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## Case Studies

# Excessive Noise Levels in Laboratory Work Spaces Produced by the Heating, Ventilating, and Air Conditioning Systems

*Dawn Tharr, Column Editor*

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Reported by Randy L. Tubbs

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The Hazard Evaluations and Technical Assistance Branch of the National Institute for Occupational Safety and Health (NIOSH) evaluated a newly constructed laboratory complex in San Juan that was about to be occupied. The occupants of the complex were concerned about the perceived excessive noise levels produced by the heating, ventilating, and air conditioning (HVAC) systems in the laboratory and insectary buildings. A sound evaluation of the buildings, visual inspection of the complex, and review of the buildings' mechanical systems' blueprints was conducted on September 26, 2000.

### Background

The complex was composed of three single-story buildings: an administration building, a laboratory building, and an insectary building. The buildings were connected on the outside by a covered breezeway. The administration building's mechanical system had one air handling unit (AHU) to deliver conditioned air to the offices. The laboratory building had three AHUs, and the insectary building had two AHUs. The administration and laboratory buildings' AHUs were located in a mezzanine below the roof, and the insectary building's AHUs were located outside, adjacent to the building, in a covered area. While the complex's floor plans designated separate office and laboratory spaces, it was generally the case that the laboratories contained a work space with computer

and telephone for the technicians working in these laboratories.

The administration building's AHU was designed to supply 4201 liters per second (L/s) of air. The make-up air consisted of 189 L/s fresh air and 4021 L/s recirculated return air. The office air supply came through flexible, round ducts off of the main supply trunk with louvered face, high-capacity ceiling diffusers. The return registers resembled an egg crate design and were also in the ceiling.

Of the laboratory building's AHUs, two were 100 percent fresh air returns, and the third recirculated about 60 percent of the return air. The fresh air supplies were designed at 3918 L/s and 3068 L/s, respectively. The third unit had 1510 L/s supply, 944 L/s recirculated return air, and 566 L/s fresh air. The supply ducts in this building were rectangular sheet-metal with short, 90° turns that deliver the air into the offices and laboratories. The supply and return diffuser were similar to that in the administration building, both in design and location. The supply ducts were lined on the outside of the duct with metal-skinned fibrous glass.

One of the air-handling units in the insectary was designed to condition air to the offices and laboratories. It is rated at 1912 L/s of supply air, 873 L/s of recirculated return air, and 1038 L/s of fresh air. The other AHU delivered air to the insect rooms and was designed to mimic the temperature fluctuations in the outdoor environment. It supplied 1227 L/s with 100 percent fresh air. The chiller was also set at a higher temperature for

this latter AHU, with the thermometer in the chilled water line set at 86° F compared to 66° F in the other line. The supply diffuser and return registers were identical to those in the other buildings. It was observed in all three of the buildings that air-balancing dampers were placed directly above the supply diffusers in all of the rooms.

### Methods

Prior to noise levels being measured at the complex, a visual inspection of the rooms and HVAC systems in the laboratories and insectary buildings was conducted. The design drawings of the buildings' mechanical systems were also reviewed. Finally, sound measurements were made in most of the rooms in the laboratory and insectary buildings. Real-time area noise sampling was performed with a Larson-Davis Laboratory Model 2800 Real-Time Analyzer and a Larson-Davis Laboratory Model 2559 1/2-inch random incidence response microphone. The analyzer allows for the analysis of noise into its spectral components in a real-time mode. The 1/2-inch diameter microphone has a frequency response range ( $\pm 2$  decibels [dB]) from 4 Hertz (Hz) to 21 kilohertz (kHz) that allows for the analysis of sounds in the region of concern. One-third octave bands consisting of center frequencies from 12.5 Hz to 16 kHz were integrated for 30 seconds and stored in the analyzer. The analyzer was mounted on a tripod and placed at various locations in the rooms with the microphone placed approximately at ear level. Usually, the investigators were the only people present in the room during

the measurements. There was no conversation, and radios were off during the measurement period. If freezers or exhaust hoods were operating when the room was entered, they were left on for the noise measurements. Full octave band data were calculated with a computer spreadsheet program from the third octave measurements made with the real-time analyzer.

### Evaluation Criteria

The American National Standards Institute (ANSI) has developed guidelines for evaluating noise levels created by HVAC systems using measurements made in unoccupied locations, the room criterion (RC) curves.<sup>(1)</sup> These curves were derived from an experimental study of noise in offices where the HVAC system was the only source of noise, and the occupants had no complaints about the background noise.<sup>(2)</sup> This meant that speech communication was satisfactory, and that there was no perception of a rumble (excessive noise in the low frequency octave bands less than 1 kHz) or hiss (excessive noise in the high frequency octave bands at 1 kHz and above). The RC value is determined by calculating the midfrequency average of 500 Hz, 1 kHz, and 2 kHz. A straight line is then plotted on the noise spectrum putting the calculated RC value at 1 kHz with a negative slope of 5 dB per octave. If the measured noise exceeds this line by 5 dB in the frequency band 500 Hz and below, the spectrum is said to exhibit a rumble (R). If the measured noise exceeds the line by 3 dB in the higher frequencies, 1 kHz and above, the spectrum exhibits a hiss (H) component. If neither of these conditions is seen, the spectrum is neutral (N), which is the desired condition for HVAC noise in a room.

### Results

Noise measurements were made in 23 laboratories, offices, and storage areas. An additional measurement was made in the outside mechanical room of the insectary building. The summary

**TABLE I**  
HVAC sound levels

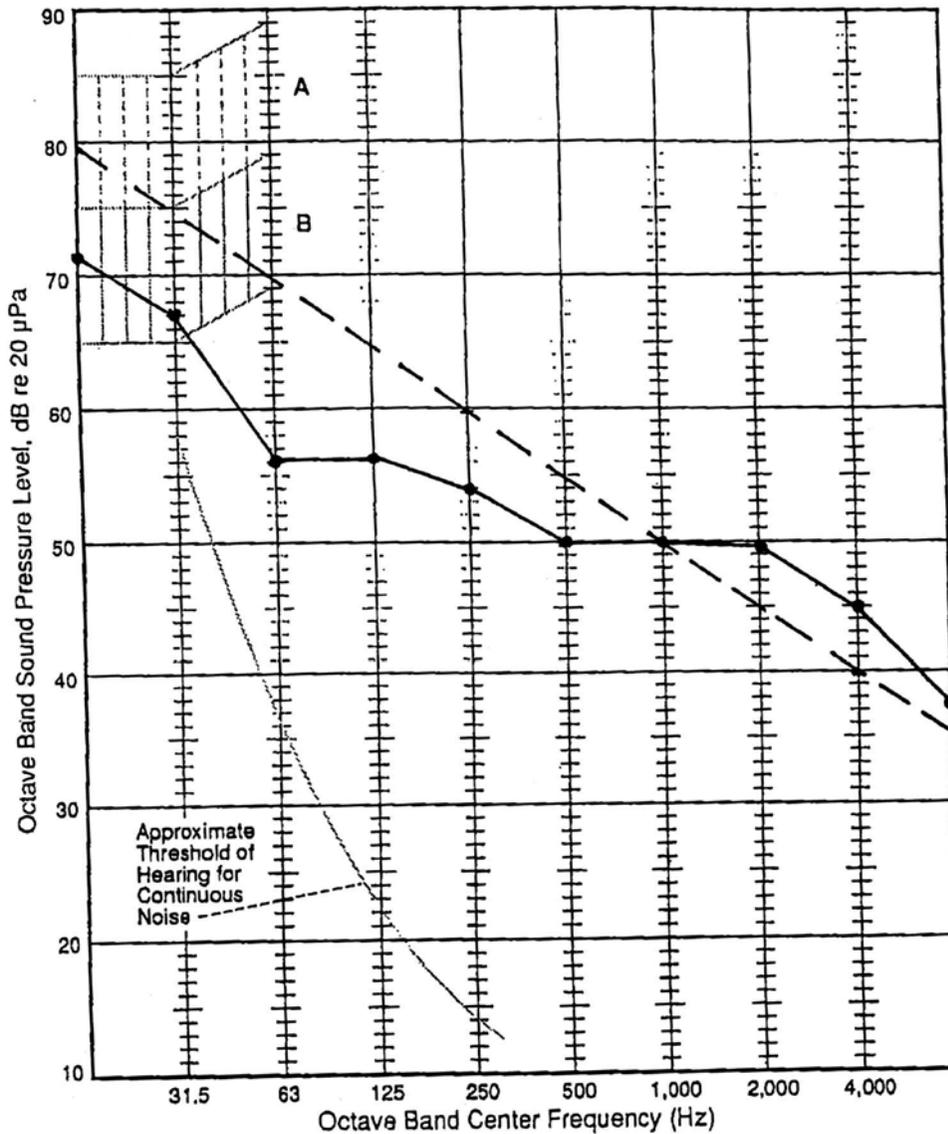
Room number	Activity	Air handling unit	A-weighted level	Room criterion level <sup>A</sup>
L001	Office/conference	AHU-4	55.5 dB(A)	49.7(H)
L002	Sample receiving	AHU-2	62.1 dB(A)	55.4(H)
L003	Isolated room	AHU-2	62.5 dB(A)	57.1(H)
L013	Serology lab	AHU-2	60.4 dB(A)	52.4(H)
L019	Research lab no. 1	AHU-2	61.7 dB(A)	55.7(H)
L011	Lab supply storage	AHU-4	48.8 dB(A)	42.6(H)
L010	Freezer room	AHU-2	70.2 dB(A)	64.9(H)
L006	Tissue culture lab	AHU-2	61.4 dB(A)	55.8(H)
L007	Isolated room	AHU-2	63.8 dB(A)	57.5(H)
L012	Glassware/autoclaves	AHU-2	60.5 dB(A)	53.7(N)
L017	Freezer room	AHU-3	71.2 dB(A)	65.3(H)
L021	Research lab no. 2	AHU-3	59.9 dB(A)	53.9(H)
L022	Dark room	AHU-3	61.1 dB(A)	55.6(N)
L025	Research lab no. 3	AHU-3	55.5 dB(A)	49.7(H)
N004	Office	AHU-6	46.7 dB(A)	38.6(H)
N005	Office	AHU-6	50.2 dB(A)	42.0(H)
N009	Office	AHU-6	58.0 dB(A)	50.4(H)
N006	Absorption lab	AHU-6	59.5 dB(A)	53.9(N)
N010	Laboratory	AHU-6	67.0 dB(A)	59.7(H)
N011	Office	AHU-6	55.3 dB(A)	46.5(H)
N014	Laboratory	AHU-6	54.6 dB(A)	48.1(H)
N020	Storage	AHU-6	50.9 dB(A)	41.4(R)(H)
A004	Director's office	AHU-1	44.8 dB(A)	35.7(N)

<sup>A</sup>Note: (N) = Neutral (1) = Hiss (R) = Rumble

results of these measurements are presented in Table I. Along with the identification of the measurement location and a description of its activity, the A-weighted decibel [dB(A)] levels and the calculated RC values with the spectrum characteristics are provided. The A-weighted sound levels ranged from 45 dB(A) in the laboratory director's office in the administration building to 72 dB(A) in a freezer room in the laboratory building. The corresponding RC values for these two rooms were calculated to be 36 and 65 dB, respectively. The octave band sound pressure levels for each of the 23 rooms were calculated and plotted on room criteria forms (examples in Figures 1 and 2). The RC line was also plotted so that the spectral characteristic could be determined. The vast majority of the rooms had RC values in excess of 50 dB, and had a hiss component in the sound spectrum. The

energy at 4 kHz is usually the cause of the hiss.

The ANSI standard recommends that the RC criteria range from 30–35 for private offices, and from 35–40 for laboratories.<sup>(1)</sup> A neutral spectrum is also specified for these spaces. The only office at the complex that meets these criteria is the director's office. All of the laboratories in the complex exceed the requirements. Because of the hiss component identified in most of the RC curves, it was concluded that the air-balancing dampers at the opening of the supply diffusers are a major contributor to the excessive noise levels. It has been reported that placing an air-balancing damper in this location can increase noise levels by 5 dB if the damper is wide open, and by as much as 15 dB–40 dB if the damper is half-closed. To alleviate this problem, the air-balancing damper should be placed at least three



Region A: High probability that noise-induced vibration levels in lightweight wall and ceiling constructions will be clearly feelable; anticipate audible rattles in light fixtures, doors, windows, etc.  
 Region B: Noise-induced vibration levels in lightweight wall and ceiling constructions may be moderately feelable; slight possibility of rattles in light fixtures, doors, windows, etc.

**RC = 49.7(H)**

**A = 55.5 dB(A)**

**Sum = 82.0 dB**

**FIGURE 1**  
L001.

equivalent duct lengths away from the supply diffuser.<sup>(3)</sup> Additional recommendations from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) on damper locations place them no closer than 5 feet from the supply diffuser, and ideally, 5 to 10 equivalent duct diameters from the supply opening.<sup>(4)</sup> Most of the

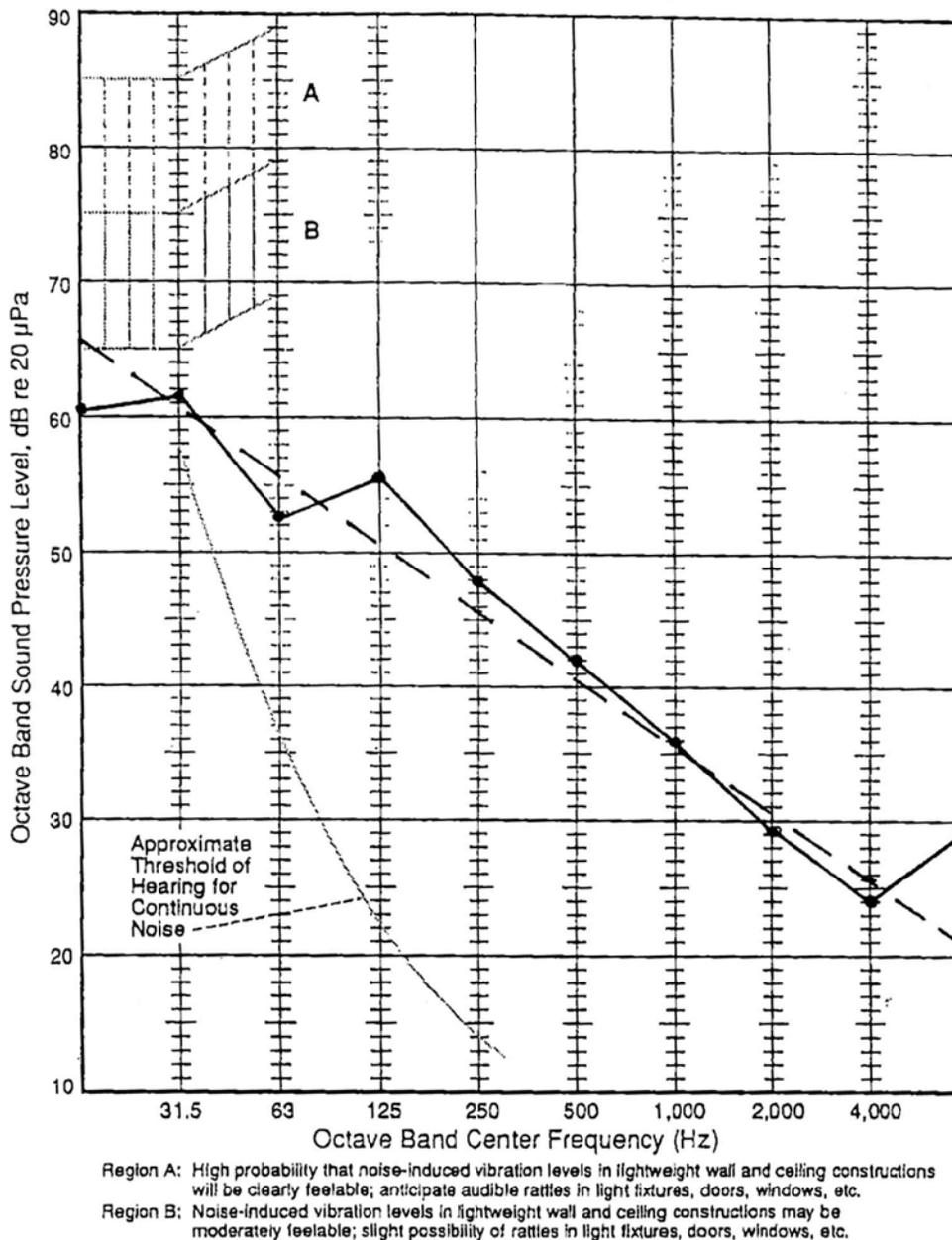
balancing dampers were observed to be in at least a half-closed condition.

Another observation made during this evaluation was that in the laboratory building, one of the AHUs produced an oil-canning effect in the return air duct. That is, the rectangular sheet metal duct would visibly collapse a small amount and return to its original shape on a

regular cycle. This same phenomenon was observed in the insectary building. However, it was the supply duct that exhibited the oil-canning.

**Conclusions and Recommendations**

Based on the observations and noise measurements of this health hazard



RC = 35.7(N)

A = 44.8 dB(A)

Sum = 70.1 dB

FIGURE 2

Director's office.

evaluation, a noise problem existed at the complex. The noise levels exceed the ANSI evaluation criteria for determining the appropriate activities for laboratory and office space designs. Because most of the RC curves in the laboratories and offices have a hiss component in the sound spec-

trum, the air-balancing upstream in dampers should be moved the supply ducts at least three equivalent duct lengths back from the supply diffusers. This could be accomplished by moving the dampers and relocating them in the existing rectangular ducts. However, it may be advantageous to change the man-

ner in which the supply air is delivered by copying the flexible duct design used in the administration building. This would eliminate the dampers being too close to the diffusers, and the short, 90° bends that create air turbulence that results in noise production. The flexible duct would have a

slightly greater resistance to air flow which may allow the dampers to be opened a little more, further reducing the high frequency noise. Finally, a review of material from the manufacturer of the supply diffuser did not find any specifications on the noise characteristics of their product. Perhaps a diffuser with better noise attenuation could be located and installed during these changes. Once the changes have been completed, the HVAC system will need to be rebalanced. The oil-canning effect can be addressed when the system is being balanced by reinforcing the existing duct or replacing it with a stiffer duct material.

Initial recommendations from an earlier survey to install isolation devices on the AHUs and pumps should be delayed until the high frequency noise is reduced.

These isolators may, however, be necessary once the RC values are reduced by the above changes in the ducts, and the RC curve lowered. The lower frequency noises could be more prominent in the rooms' sound spectra to the point where these additional isolation changes will be necessary.

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**EDITORIAL NOTE:** Randy L. Tubbs, Ph.D. is with the Hazard Evaluation and Technical Assistance Branch of the National Institute for Occupational Safety and Health. For more detailed information, contact Dr. Tubbs at NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, MS R-11, Cincinnati, OH 45226, Telephone: 1-800-35-NIOSH; Fax (513) 533-8513.

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