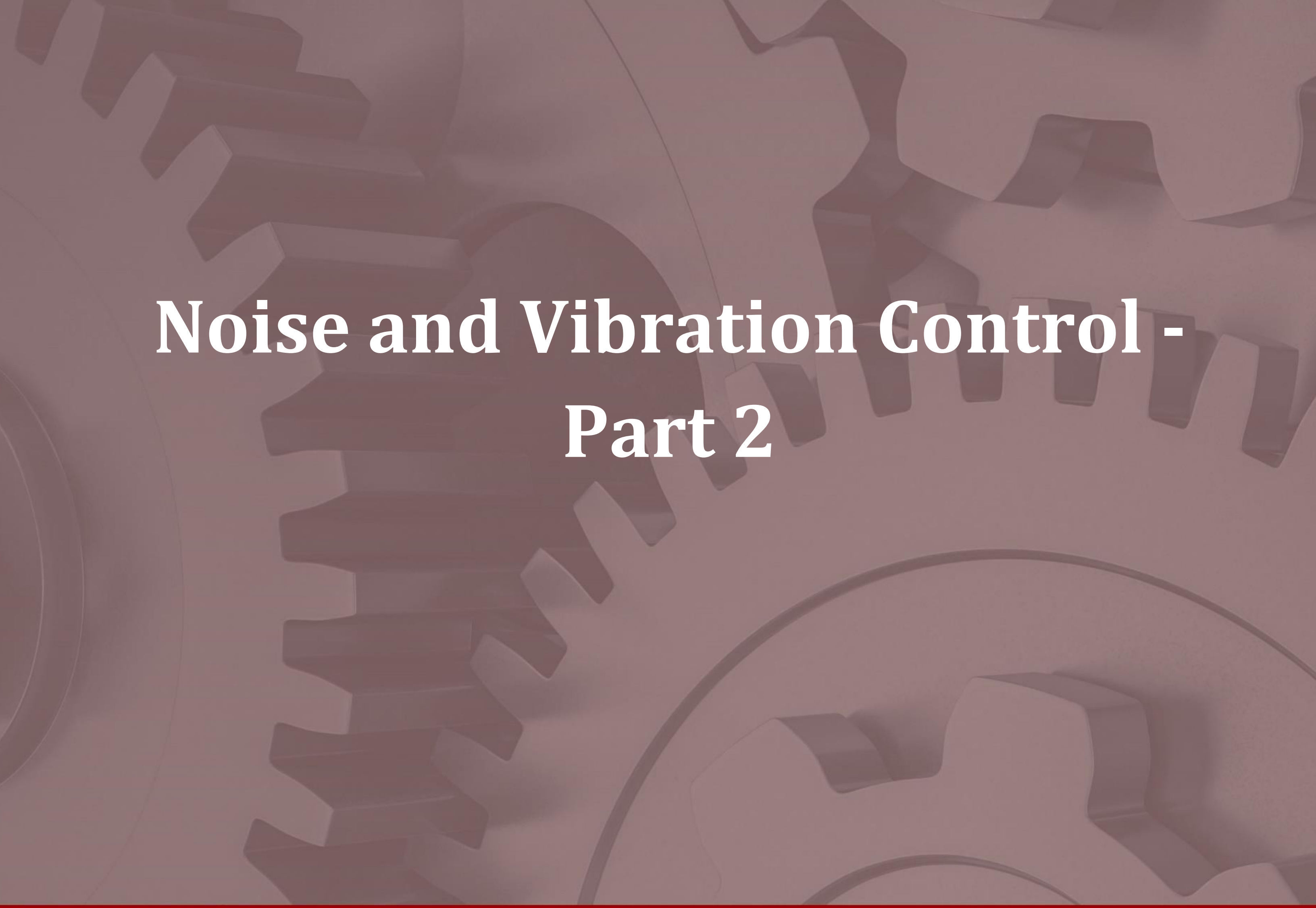

# Noise and Vibration Control - Part 2

An Online Continuing Education Course for Engineers

**Course Number: M-4040**

**Credit: 4 Hours / 4 PDH / 4 CPD**

# Noise and Vibration Control - Part 2

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## Introduction

This course is the second of two volumes about controlling man-made noise in indoor and outdoor environments.  This course provides guidance for the design and construction of those features related to noise and vibration control of mechanical equipment systems most commonly encountered.  These two volumes should be studied in sequence to ensure a complete understanding of the material.

The first volume covered the basics of acoustics and vibration criteria for acceptable noise and vibration for indoor applications and how to calculate sound levels in indoor environments. Vibration control is only covered tangentially in this course as it relates to noise.

Volume II discusses how sound propagates out of doors and explains how to mitigate the impacts of outdoor noise.  Volume II also covers noise control of HVAC systems for both indoor and outdoor components.

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 this 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.

Before beginning the course we will explain the definitions of a few terms commonly encountered in the study of noise and vibration.

**Definitions**

**Absorption.** Conversion of acoustic energy to heat energy or another form of energy within the medium of sound-absorbing materials.

**Absorption Coefficient.** The ratio of sound energy absorbed by the acoustical material to that absorbed by a perfect absorptive material. It is expressed as a decimal fraction.

**Average Sound Level and Average SPL.** The arithmetic average of several related sound levels measured at different positions or different times, or both.

**Decibel (dB).** A unit for expressing the relative power level difference between acoustical or electrical signals. It is ten times the common logarithm of the ratio of two related quantities that are proportional to power.

**Noise Criteria (NC).** Octave band curves used to define acceptable levels of mechanical equipment noise in occupied spaces. Superseded by the Room Criteria (RC).

**Noise Isolation Class (NIC).** A single-number rating derived from measured values of noise reduction, as though they were values of transmission loss. It provides an estimate of the sound isolation between two enclosed spaces that are acoustically connected by one or more paths.

**Octave Band.** A range of frequencies whose upper band limit frequency is nominally twice the lower band limit frequency.

**Octave-Band Sound Level.** The integrated sound pressure level of only those sin-wave Pressure components in a specified octave band, for a noise or sound having a wide spectrum.

**Residual Noise.** The measured sound level which represents the summation of the sound from all the discrete sources affecting a given site at a given time, exclusive of the Background Noise or the sound from a Specific Sound Source of interest

**Room Criteria (RC).** Octave band criteria used to evaluate acceptable levels of mechanical equipment noise in occupied spaces.

**Sound Power level (Lw or PWL).** Ten times the common logarithm of the ratio of the total acoustic power radiated by a sound source to a reference power.

**Sound Pressure Level (Lp or SPL).** Ten times the common logarithm to the base 10 of the ratio of the mean square sound pressure to the square of a reference pressure.

**Sound Transmission Class (STC).** A single-number rating derived from measured values of transmission loss in accordance with ASTM E-413. It is designed to give an estimate of the sound insulation properties of a partition or a rank ordering of a series of partitions.

**Sound Transmission Loss (TL).** A measure of sound insulation provided by a structural configuration. Expressed in decibels, it is ten times the common logarithm of the sound energy transmitted through a partition, to the total energy incident upon the opposite surface.

# Chapter 1: Sound Propagation Outdoors

Mechanical equipment such as cooling towers, rooftop units and exhaust fans are commonly located outdoors. Unacceptable noise from electrical or mechanical equipment, whether located indoors or outdoors, may be strong enough to be transmitted to neighbor locations. The sound transmission paths are influenced by three broad types of natural effects: distance effects, atmospheric effects, and terrain and vegetation effects. In addition, structures such as barriers and buildings influence the transmission of sound to the neighbor positions. The quantitative values of these natural effects and structural interferences in outdoor sound propagation are given in this chapter.

## Distance Effects

Acoustical energy from a source spreads out as it travels away from the source, and the sound pressure level drops off with distance according to the “inverse square law.” This effect is common to all types of energy propagation originating from an essentially point source and free of any special focusing. In addition, the air absorbs a certain amount of sound energy by “molecular absorption,” and small amounts of ever-present air movement and inhomogeneities give rise to “anomalous excess attenuation.” These three distance effects are summarized in the following paragraphs.

### 1. Effect of distance

Figure 1 illustrates the “inverse square law” for drop-off of *Sound Pressure Level* (SPL) with distance. A point source of sound is shown at point “X”, and the rays show the path of an element of sound energy traveling away from the source. At the distance “d” from the source, the sound energy is assumed uniformly spread over the small area “A” (which is the product of the two lengths “a” and “b”). At twice the distance, “2d”, the lengths a and b are expanded to “2a” and “2b”, and the resulting area over which the sound is now spread has become “4A”, four times the area back at distance “d”. Sound pressure level is related to the “energy per unit area” in the sound wave; so, in traveling twice the original distance from the source, the energy per unit area has decreased by a factor of four which corresponds to a reduction of 6 dB in the sound pressure level. Simply illustrated, this is the “inverse square law”; that is, the SPL decreases at the rate of 6 dB for each doubling of distance from the source.

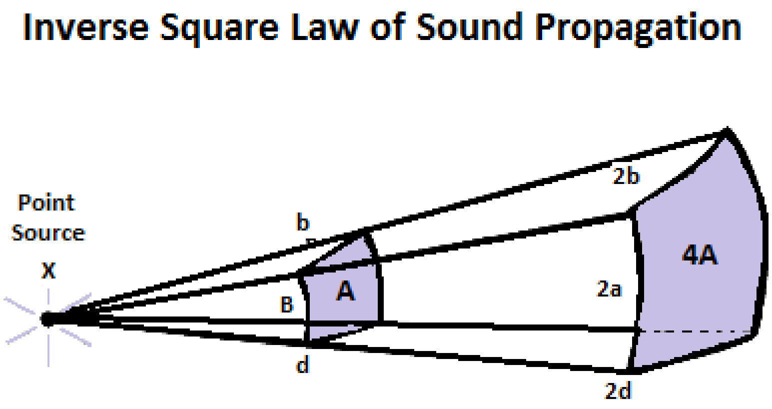

Figure 1

2. <u>Molecular absorption</u>

In addition to the reduction due to the inverse square law, air absorbs sound energy, and that the amount of absorption is dependent on the temperature and humidity of the air and the frequency of the sound. Table 1 gives the molecular absorption coefficients in dB per 1000-foot distance of sound travel for a useful range of temperature and relative humidity of the octave frequency bands.

**Table 1**
**Molecular Absorption Coefficients, dB per 1000 ft., as a Function of Temperature and Relative Humidity**
$\alpha_m$

| **Temp (C)** | **Relative Humidity (%)** | **Octave Band Center Frequency (Hz)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **63** | **125** | **250** | **500** | **1000** | **2000** | **4000** | **8000** |
| -10 | 10 | 0.3 | 0.5 | 0.6 | 0.9 | 1.2 | 1.8 | 2.8 | 4.0 |
| | 50 | 0.1 | 0.2 | 0.6 | 1.6 | 4.4 | 8.6 | 13.9 | 17.0 |
| | 90 | 0.1 | 0.1 | 0.3 | 0.9 | 2.6 | 7.2 | 18.3 | 26.6 |
| 0 | 10 | 0.2 | 0.6 | 1.3 | 2.4 | 3.5 | 4.8 | 6.9 | 8.9 |
| | 50 | 0.1 | 0.1 | 0.3 | 0.9 | 2.6 | 7.5 | 20.3 | 32.9 |
| | 90 | 0.1 | 0.1 | 0.3 | 0.6 | 1.4 | 4.1 | 12.1 | 21.9 |
| 10 | 10 | 0.1 | 0.3 | 1.0 | 2.7 | 6.5 | 11.9 | 17.5 | 21.1 |
| | 50 | 0.1 | 0.2 | 0.3 | 0.7 | 1.6 | 4.4 | 13.3 | 24.0 |
| | 90 | 0.1 | 0.2 | 0.3 | 0.7 | 1.3 | 2.8 | 7.3 | 13.3 |
| 15 | 10 | 0.1 | 0.3 | 0.8 | 2.3 | 6.1 | 14.4 | 25.9 | 32.6 |
| | 30 | 0.1 | 0.2 | 0.4 | 0.8 | 2.0 | 6.1 | 17.7 | 31.6 |
| | 50 | 0.1 | 0.2 | 0.4 | 0.7 | 1.5 | 3.6 | 10.5 | 19.3 |
| | 70 | 0.1 | 0.2 | 0.4 | 0.7 | 1.5 | 3.0 | 7.6 | 13.7 |
| | 90 | 0.1 | 0.2 | 0.4 | 0.7 | 1.5 | 3.0 | 6.6 | 11.2 |
| 20 | 10 | 0.1 | 0.2 | 0.6 | 1.8 | 5.3 | 14.2 | 31.9 | 44.9 |

**Table 1**
**Molecular Absorption Coefficients, dB per 1000 ft., as a Function of Temperature and Relative Humidity**
$\alpha_m$

| Temp (C) | Relative Humidity (%) | Octave Band Center Frequency (Hz) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| | 30 | 0.1 | 0.2 | 0.4 | 0.8 | 1.8 | 4.8 | 14.4 | 26.2 |
| | 50 | 0.1 | 0.2 | 0.4 | 0.8 | 1.6 | 3.4 | 8.6 | 15.6 |
| | 70 | 0.1 | 0.2 | 0.4 | 0.8 | 1.6 | 3.3 | 7.1 | 11.9 |
| | 90 | 0.1 | 0.2 | 0.4 | 0.8 | 1.6 | 3.3 | 7.0 | 10.8 |
| 25 | 10 | 0.1 | 0.2 | 0.5 | 1.5 | [illegible] | [illegible] | 33.5 | 52.6 |
| | 30 | 0.1 | 0.2 | [illegible] | [illegible] | [illegible] | [illegible] | 11.6 | 21.7 |
| | 50 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 8.0 | 13.4 |
| | 70 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 7.6 | 11.7 |
| | 90 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 7.6 | 11.7 |
| 30 | 10 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 29.3 | 50.7 |
| | 50 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 8.3 | 12.9 |
| | 90 | 0.1 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 8.3 | 12.8 |
| 38 | 10 | 0.1 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 23.0 | 41.3 |
| | 50 | 0.1 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 9.6 | 14.6 |
| | 90 | 0.1 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 9.6 | 14.6 |

A *standard day* is frequent [illegible] lative humidity of 70 percent. For long-time a [illegible] ar absorption coefficients for standard da [illegible] cation of measured or estimated SPL for know [illegible] values should be taken into account.

3. Anomalous excess attenu [illegible]

Large-scale effects of wind [illegible] gradients in the air can cause large differences in sound tra [illegible] large distances. Almost all the time, however, there are small-scale influences of these atmospheric factors. Even under fairly stable conditions for sound propagation through the air, small amounts of diffraction, refraction (bending), and sound interference occur over large distances as a result of small wind, temperature, and humidity differences in the air. These are combined into *anomalous excess attenuation* which is applied to long-term sound level estimates for average-to-good sound propagation conditions. Table 2 gives the values of anomalous excess attenuation, in dB per 1000 foot distance. These are conservative average values; higher values than these have been measured in long-time studies of sound travel over a variety of field conditions. Anomalous excess attenuation helps explain the fact that measure SPLs at large distances are frequently lower than estimated SPLs even when sound propagation conditions seem quite good.