIGURE 2 The RT60 (reflection) of a typical room before and after acoustic treatment, defined by ft^2.

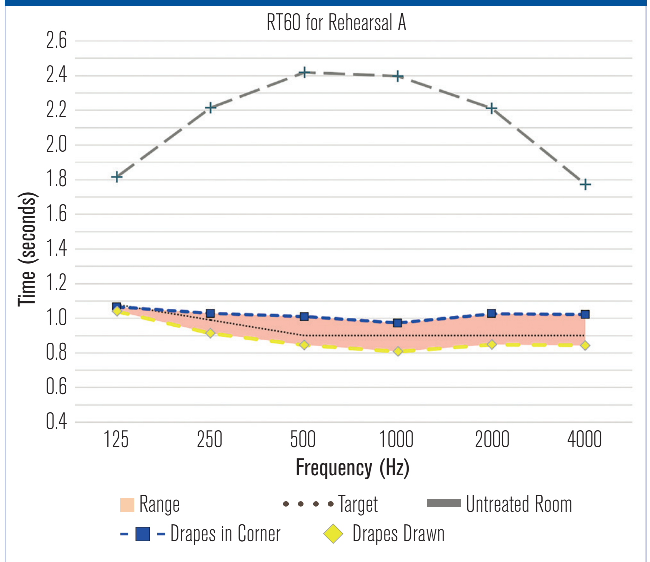
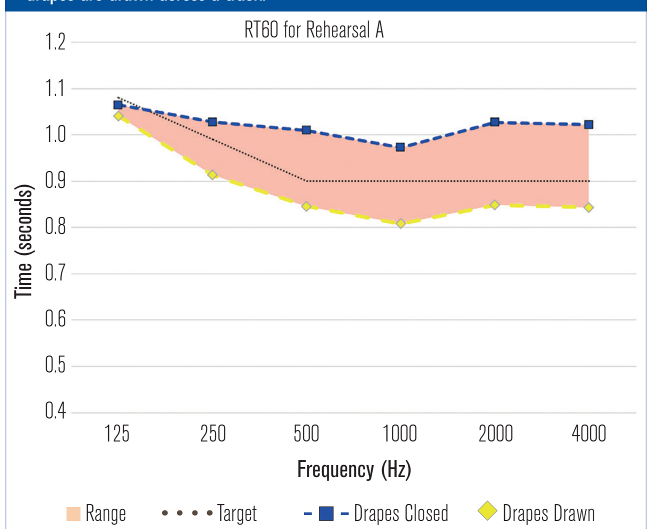


FIGURE 3 The RT60 for a music education facility showing the ranges of time as drapes are drawn across a track.



value for a barrier is cited from the blue line in *Figure 4*, which is curve fit to 500 Hz. This leads to selection of appropriate wall types or duct wraps (*Figures 4* and *5*). It does not measure HVAC rumble nor bass music. And as illustrated, a single STC value can vary widely for types of assembly based on field conditions (*Figure 6*). As field construction never achieves a lab-measured value, STC becomes (F)STC for field STC. Therefore "your stated STC mileage may vary."

While STC is still a common standard, the best barrier metric for walls is noise isolation class (NIC). The physics of STC and NIC is that the features that help are greater mass in a barrier or physically decoupling the two sides of a wall with non-contiguous framing separated by an air gap. Thicker walls with added mass are considered improvements.

Impact Insulation Class (ICC)

A fourth important metric is impact insulation class (IIC) (*Figure 7*). The current architectural style of hard exposed floors affects IIC because high heel shoes on hard floors or dropping weights from a training center are the most common issues. It cannot easily be fixed during a later design phase and especially not if construction has begun. Early detection is the cure for IIC, and if not considered early it will increase acoustic risk, especially in a multifamily ownership condition.

Reducing IIC may only add a few millimeters to an inch of thickness to abate and improve structural vibration to an occupied space below. The IIC value is notable on stairs tied to a structure where impact on stair treads is not easily decoupled from an adjacent tenant wall.

A common misconception is that a concrete floor is perceived to be solid and massive with high STC values. But concrete has a very low, ineffective IIC value. For example, a high heeled shoe will drive a sleeper below crazy! This is because solid concrete is a very effective medium for sound travel. People often construe concrete as a good IIC for impact when they are thinking of STC barrier instead.

Improperly selected IIC design will prevent sleep in a hotel room and can result in an angry guest the next morning who refuses to pay the bill. Sleepers can trace a walker on their ceiling as they lay awake at night. Carpet improves IIC, but design styles are trending toward hard exposed floors. As marketing departments invariably try to publish the highest IIC value they can, they often show high performance assemblies, implying high IIC values that may not be used in the project. Hence, the risk and confusion of this metric is high, and it represents the type of risk that a lack of knowledge of acoustics can create.

FIGURE 4 STC 50 values are all similar, but widely vary in performance.

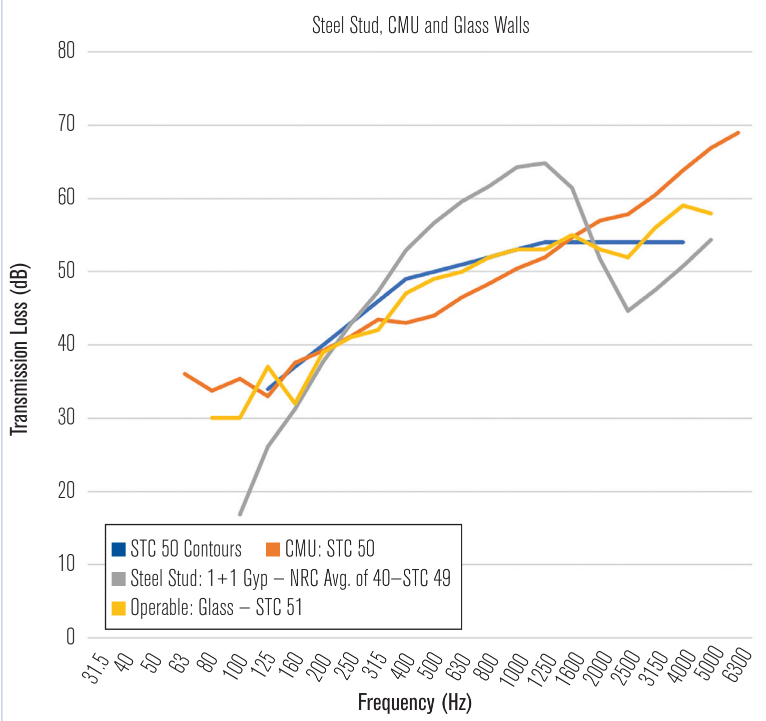
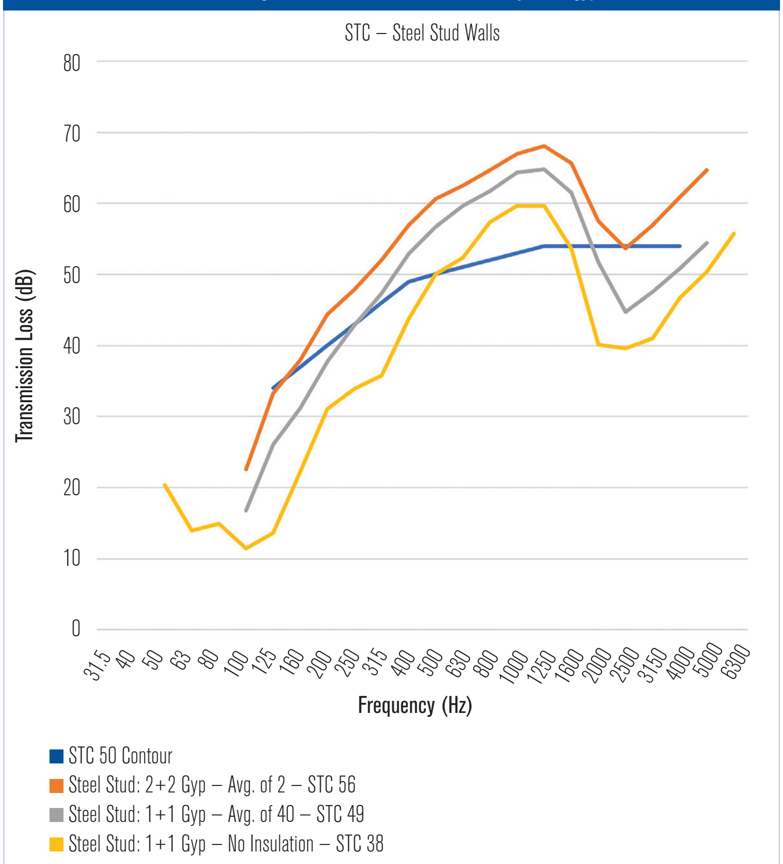


FIGURE 5 Steel stud wall showing effects of insulation and added layers of gypsum.



A Note About Using AC Grilles with NC Ratings

One purpose of this column is to promulgate simplified acoustics terms. If we select the first basic metric most often associated with mechanical design, the ubiquitous HVAC air supply grille with an NC rating, we often find a single grille rated in the high teens or low NC-20s. But it is common for the NC term of a lone grille to be incorrectly assessed as the NC rating for a complete room. This is a misunderstood application of the NC rating. NC rated grilles are not the same as the NC rating for a room, but they do contribute to the room noise and its composite room NC value.

Here we consider simple decibel (dB) and NC addition as equivalent for choosing a proper NC rating, and this illustrates how basic acoustics can be simplified. For example, "NC grille addition" can be made by adding two NC rated grilles in a room with 3 NC points added for each pair used (assuming that the listener is directly between them). Two NC-20 grilles produce NC-23. Further, doubling that pair to four grilles adds another 3 NC points to the mix, and the room is now an NC-26 rated room. Now it is not so quiet, especially if there are four more grilles added (eight total) for NC-29. Ten sound sources result in a 10 dB increase.

While this illustration is certainly not a complete picture and other factors come into play (low frequency rumble, unbalanced hiss, upward masking, distance or tonal noise), the illustration is true for grilles in most rooms and leads to a basic understanding of how acoustics can work for you.

Conclusion

Acoustics and noise control are design needs now more than ever. Basic acoustics can be handled by mechanical engineers or architects with acoustic knowledge, but for more critical spaces or things beyond the knowledge of your staff, a professional acoustician is a valuable member of any A/E team. ■

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FIGURE 6 STC chart for three different lab-tested barriers, all with the same single number STC rating but dramatically different transmission loss.

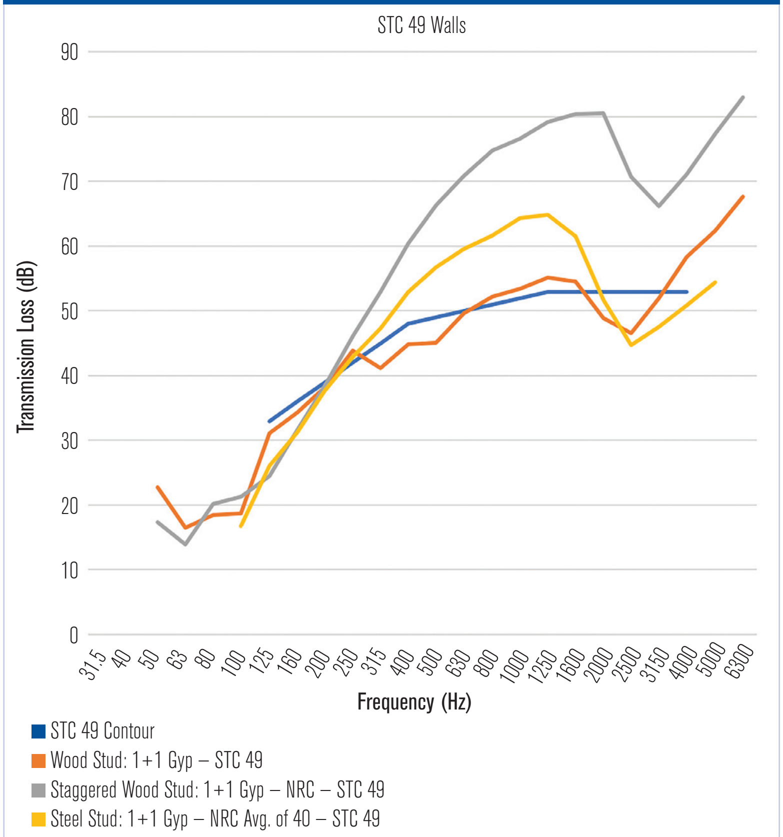

FIGURE 7 IIC chart showing the effects of carpet on a floor by frequency.