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The formulae $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_j U_i)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho\overline{U}_i\overline{U}_j)=-\frac{\partial \overline{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U}_i}{\partial x_j}-\rho\overline{u_i'u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho\overline{U}_i\overline{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial \overline{T}}{\partial x_i}-\rho\overline{u_i'h'}\right)$ *biomedical research facilities.*

Sound Design Metrics

Sound is a predictor of comfort for the individuals working within a space. When designing for healthcare environments, lab equipment or HVAC equipment designers often interchangeably use terms such as Sound Transmission Class (STC), Noise Criteria (NC), and Noise Reduction Coefficient (NRC). However, it should be noted that these are three distinct terms for measuring different aspects of acoustics by voice, decibels (dB), and material sound absorption.

STC is an attribute of a wall or floor-ceiling assembly that measures the amount of a sound, such as from the human voice, that is blocked as it passes from room to room. STC determines the sound isolation between spaces, which can be important for speech privacy. For example, in patient exam rooms in a medical building, conversations between patients and their doctors are meant to be private, as are closed-office discussions between an HR director and an employee. Even when speech privacy is not a concern, sound transmitting from one room into another can be distracting and inhibit productivity, concentration, or relaxation.

Figure 1: Sound blockage (image courtesy of The Soundproofing Company)

The Minnesota Sustainable Housing Initiative explains STC in the following way:
An STC rating roughly equals the decibel (dB) reduction in noise volume a wall or partition can provide… The STC number (i.e. decibel reduction) does not apply equally across the entire range of frequencies measured [because] in general, it is more difficult to block the transmission of low frequency sound, so any partition will have less sound attenuation at lower frequencies.[1]

For our example (see Figure 1), a sound that is 100dB on one side of a partition is reduced to 55dB as it passes through to the other side, which means the partition has an STC of 45.

The STC ratings for walls are only one aspect to consider when designing for sound reduction within laboratories. Labs containing specialized or sensitive equipment may have unusual utility, environmental, and other requirements. Reverberation from the room's surfaces or the noise of equipment should also be considered. According to DRM section 2.1.3.7.7, areas where noise-sensitive procedures occur particularly need to be isolated from noise sources, and it's important to consider that some instruments, such as high magnification microscopes, are sensitive to noise too. This means that coordinating with laboratory personnel to determine acoustic requirements for each type of specialty laboratory space is important. Consultants may include, but are not limited to, acousticians, vibration engineers, and shielding specialists. Acoustics play a vital part of learning in the lab and can significantly impact the focus (or lack thereof) of the scientists using the lab space. See News to Use article "Demising Partition Acoustic Requirements" (June 2018) for additional information on wall and acoustic STC.

NC is a measure of the background sound level in a space. According to Jonah Sacks, Principal Consultant at ACENTECH, dBA (A-weighted decibels) should be used to measure intrusive transient sounds and NC for steady background noise. Sacks says that this is because "Intrusive transient sounds, like voices, or a truck going by, or the bass beat of music, are more noticeable and disturbing than steady noise from HVAC." He adds that while there is no perfect conversion, a rule of thumb is 35 dBA is about NC-30, which is roughly 5 points smaller for the same actual sound level.

For mechanical system noise and vibration, sound analysis required by DRM section 6.5.2 begins with the supply fan, return, or exhaust fan and includes ductwork, terminal units, and diffusers. The primary objective of HVAC system acoustic design is to ensure that facility spaces are not unacceptably affected by HVAC system-related noise or vibration. However, HVAC acoustic design features such as duct silencers and vibration isolators are often added late in the construction document phase. This results in poorly integrated design and problematic acoustics and vibrations, which are significant issues because Sacks notes that the HVAC system is one of the noisiest parts of the building infrastructure.

NRC measures how much sound a material absorbs, which impacts how things sound inside the room for users. It does not relate to mechanical equipment noise or sound isolation between rooms, but instead to the reverberation of noise off surfaces. In most spaces, Sacks says the best way to control reverberation is to include a sound absorbing ceiling material with a rating of NRC 0.70 or greater. In situations where excess noise is a concern, the Facility Guidelines Institute has recommended noise levels which NIH expects designers to adhere to as a minimum requirement; designs with sound absorbing materials can help meet these requirements. See additional information from the references below.

Conclusion

STC, NC, and NRC are all unique measures of sound and are all important to consider, since acoustic quality can significantly impact a space and its occupants. Proper acoustic design requires broad engineering cooperation across multiple disciplines; waiting to design for sound after construction is expensive and poor planning. Instead, a stakeholder meeting should be held early in the project's programming stage to determine the scope and any additional studies required. The goal for designers should be to ascertain what equipment will be in the newly designed space, then discuss further with manufacturers to provide adequate sound absorption.

References

1. Minnesota Sustainable Housing Initiative, Information Brief – Sound Transmission www.mnshi.umn.edu/kb/scale/soundtransmission.html
2. Thank you to Jonah Sacks of Acentech for Publication Review.
3. Sykes, David and Tocci, Gregory C. *Sound & Vibration 2.0: Design Guidelines for Health Care Facilities*, 2010.

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Further details on this month's topic are available on the DRM website: Section 6.5 Noise and Vibration
https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx