NUMBER 6
Applying Acoustics—Part 3

Acoustical Engineering Report

McGill AirSilence LLC
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Qualitative Analysis: Establishing Acoustical Design Goals

Introduction

Acoustical Engineering Report Number 5, *Quantitative Analysis: A-Weighting and Decibel Addition/Subtraction*, addressed quantitative noise evaluation. Quantitative analysis uses A-weighting to obtain a single-number sound level reading that represents the human perception of relative loudness. *Qualitative* analysis evaluates the sound level at different frequencies to determine the subjective quality of sound.

Qualitative Sound Evaluation

Sound quality is a function of the relative intensities of the sound level in each frequency within the audible spectrum. **Figure 1** shows a plot of

Figure 1 Noise Criteria (NC) Curves

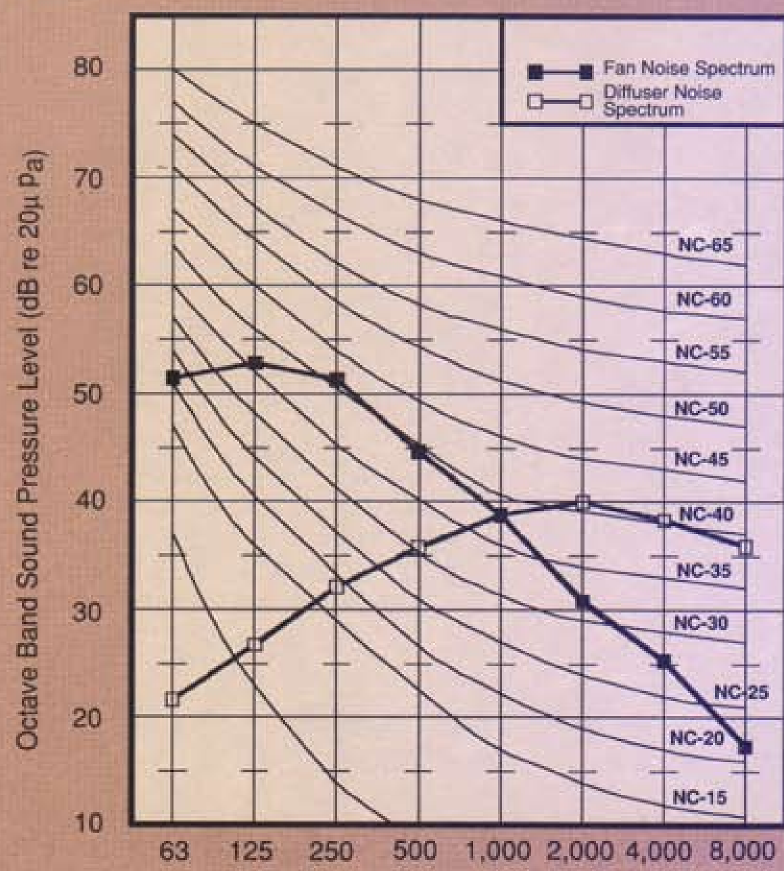
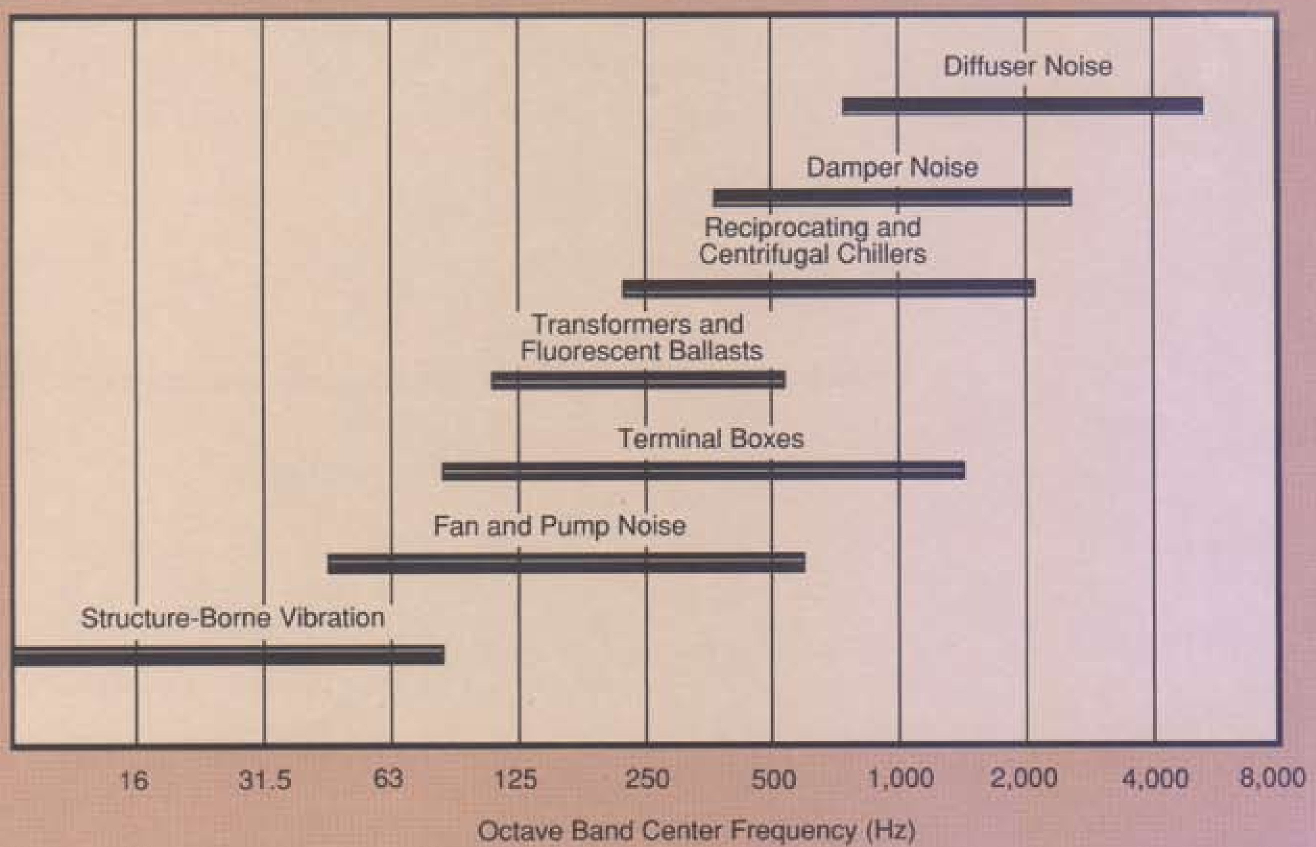


Figure 2 Prominent Frequency Signature Range of Typical HVAC System Components



attenuated fan noise versus diffuser noise on the Noise Criteria (NC) curves.

Fan noise has been attenuated such that it follows the NC 40 curve only in the lower frequencies, whereas the diffuser has been selected to follow the NC 40 curve in the higher frequencies. The airflow system represented in **Figure 1** has an overall balanced sound spectrum. Listeners would have heard a rumbling sound had the diffuser sound spectrum been selected at a lower NC curve, or a hissing sound had the fan noise been attenuated such that its low frequency sound levels fell along a lower NC curve. To eliminate rumbling and hissing sounds, it is important to evaluate the entire noise spectrum when selecting attenuation devices. Unfortunately, balancing sound spectrums is not this easy. **Figure 2** shows the more common noise sources and frequencies that affect a system's audible spectrum.

Establishing Design Goals

In Acoustical Engineering Report Number 5, background sound was shown as a deterrent to obtaining proper sound level measurements in an industrial environment. For commercial air conditioning systems, the acoustical design goal is to provide unobtrusive, *qualitative* background sound in low enough levels to block out surrounding environment and equipment noise yet maintain occupant comfort.

Occupant comfort depends on the work environment as well as the occupant's objectivity in defining noise. Background noise is considered to be unobtrusive when there is:

1. A balanced distribution of unobtrusive sound energy over a broad frequency range.
2. No audible tonal characteristics such as a hiss, hum, rumble, or whistle (equipment noise).
3. No noticeable time-varying levels such as ductwork vibrations or other aerodynamic noise produced by the system.

Establishing Design Criteria

Three major acoustical design criteria are used in the air handling industry: A-Weighted Sound Levels (dB) discussed in Acoustical Engineering Reports 4 and 5, NC curves, and Room Criteria (RC) curves.

NC Curves

NC curves are currently the most prominent for establishing commercial acoustical design goals. These curves, as shown in **Figure 1**, establish the maximum sound levels for each octave band center frequency in the audible frequency range. Again, occupant acceptance of noise for a given NC curve depends on work environment and how the occupant perceives noise. **Table 1** lists the NC and RC acceptable for various work environments.

Figure 1 shows how establishing goals against NC curves can present problems. Establishing the NC level based on a tangent peak or partial curve fit may result in sound level values lacking sufficient background sound to mask out unwanted environment noise.

RC Curves

RC curves are generally used where critically balanced background noise is essential to control environment noise (such as concert halls, studios, and performing art centers), including that generated by the air handling system.

The shape of the RC curve offers the optimum balance in sound quality. Exceeding the design curve by as much as 5 dB in the 31.5 to 250 Hz band is likely to result in a rumbling noise, whereas in the 2,000 to 4,000 Hz band it causes a hissing sound.

The ranges listed in **Table 1** are specified for air handling systems typically steady and broadband in character. For systems exhibiting prominent tonal pure tones, these values should be reduced 5 to 10 dB. **Figure 3** shows a plot of the fan/diffuser sound spectrum shown in **Figure 1** against an RC curve. The conditions that were acceptable based on NC curves would now appear to be unacceptable. The noise spectrum is improperly

Table 1 Acceptable Noise Rating Criteria for Unoccupied Rooms

Occupancy	RC/NC Rating
Hotels/Motels	
Individual rooms or suites	30-35
Meeting/banquet rooms	30-35
Halls, corridors, lobbies	35-40
Service/support areas	40-45
Offices	
Executive	25-30
Conference rooms	25-30
Private	30-35
Open-plan areas	35-40
Business machines/computers	40-45
Public circulation	40-45
Hospitals and clinics	
Private rooms	25-30
Wards	30-35
Operating rooms	25-30
Laboratories	35-40
Corridors	30-35
Public areas	35-40
Churches	30-35
Schools	
Lecture and classrooms	25-30
Open-plan classrooms	35-40
Libraries	35-40
Courtrooms	35-40
Legitimate theaters	20-35
Movie theaters	30-35
Restaurants	40-45
Concert and recital halls	15-20
Recording studios	15-20
TV studios	20-25

Note: The RC curve noise rating procedure should be incorporated when tight acoustical noise control is required across the audible spectrum. Otherwise, the NC curve noise rating procedure is acceptable.

balanced and would hiss (nearly RC-50) due to aerodynamic noise generated by air exiting the diffuser. Selecting a diffuser with NC-35 would provide an RC of 40, resulting in a balanced spectrum.

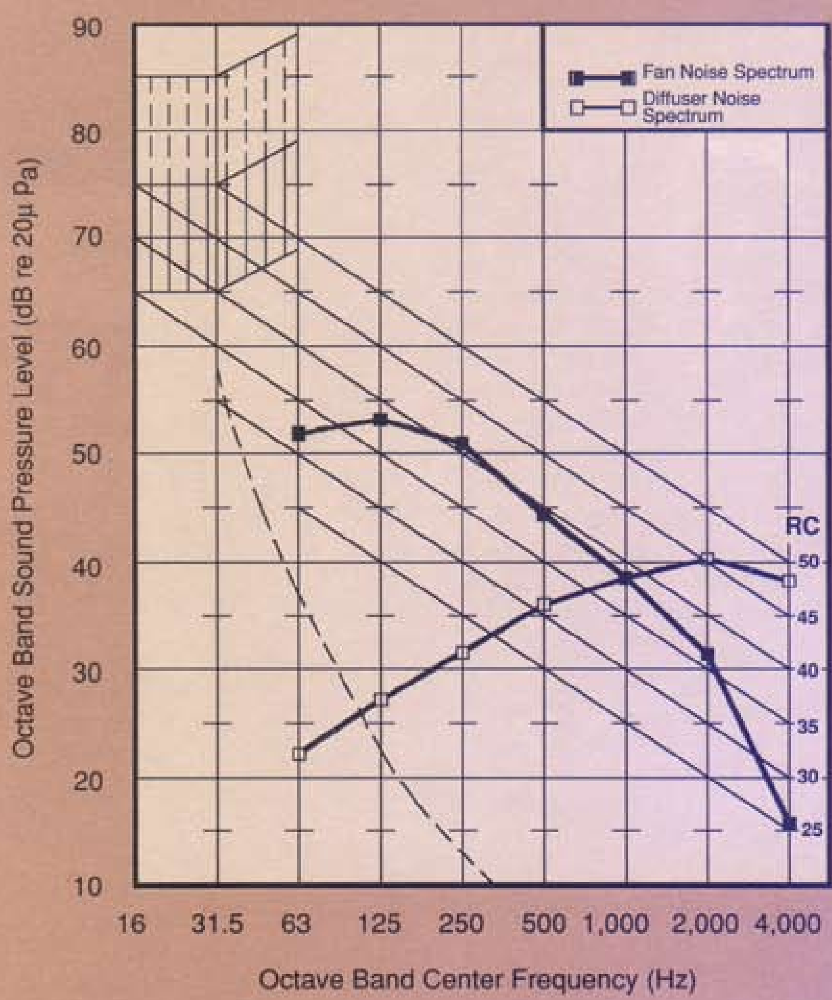
Summary

A qualitative analysis of a system's acoustical performance requires that the following characteristics be observed in the assessment of HVAC system background noise:

1. Level—maximum loudness.
2. Spectrum Balance—low, middle, and high frequency.
3. Tonal Content—rumble, hiss.
4. Temporal Fluctuations—aerodynamic and equipment pulsations.

Proper evaluation of ductwork and room acoustics requires the use of computers to simplify designs and to solve acoustical problems before they occur. Acoustical Engineering Report Number 7, *Computer-Aided In-Duct Acoustical Performance Evaluation* will explain in detail how to properly evaluate duct-borne noise.

Figure 3 Room Criteria (RC) Curves



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