Vibration and Noise Control

An Online Continuing Education Course for Engineers

Course Number: HV-8003

Credit: 8 Hours / 8 PDH / 8 CPD

CHAPTER 1

GENERAL

1-1. Purpose.

This course provides qualified designers the criteria and guidance required for design and construction of those features related to noise and vibration control of mechanical equipment systems.

1-2. References.

Appendix A contains a list of references used in this course.

1-3. Noise Estimates.

Noise level estimates have been derived for various types of mechanical equipment, and in some cases graded for power or speed variations of the noise-producing machines. The noise level estimates quoted in the course are typically a few decibels above the average. Therefore, these noise level estimates should result in noise control designs that will adequately "protect" approximately 80 to 90 percent of all equipment. It is uneconomical to design mechanical equipment spaces to protect against the noise of all the noisiest possible equipment; such overdesign would require thicker and heavier walls and floors than required by most of the equipment. The noise estimates and the noise control designs presented may be used with reasonable confidence for most general purposes. Data and recommendations are given for mechanical equipment installations on-grade and in upper-floor locations of steel and concrete buildings. Though they can also be applied to equipment located in upper floors of buildings on all-wood construction, the low mass of such structures for the support of heavy equipment will yield higher noise and vibration levels than would normally be desired. Data and recommendations are also given for the analysis of noise in the surrounding neighborhood caused by mechanical equipment, such as cooling towers. On-site power plants driven by reciprocating and gas turbine engines have specific sound and vibration problems.

1-4. English Metric Units.

English units are used throughout this course for conventional dimensions, such as length, volume, speed, weight, etc.

1-5. Explanation of Abbreviations and Terms.

Abbreviations and terms used in this course are explained in the glossary.

CHAPTER 2

NOISE AND VIBRATION CRITERIA

2-1. General.

This chapter includes data and discussions on generally acceptable indoor noise and vibration criteria for acceptable living and working environments. These criteria can be used to evaluate the suitability of existing indoor spaces and spaces under design.

2-2. Noise Criteria In Buildings.

Room Criteria (RC) and Noise Criteria (NC) are two widely recognized criteria used in the evaluation of the suitability of intrusive mechanical equipment noise into indoor occupied spaces. The Speech Interference Level (SIL) is used to evaluate the adverse effects of noise on speech communication.

a. NC curves. Figure 2-1 presents the NC curves. NC curves have been used to set or evaluate suitable indoor sound levels resulting from the operation of building mechanical equipment. These curves give sound pressure levels (SPLs) as a function of the octave frequency bands. The lowest NC curves define noise levels that are quiet enough for resting and sleeping, while the upper NC curves define rather noisy work areas where even speech communication becomes difficult and restricted. The curves within this total range may be used to set desired noise level goals for almost all normal indoor functional areas.

In a strict interpretation, the sound levels of the mechanical equipment or ventilation system under design should be equal to or be lower than the selected NC target curve in all octave bands in order to meet the design goal. In practice, however, an NC condition may be considered met if the sound levels in no more than one or two octave bands do not exceed the NC curve by more than one or two decibels.

b. Room criterion curves. Figure 2-2 presents the Room Criterion (RC) curves. RC curves, like NC curves, are currently being used to set or evaluate indoor sound levels resulting from the operation of mechanical equipment. The RC curves differ from the NC curves in three important respects. First, the low frequency range has been extended to include the 16 and 31.5 Hz octave bands. Secondly, the high frequency range at 2,000 and 4,000 Hz is significantly less permissive, and the 8,000 Hz octave band has been omitted since most mechanical equipment produces very little noise in this frequency region. And thirdly, the range over which the curves are defined is limited from RC 25 to RC 50 because; 1) applications below RC 25 are special purpose and expert consultation should be sought and; 2) spaces above RC 50 indicate little concern for the quality of the background sound and the NC curves become more applicable.

Table 2-1 lists representative applications of the RC curves. The evaluation of the RC curves is different than that for the NC curves. In general the sound levels in the octave bands from 250 to 2,000 Hz are lower than those of the NC curves. Should the octave band sound levels below 250 Hz be greater than the criteria a potential “rumble” problem is indicated. As a check on the relative rumble potential, the following procedure is recommended:

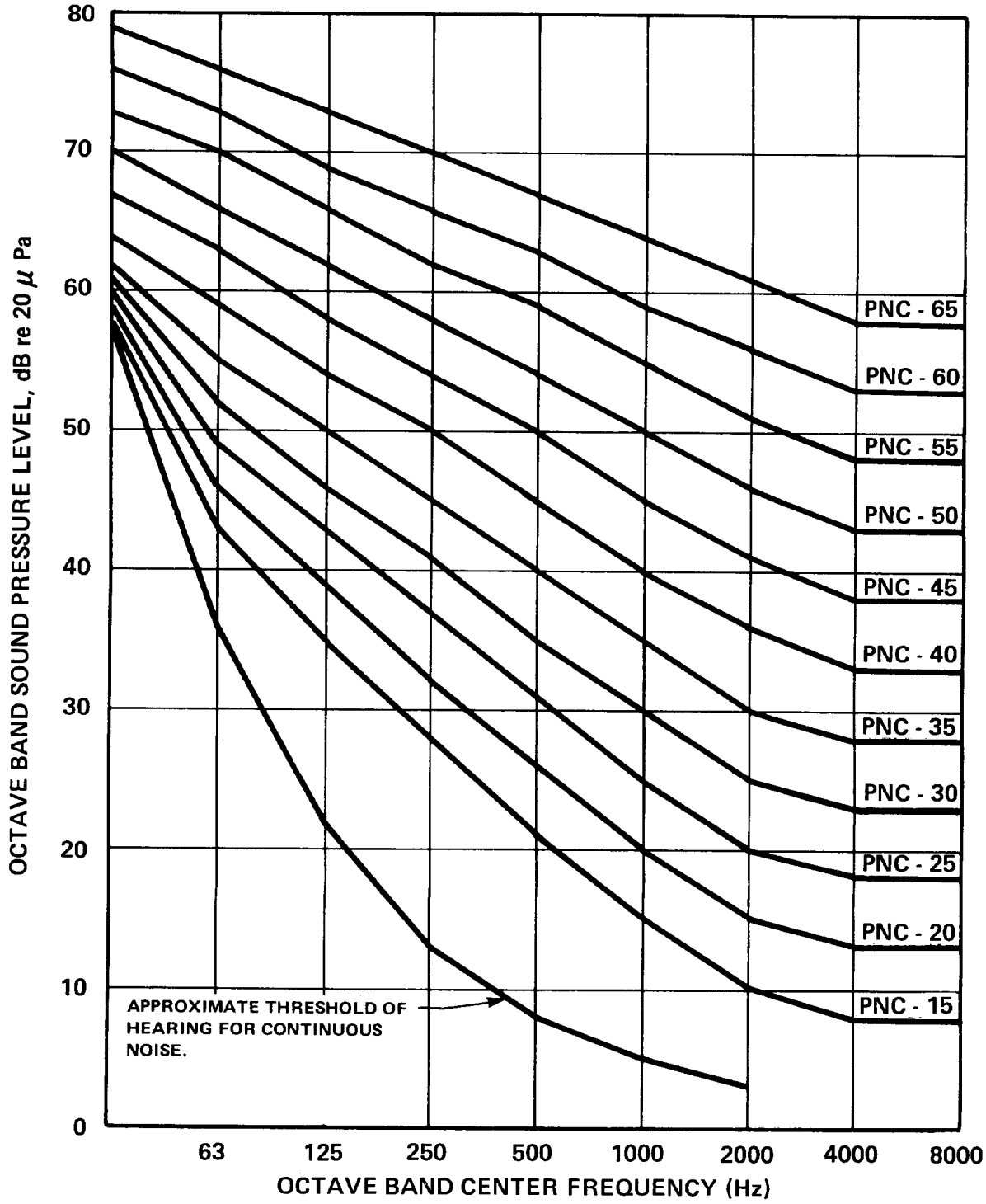
(1) Sum the sound pressure levels in the octave bands from 31.5 through 250 Hz on an energy basis (See app B).

(2) Sum the sound pressure levels in the octave bands from 500 through 4,000 Hz on an energy basis.

(3) Subtract the high frequency sum (step 2) from the low frequency sum (step 1).

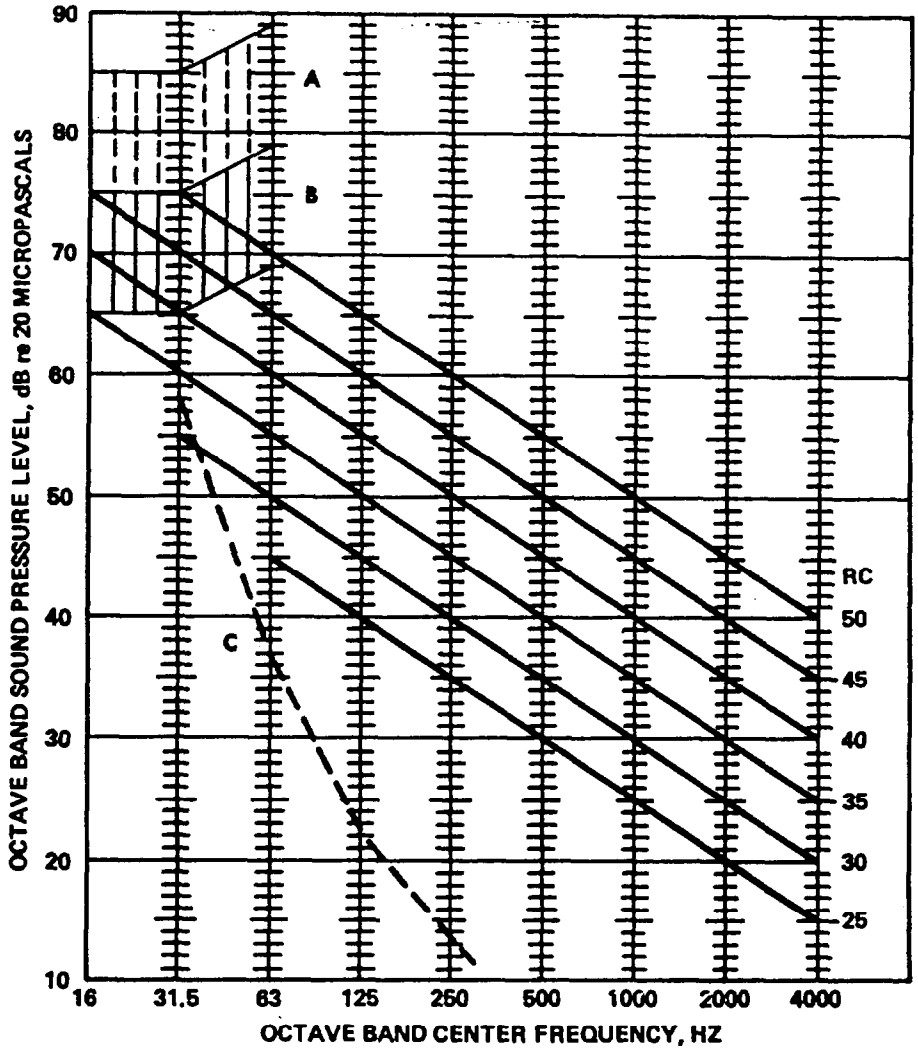
(4) If the difference is +30 dB or greater, a positive subjective rating of rumble is expected, if the difference is between +25 and +30 dB a subjective rating of rumble is possible, if the difference is less than +20 dB a subjective rating of rumble is unlikely. Also indicated on the RC curves (fig 2-2) are two regions where low frequency sound, with the octave band levels indicated, can induce feelable vibration or audible rattling in light weight structures.

c. Speech interference levels. The speech interference level (SIL) of a noise is the arithmetic average of the SPLs of the noise in the 500-, 1000-, and 2000-Hz octave bands. The approximate conditions of speech communication between a speaker and listener can be estimated from table 2-2 when the SIL of the interfering noise is known. Table 2-2 provides “barely acceptable” speech intelligibility, which implies that a few words or syllables will not be understood but that the general sense of the discussion will be conveyed or that the listener will ask for a repetition of portions missed.



Reprinted with permission from
The ASHRAE Handbook,
HVAC Systems and Applications

Figure 2–1. Noise Criterion (NC) Curves.



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.
Region C: Below threshold of hearing for continuous noise.

Reprinted with permission from
The ASHRAE Handbook,
HVAC Systems and Applications

Figure 2-2. Room Criterion (RC) Curves

The quality of telephone usage is related to SIL approximately as follows:

SIL Range (dB) for Telephone Usage	
30-45	Satisfactory
45-60	Slightly difficult
60-75	Difficult
Above 75	Unsatisfactory

d. Limitations. The indoor noise criteria considered above assume that the noise is almost continuous and of a fairly steady nature (not enough modulating or fluctuating up and down in level or frequency to attract attention), and there are no raucous, unpleasant sounds or strongly tonal sounds. If any of these assumptions are not met,

Table 2-1. Category Classification and Suggested Noise Criterion Range for Intruding Steady-State Noise as Heard in Various Indoor Functional Activity Areas.

Category	Area (and Acoustic Requirements)	Noise Criterion[a]
1	Bedrooms, sleeping quarters, hospitals, residences, apartments, hotels, motels, etc. (for sleeping, resting, relaxing).	NC-20 to NC-30
2	Auditoriums, theaters, large meeting rooms, large conference rooms, radio studios, churches, chapels, etc. (for very good listening conditions).	NC-15 to NC-30
3	Private offices, small conference rooms, classrooms, libraries, etc. (for good listening conditions).	NC-30 to NC-35
4	Large offices, reception areas, retail shops and stores, cafeterias, restaurants, etc. (for fair listening conditions).	NC-35 to NC-40
5	Lobbies, drafting and engineering rooms, laboratory work spaces, maintenance shops such as for electrical equipment,etc. (for moderately fair listening conditions).	NC-40 to NC-50
6	Kitchens, laundries, shops, garages, machinery spaces, power plant control rooms, etc. (for minimum acceptable speech communication, no risk of hearing damage).	NC-45 to NC-65

the sound level criteria should be even lower than the criteria normally considered applicable. This criteria given above is intended to be illustrative; any occupied or habitable area not identified in the list can be assigned to one of these categories on the basis of similarity to the types of areas already listed. Generally, where a range of criteria is given, the lower values should be used for the more critical spaces in the category and for areas outside the control of the facility;the higher of the range of criteria may be used forthe less critical spaces in the category. Certain short-term infrequent sounds (such as the weekly testing of a fire pump or an emergency power generator) may be allowed to exceed normal criteria in relatively noncritical areas as long as the normal functions of these areas are not seriously restricted by the increase in noise.

2-3. Vibration Criteria In Buildings.

Structural vibration in buildings, which results in feelable vibration, produces structural or superficial damage of building components or interferes with equipment operation is unacceptable. In addition large building components that vibrate can produce unacceptable sound levels.

a. Vibration criteria for occupants. Figure 2-3 shows the approximate occupant response to building vibration levels. An approximation of the "threshold of sensitivity" of individuals to feelable vibration is shown by the shaded area of figure 2-3, labeled "barely perceptible." Other typical responses of people to vibration are indicated by the other zones in figure 2-3. These reactions or interpretations may vary over a relatively wide range for different individuals and for different ways in which a person might be subjected to

Table 2-2. Speech Interference Levels (SIL) That Permit Barely Acceptable Speech Intelligibility at the Distances and Voice Levels Shown.

Distance (ft.)	Voice Level			
	Normal	Raised	Very Loud	Shouting
1/2	74	80	86	92
1	68	74	80	86
2	62	68	74	80
4	56	62	68	74
6	53	59	65	71
8	50	56	62	68
10	48	54	60	66
12	46	52	58	64
16	44	50	56	62

SIL is arithmetic average of noise levels in the 500-, 1000-, and 2000-Hz octave frequency bands. SIL values apply for average male voices (reduce values 5 dR for female voice), with speaker and listener facing each other, using unexpected work material. SIL values may be increased 5 dB when familiar material is spoken. Distances assume no nearby reflecting surface to aid the speech sounds.

vibration (standing, seated, through the finger tips). The lower portion of the "barely perceptible" range is most applicable to comm tions. Complaints of buildi tial situations can arise levels are slightly below th "barely perceptible" range. tion criteria, for annoyance tion, will be determined by t and the perceived sensitivi There should not be a prob vibration if the levels are 6 "barely perceptible" range of

b. Vibration Criteria for B High amplitude vibration level to building structures and con bration is destructive to build vibration will be highly percept occupants. A structural vibrat in/sec has commonly been used limit for building structures, an this value will have adverse e pact. A vibration velocity of 1.0 i normally safe vibration upper lim spect to structural damage. Vibrations with a velocity level greater than 1.0 in/sec should be avoided or special

arrangement be made with the owners of . Even with a vibration level cial damage may occur in perficial damage can consist ttle facades such as plaster. t the possibility of superfi- zed a vibration criteria of ommended. And finally for even lower level of 0.05 The manner in which the is a function of the type experienced. For continu- vel should be used. For eak value is to be used. ssion of Peak and RMS e vibration limits men- ted in terms of acceler- G.

Sensitive Equipment. sturbing to the use or -sensitive equipment, microscopes and other special linical, medical, or industrial instruments or processes. Figure 2-5 shows vibration criteria for some sensitive equipment types. To achieve these low level vibration levels special building construc-