



MECHANICAL SYSTEMS NOISE IN CLASSROOMS

By Timothy Foulkes

Everyone understands the need for quiet sound levels in school classrooms. This article explores the need to achieve low sound levels, some of the different sound criteria, and their implications for system design. This article covers only noise inside the classroom. Noise outdoors is equally important but is a subject for an article of its own.

Maintaining low sound levels in classrooms is increasingly difficult due to several trends in building design. One of these, mandated by code, is the need to provide increased amounts of outside air. Another trend that has been with us since the 1970s is the need for energy efficiency. This requires the use of energy recovery systems, adding even more fans and ducts to the building. A third, more recent development is the concern about the use of sound absorptive duct linings. Finally, school officials and parents are becoming more aware of acoustics and sound levels, especially the parents of hearing impaired students who are often placed in mainstream classrooms.

In classrooms, the ability of students to understand speech is inhibited by two sources of unwanted sound, i.e. noise. One is reverberation, or excess reflected sound energy from too many hard surfaces. A limited amount of reflected energy provides beneficial reinforcement of speech. With too much reflected sound energy, the excess ringing of the room begins to interfere with speech. Reverberation control is the responsibility of architects because they select the finish materials.

The other significant source of noise is the continuous sound of the ventilation system. The potential sources of mechanical noise include fans, pumps, chillers, condensers, and ducts and diffusers.

Working together, background noise and excess reverberation degrade speech intelligibility. When either of these noise sources

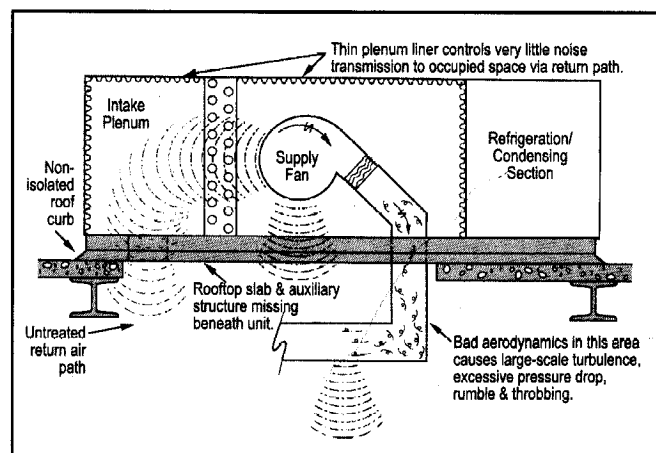


Figure 1: Very noisy rooftop unit installation. This kind of installation is responsible for rooftop unit noise and vibration complaints. It should not be used in schools.

begins to interfere with speech, the brain automatically goes to work and filters the desired information out of the extraneous signals. Unfortunately, the additional workload of filtering reduces our attention span. These noise sources erode our attention span long before we recognize a significant problem with either reverberation or background noise.

Criteria

Noise criteria for mechanical systems have been actively debated for the past several years. The differences between NC, RC, and NCB are fairly subtle compared with the gross noise problems most consultants encounter when responding to a complaint. In other words, achieving the desired sound level is more important than which rating system is used. Currently, the 1995 ASHRAE Handbook—Applications (Chapter 43: Noise and Vibration Control) recommends RC 35 as a maximum sound level for large classrooms (over 750 ft² [70 m²] floor area)

and RC 40 for smaller classrooms. Much discussion is taking place within the acoustical community about the need for even lower sound levels in classrooms. The desirable sound level is at least 5 decibels lower than the maximum values in the ASHRAE table. To put these criteria in perspective, the electronic sound masking systems that are often installed to mask speech in open offices are normally adjusted close to the NC 40 curve. This means that background noise above NC 40 in a classroom will seriously interfere with speech communication.

Higher background sound levels are acceptable in laboratory classrooms and industrial arts areas. In these areas, it is not feasible to achieve the same low sound levels as in classrooms because of process ventilation and exposed ductwork. Also, the learning activity in these areas is based on smaller group interactions and hands-on work as opposed to large group lectures and discussions. As the speaking distance gets shorter, the need for low background noise is reduced. For the purposes of this article, the word classroom will not include these spaces.

Systems

The mechanical system design concept is critical to achieving low sound levels. The decisions about what type of equipment to use and where to locate it have the most far reaching impact on the mechanical system sound levels. In some cases it simply is not feasible to achieve quality sound levels when a noisy piece of

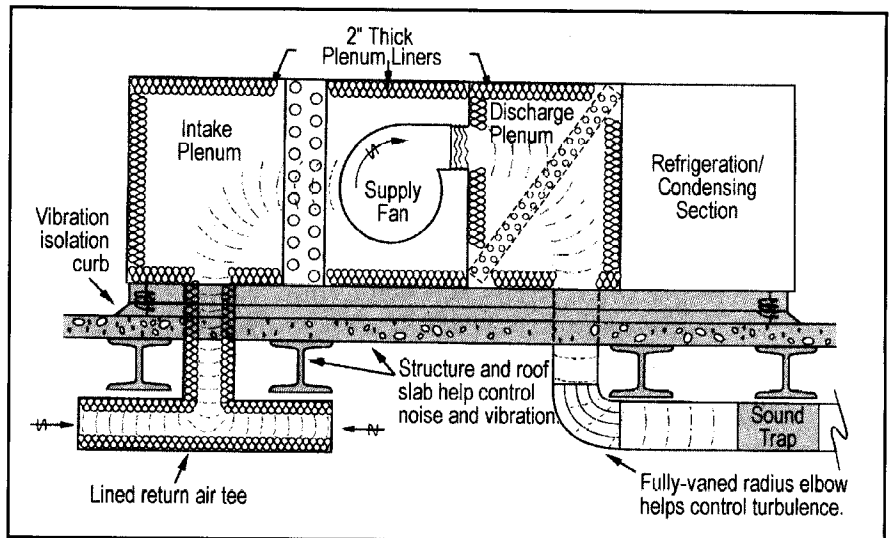


Figure 2: Moderately noisy rooftop unit installation. This installation is usually acceptable over corridors.

equipment has been located too close to a sensitive space.

It is difficult to summarize all the different types of ventilation systems used in modern schools. Needless to say, the design team should be careful about locating fans or noise producing devices within the classroom envelope. The closer the equipment is to the students, the more significant the potential problem.

Unit Ventilators

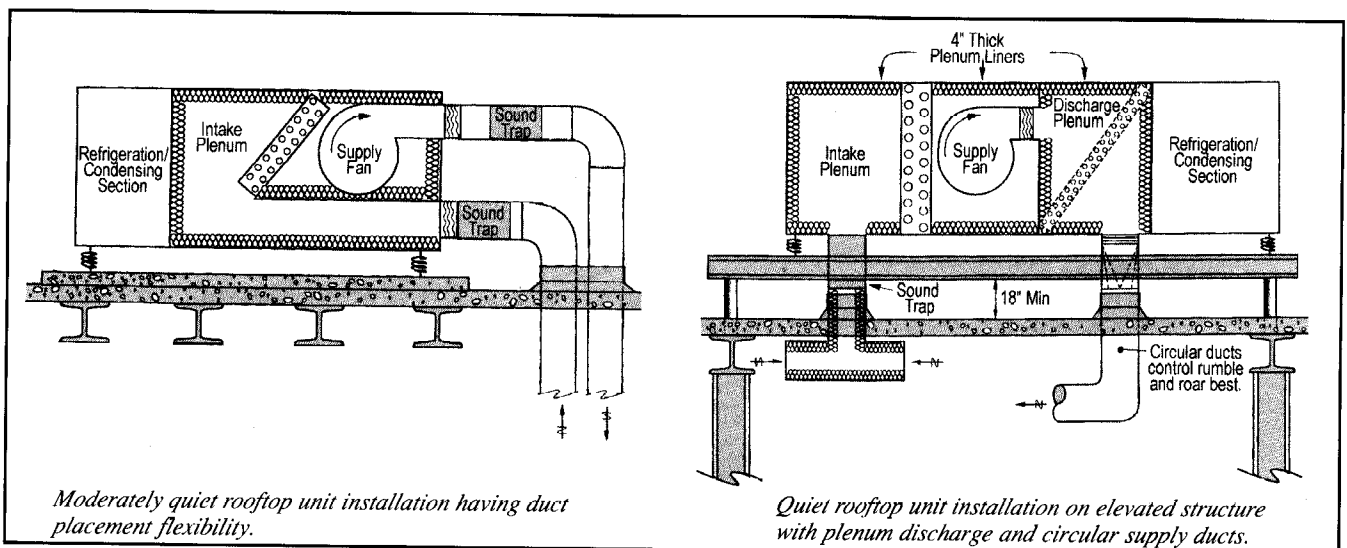
Unit ventilators and console fan coil units are a particular problem since they are normally located within 3 ft (0.90 m) of student desks, and there is no ductwork in which attenuation can be added. Unit ventilators have been an accepted class-

room design for many years. However, current guidelines for outside air require these units to deliver significantly more total airflow to each classroom.

The guidelines also require that they run at all times. There are reports that quieter models exist, designed to comply with strict sound criteria set by the Los Angeles School Department. The author has no specific information yet on manufacturers or actual sound levels.

Rooftop Equipment

Extreme care is necessary when designing rooftop equipment directly above noise sensitive space. The design must take into consideration the capacity of the equipment (cooling capacity or fan



Moderately quiet rooftop unit installation having duct placement flexibility.

Quiet rooftop unit installation on elevated structure with plenum discharge and circular supply ducts.

Figure 3: Minimum recommended practice when units are located over classrooms.

power), the acoustical characteristics of the roof structure, and the finish ceiling. Large rooftop units with greater than 25 tons (88 kW) cooling capacity should never be placed directly above classroom space.

To achieve low sound levels directly below large rooftop equipment requires special features such as a heavy concrete roof slab or floating slab system and a custom built-up unit with internal duct silencer banks for the supply and return air paths.

Medium size rooftop equipment (up to 25 tons [88 kW] cooling capacity) can be successfully located above corridor space, assuming that vibration isolation of the machinery and sound attenuation of the ductwork are properly treated.

Figure 1 shows a rooftop unit installation that is not suitable for schools because of the risk of noise and vibration transmission to the occupied space. Figure 2 shows an improved arrangement that can often be used with success over corridors and non-critical spaces. Figure 3 shows minimum recommended practices when units are located over classrooms.

VAV Systems

If a classroom is served by a VAV system, the designer should place the VAV box outside the classroom space, above a storage room or corridor. This location allows casing noise to radiate into a non-critical area. It also provides a longer duct run for sound attenuation between the VAV discharge and the classroom diffuser.

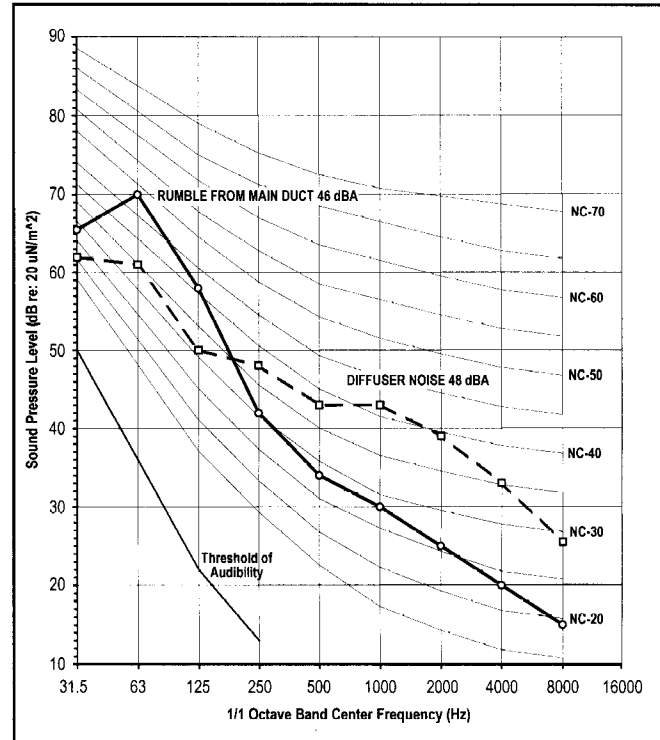


Figure 4: Typical noise spectra found in buildings.

When selecting VAV terminals for sound levels, keep in mind that the NC levels published in the catalog for VAV discharge noise are based on 10 ft (3.0 m) of lined ductwork between the VAV discharge and the diffuser, plus a 10 decibel room effect. The actual room effect in most classrooms is more likely to be 5 or 6 decibels. If the design does not use acoustic duct lining downstream of the VAV terminal, a duct silencer with attenuation values that are equivalent to a 10 ft (3.0 m) lined duct should be used instead.

Diffuser Noise

Air diffusers are the final element of the HVAC system before the air is delivered to the occupant. Diffuser noise characteristics are critical because they are close to the occupant and no further attenuation is possible. Also, diffuser noise tends to be significant in the frequency range that interferes most directly with speech. *Figure 4* shows a typical diffuser noise spectrum. Compare the diffuser noise to the rumble from a main duct shown on the same graph. The two types of noise have different causes and therefore require different treatments.

Basic catalog sound ratings for diffusers are optimistic by 5 to 10 decibels. This means that the as-built sound levels will normally be 5 to 10 decibels louder than the NC rating in the catalogue. This difference is due to room effects and the summation of multiple diffusers in the same space.

Diffusers with integral balancing dampers should be used with caution. In the full open position, these dampers add approximately 3 decibels to the diffuser sound level. The difference increases to 10 decibels or more when the balancing dampers are 50% closed. In general, pushing air through a multitude of small elements generates noise. Perforated face diffusers are noisier than conventional vaned diffusers for the same size and air quantity. Quiet diffuser designs are characterized by widely spaced, large-scale vane elements.

Summary

In summary, quiet classrooms are important to the educational process. The most important step is concept design—selecting a system with low sound levels and locating large equipment away from the classroom. Vibration isolation of rotating equipment is essential, as is low velocity aerodynamic duct design. Some form of sound attenuation is needed for all air moving devices and VAV terminals. Finally, diffusers must be selected for quiet sound levels.

Bibliography

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