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Applying Acoustics—Part 1

Acoustical Engineering Report

McGill AirSilence LLC
An enterprise of United McGill Corporation — Founded in 1951

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Controlling Industrial Noise Pollution

Introduction

Previous engineering reports (AER Numbers 1, 2, and 3) introduced the concepts of sound pressure levels, octave bands, and sound power levels. Properly understood and applied, these concepts can be used to provide solutions to noise pollution problems.

Noise is sound that is undesirable because it interferes with speech and hearing, is intense enough to cause hearing damage, or is annoying.

Due to a public awareness of the problems associated with noise pollution, governmental agencies have written strict noise regulation standards. Excessive exposure to noise can create hearing damage, and many industrial corporations have instituted hearing loss prevention programs into their safety regulations.

There is no universally accepted point at which sound is perceived as noise. The potential for hearing damage due to excessive sound levels, however, has been quantified and is a function of the length of time exposed to the sound, the actual level of the sound, and the nature of the sound's frequency content.

Hearing damage is the most obvious effect of exposure to excessive sound levels. In addition, exposure to noise can make people nervous, irritable, and anxious; and research has indicated that noise may be related to many physiological problems.

Job-related noise can also make the working environment uncomfortable, leading to decreased productivity, and can create unsafe working conditions in which verbal communications and warnings cannot be heard.

OSHA Regulations

In 1970, in an attempt to prevent job-related hearing damage, the federal government set legal standards for allowable occupational noise exposures. These standards are enforced by the Occupational Safety and Health Administration (OSHA) and define the maximum permissible levels of industrial noise an employee may be exposed to. If daily noise exposure is composed of sounds at several levels for varying periods of time, a cumulative exposure effect must be determined.

Table 1 presents the permissible occupational noise exposure limits that are recognized by OSHA and published in the Federal Register. The method of calculating the effect of cumulative noise exposures is also presented.

Basic Acoustical Concepts

When sound is measured, it is often referred to as the sound pressure level and expressed in decibels (dB). For any given sound, the higher the amplitude of pressure fluctuation, the greater its decibel level is, and the louder it sounds. **Table 2** illustrates sound pressure levels generated by some typical sound sources.

The audible frequency range for people with perfect hearing is generally 20 Hz to 20,000 Hz and can be broken into 10 octave bands. Those of concern are the eight consecutive octave bands that have center frequencies from 63 to 8000 Hz.

When we hear a sound, our ears

are less sensitive to the frequency components below 1000 Hz than to those at 1000 Hz and higher. For example, a 65 dB sound in the 63 Hz octave band will be sensed as being only as loud as a 50 dB sound in the 1000 Hz octave band. This concept is often called equal loudness.

One common way of applying this concept is to present the total effective level of sound in the audible frequency range as a single A-weighted sound level. When this is done, the decibel level of a sound's frequency components below 1000 Hz are weighted to lower values (de-emphasized) to compensate for the reduced sensitivity of the human ear to low frequency sound. An A-weighted overall sound level provides a single number rating that is commonly accepted as representative of the perceived loudness of the sound if it were at low to moderate overall sound pressure levels. A-weighted sound levels are common design goals in occupational and outdoor noise control projects. When sound is A-weighted, it should be followed by the unit dBA.

Solving Noise Problems: Three Approaches

There are three basic areas to examine when first confronting an industrial noise problem: **the noise source, the noise path, and the noise receiver.** You must evaluate each of these areas to determine where the simplest, least costly noise control measure can be applied to do the most good.

A number of factors determine the choice. They are:

- financial and technical feasibilities
- safety
- maintenance accessibility
- minimum allowable disruption time for a particular production operation or process

Approach #1—Source Control

Noise radiates from a source. For projects in the design stage, it is wise to choose machinery that is relatively quiet to begin with, if the option is available. This may not eliminate all potential for a noise problem, but it will make the noise control project easier and less expensive to implement.

When a noise problem already exists, it is unusual that the mechanisms or processes that generate the noise can be quieted. In these situations, adding acoustical materials to the noise radiating surfaces may help reduce the noise strength at the source, either eliminating the noise problem or partially controlling the problem. The materials that are added in these situations may require sound absorbing, sound blocking, or damping properties (or any combination of these three properties). Particularly in industrial noise problems, compressed air discharge noises are easily treatable with the addition of pneumatic silencers.

Approach #2—Path Control

Noise is transmitted via sound waves through the space that separates the source from the receiver. Altering the path of this transmission to reduce the amount of acoustical energy that will reach a receiver is an effective approach to industrial noise control. Usually, this involves impeding the sound transmission by interfering with its reflected and direct paths.

Reflected noise paths can be reduced by adding sound absorbing panels to walls and by hanging sound absorbing devices (unit absorbers) from ceilings. Direct noise paths can be disrupted by using enclosures or acoustical barrier walls between the source and receiver. These barriers are most effective when used in combination with materials designed to treat reflected sounds.

Table 1 Permissible Noise Exposures

Duration per Day (hours)	Sound Level (dBA-slow response)
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: $C_1/T_1 + C_2/T_2 + \dots + C_n/T_n$, exceeds one, then the mixed exposure should be considered to exceed the limit value. C_n indicates the total time of exposure at a specified noise level, and T_n indicates the total time of exposure permitted at that level.

Example: If an employee were exposed to a 90 dBA noise level for 5 hours and a 95 dBA noise level for 3 hours, the exposure would be evaluated as follows:

$$C_1/T_1 + C_2/T_2 = 5/8 + 3/4 = 1.37 > 1.0$$

Therefore this exposure exceeds the allowable limits, and corrective noise abatement measures would be required.

(Additionally, the government recommends a voluntary hearing conservation program if 8-hour exposure exceeds 85 dBA.)

Approach #3—Receiver Control

Ear plugs or ear muffs are considered highly economical methods for reasonably effective receiver noise control. However, employees are often uncomfortable having to constantly wear these devices. They note their inability to detect changes in the sound of their equipment and problems in communicating with other employees. In environments with a lot of material handling equipment such as forklifts, the use of hearing protection devices can create unsafe working conditions because employees may not be able to hear

Table 2 Typical Sound Pressure Levels

Sound Pressure Level (dB)	Source	Subjective Reaction	Sound Pressure	
			N/m^2	inch wg
0	Threshold of excellent youthful hearing	Threshold of hearing	0.00002	0.00000008
10	Threshold of good hearing		0.00006	0.0000002
20	Buzzing insect at 3 feet	Faint	0.0002	0.0000008
30	Whispered conversation at 6 feet		0.0006	0.000002
40	Quiet residential area		0.002	0.000008
50	Window air conditioner	Moderate	0.006	0.00002
60	Conversational speech at 3 feet		0.02	0.00008
70	Freight train at 100 feet		0.06	0.0002
80	Computer printout room	Loud	0.2	0.0008
90	Unmuffled large diesel engine at 130 feet	Very loud	0.6	0.002
100	Platform of subway station (steel wheels)		2	0.008
110	Loud rock band	Threshold of discomfort	6.3	0.02
120	Passenger ramp at jet airliner (peak)	Threshold of pain	20	0.08
130	Artillery fire at 10 feet	Extreme danger	63.2	0.2
140	Military jet takeoff at 100 feet		200	0.8

equipment entering their work areas. Quiet zones or personnel enclosures are preferred to reduce the noise level that reaches the receiver.

The Use of Enclosures

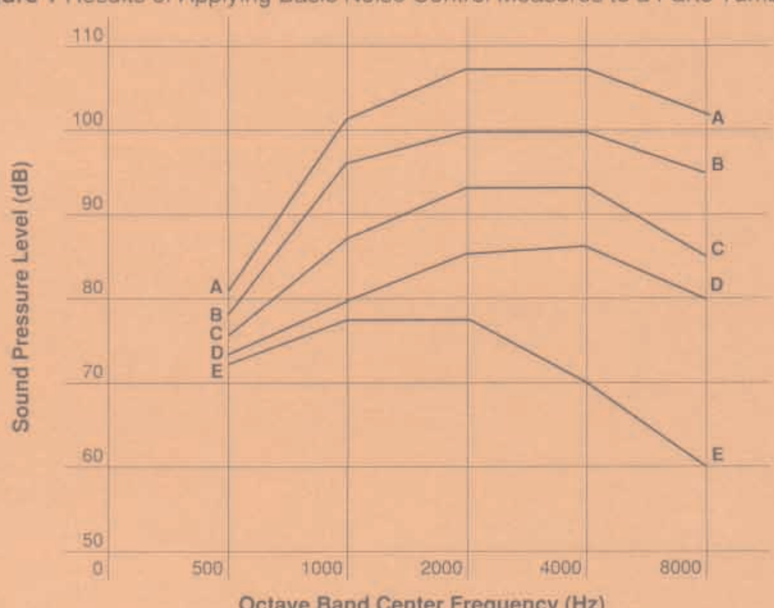
Maximum noise control is provided by quality sound enclosures because they normally include materials and design features which provide sound absorption, transmission loss, sealing, and ventilation in one system. Noise is blocked from either leaving or entering the enclosure. This provides the option of enclosing either the noise source or the noise receiver.

Proper sealing is required for an enclosure to maintain its acoustical integrity. Access doors, windows, and ventilation systems can pose special problems. Doors, windows, and structural joints must be properly sealed and caulked to ensure that no sound leakage, in or out, occurs to degrade an enclosure's performance. In cases where a manufacturing process requires materials to be constantly moved in and out of an enclosure, acoustic tunnels or shields must be incorporated into the design to ensure acoustical integrity. The enclosure's ventilation system may also require adequate silencing of the inlet and outlet paths.

Typical Noise Control Results

Figure 1 and the following illustrations demonstrate the relative noise reductions that can result when various basic noise control measures are applied to a typical industrial noise problem. In this case, the machinery did not generate any significant noise at frequencies below the 500 Hz octave band.

Figure 1 Results of Applying Basic Noise Control Measures to a Parts Tumbler



Curve	Data Points for Graph — Octave Band Center Frequency (Hz)				
	500	1000	2000	4000	8000
	Sound Pressure Level (dB)				
A	81	101	107	107	102
B	78	96	100	100	95
C	77	87	93	93	85
D	74	80	85	86	80
E	73	77	77	70	60

(A) Original noise spectrum —— 112 dBA overall
(B) After damping material only —— 105 dBA overall
(C) After panel barrier only —— 98 dBA overall
(D) After damping material and panel barrier together —— 91 dBA overall
(E) After complete enclosure —— 82 dBA overall (same level as ambient noise due to other machinery in the vicinity)

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