# Background Noise Levels in Classrooms

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**Summary:** Field measurements of background noise levels produced by air-conditioning systems were measured in a sample of 46 elementary school classrooms. Noise levels were grouped by air-conditioning system type and resulting Noise Criterion levels. Eight computer models of classrooms were constructed with varying combinations of absorbent materials on the surfaces of the room. A sound source was configured to approximate the normal speaking voice of a teacher in the room. RASTI measures were estimated for six seating locations in each room for background noise levels from NC 15 to NC- 55 in 5 NC point increments. RASTI values remained above 0.7 in seven of the eight rooms at NC levels of 30 and below. RASTI levels decreased to 0.50 and less in all eight rooms at levels of NC- 45 were exceeded. The one exception to this was the room that was constructed with a gypsum board ceiling, vinyl tile floor and gypsum board walls. Even with no background noise, RASTI values in this room never exceeded 0.60. Background noise levels of NC 30 or less appear to be necessary in most typical classrooms to maintain reasonable RASTI values. Very few of the actual classrooms visited achieved these noise levels.

## THE CLASSROOMS

Acoustical measurements of reverberation time and background noise were made at multiple source and receiver locations in 46 different classrooms in 25 different schools in 10 different school districts. One of the schools was a private school. One of the schools was a school for emotionally and physically handicapped students. The rooms are perhaps indicative of the acoustical conditions of the 722 similar rooms within the schools measured. If one includes the identical schools built using the same architectural designs in the school districts visited, the sample becomes indicative of over 5000 rooms. This was not a spot sample intended to illustrate extreme conditions, but rather an effort to examine “typical” classrooms.

Many of the classrooms were relatively similar to each other in room volume and interior finishes. The floors were carpeted. The ceilings were mostly acoustical ceiling tile with an NRC estimated to be 0.50-0.60. The walls were painted masonry. Some of the walls were gypsum board. One wall was typically an exterior wall that had windows from desk height to the ceiling. One of the classrooms had a sloping ceiling that was approximately 9 ft tall on one side and 18 ft tall on the other. Several of the rooms were portable classrooms. All of the rooms had some partial height furniture such as book shelves to divide the room into smaller sections. They also had tables, chairs and a teacher’s desk. The ceilings were flat with a height of between 2.5 m (8.5 ft) and 4 m (11 ft). The length and width of the rooms were slightly less than 10 m. (30 ft).

## AIR-CONDITIONING SYSTEM NOISE

Noise levels from air-conditioning units were measured in both octave band and A-weighted sound pressure levels and on Noise Criterion (NC) curves. There is a cause and effect relationship between system selection, system design and noise the rooms studied.

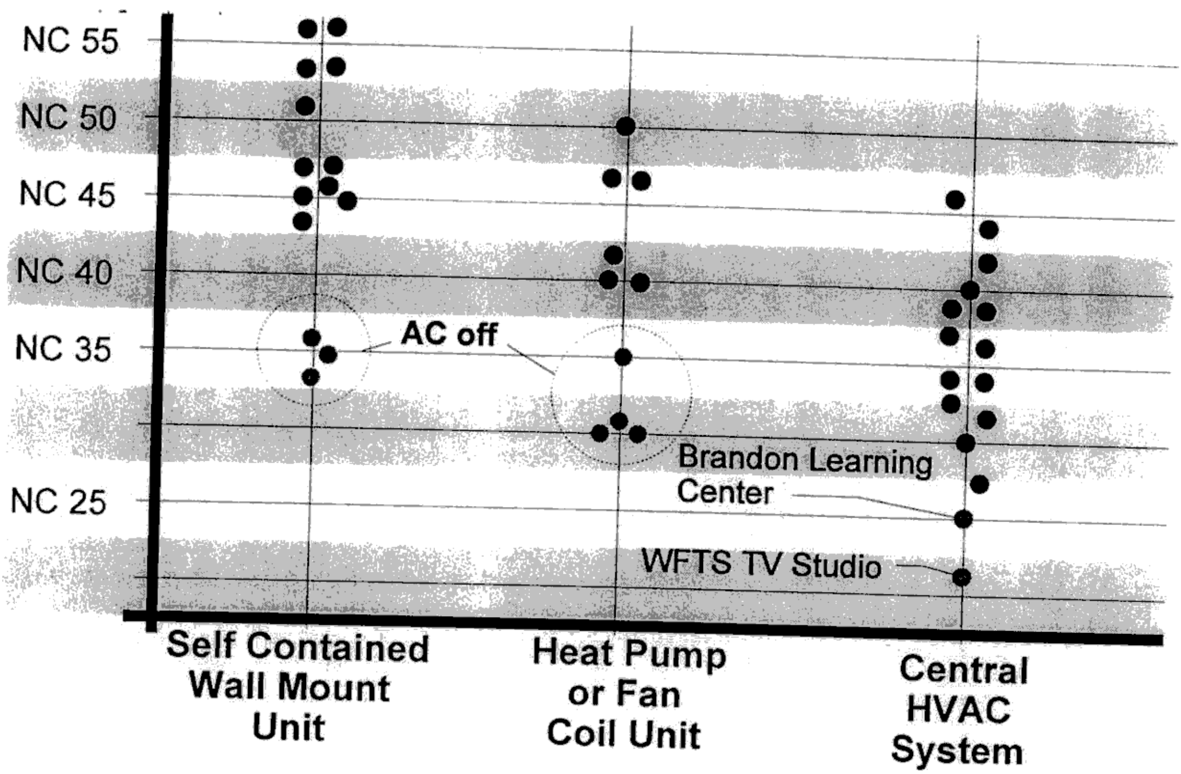


**FIGURE 1.** Background noise levels plotted vs. air-conditioning system type in representative rooms.

Several general types of air-conditioning systems were found in the classrooms including: self-contained, wall-mounted air-conditioning units; decentralized fan coil units and heat pumps with short duct runs; central rooftop units serving multiple rooms; and central systems with variable air volume controls. Rooms with the wall-mounted units and decentralized heat pumps with short duct runs had the highest NC levels. Rooms with central systems and sufficient duct lengths to attenuate sound had the lowest NC levels.

## THE COMPUTER MODEL

Computer models of 8 classrooms were constructed in Autocad and imported into CATT acoustical modeling program. A loudspeaker was designed to approximate the sound power level, frequency response and directional characteristics of a female speaking voice. The source was located in the front, center of the room slightly off the center axis of the room. Listeners were located at six locations in each room. The rooms were approximately 10 m (30 ft) x 10 m (30 ft) x 3 m (9 ft high).

**Table 1.** Description of Room Characteristics Used in the Computer Model Studies.

| Room Number | Ceiling | Walls | Floor |
|---|---|---|---|
| 1 | 50% Acoustical tile<br>50% Gypsum board | Gypsum board<br>Acoustic wall panels on upper walls | Carpet |
| 2 | 50% Acoustical tile<br>50% Gypsum board | Gypsum board | Carpet |
| 3 | Acoustical tile | Acoustic wall panels on side and rear walls | Carpet |
| 4 | Acoustical tile | Gypsum board | Carpet |
| 5 | Acoustical tile | Gypsum board | Vinyl tile |
| 6 | Gypsum board | Gypsum board | Carpet |
| 7 | Gypsum board | Gypsum board | Vinyl tile |
| 8 | 50% Acoustical tile<br>50% Gypsum board | Gypsum board | Vinyl tile |

## RESULTS

Relative loudness values decreased as one moved away from the source and off-axis from the source. The highest loudness values (by 3 dB) were obtained in the room with all reflective surfaces. However, much of the loudness in this room was a result of late arriving, multiple order reflections that would reduce speech intelligibility in the room. This was reflected in the RASTI values which were the lowest in this room.

The room with all absorbent surfaces had the lowest reverberation time values (0.20 s at mid-frequencies), but also had the lowest loudness values. The decrease in sound level with distance in this room was also the greatest of all rooms. Sound levels at the rear of the room were 3 dB less than the other rooms. RASTI scores in this room were among the highest with no background noise and fell to among the poorest as the background noise levels increased. .

The rooms with the center front portion of the ceiling as sound reflecting with strategically-located absorbent material located on the perimeter of the ceiling and the upper side walls had reverberation times of 0.38 s. They also had the highest RASTI scores of all rooms for all levels of background noise. Furthermore, the decrease in sound level and RASTI towards the rear of the rooms was the least for this condition. The difference between RASTI values at each background noise level was also the least for these rooms. The benefits of this classroom design bear further investigation. These rooms are also configured in a way that meets the intent of the Swedish recommendations for classroom design.

A prediction equation for RASTI by location in a room based on NC level and distance form the source is presented below. The model $r^2$ is 0.96. The equation is based on all positions and all NC values in Rooms 1-6 and 8 in table 1 above.

$$\text{RASTI} = -0.00059\ \text{NC}^2 + 0.026\ \text{NC} - 0.0049\ \text{Distance} + 0.618 \quad \text{(Equation 1)}$$

## CONCLUSIONS

There were three major results from the acoustical model studies to date.

I. Air-conditioning system noise is many schools is directly related to the type of system selected.

2. Measured values of background noise from air-conditioning systems in schools exceeded generally recommended values except in rooms with central air-conditioning systems with some noise control design or in rooms where the air-conditioning systems were turned off.

3. In rooms with low levels of background noise ( < NC 30), room acoustics design plays an important role in contributing to RASTI scores. An area of absorbent material equal to approximately 100% of the ceiling area is necessary for reasonable RASTI scores. If this material is strategically located on the side and rear portions of the ceiling and on the upper portions of the side and rear walls, RASTI values can be maximized.

In rooms with higher levels of background noise (> NC 40), the background noise dominates the RASTI scores and room acoustic design plays a lesser role.

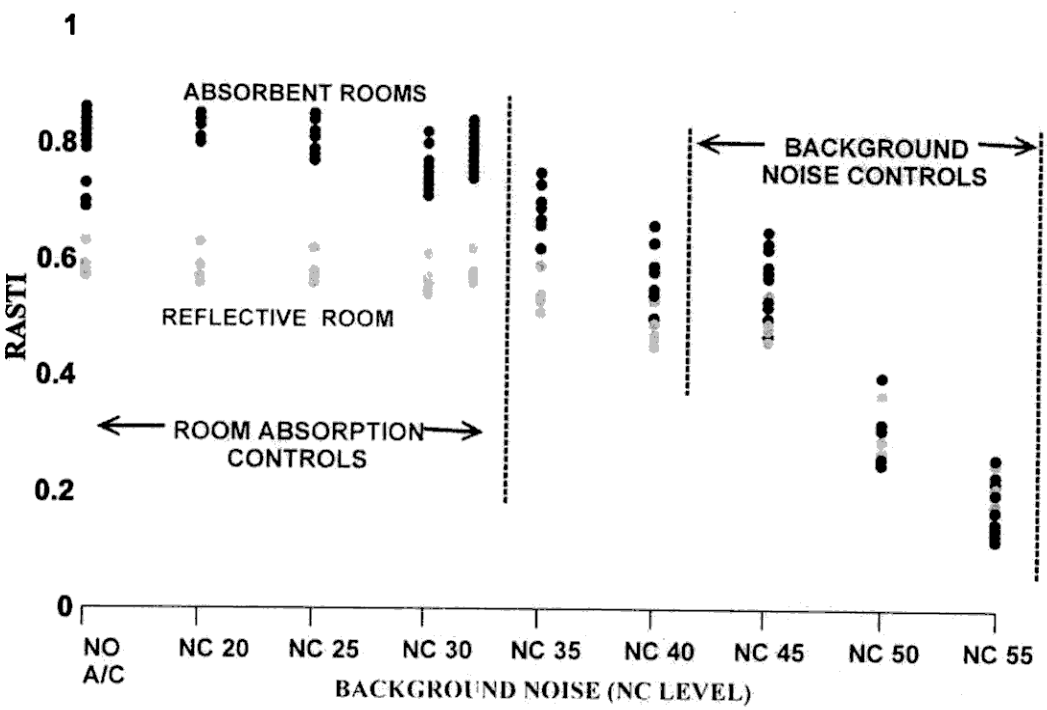


Figure 2. RASTI vs. Background Noise Level in the Computer Model Study.