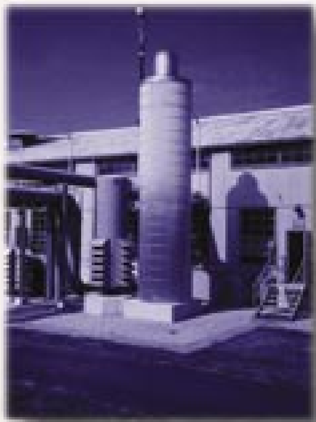
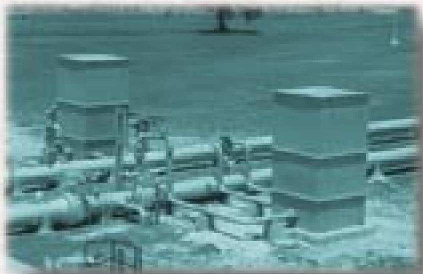
FUNDAMENTALS OF SOUND



Mueller Environmental Designs, Inc.



Air Filtration
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FUNDAMENTALS OF SOUND

Sound is the sensation of hearing. It is any pressure variation (in air, water, or other medium) that the human ear can detect. Sound is produced when a source sets the air nearest to it in motion. For example, when a tuning fork is struck, it vibrates causing the air around it to move back and forth producing a variation in normal atmospheric pressure creating alternate layers of expansion and contraction to move away from the vibrating source. These compression waves are perceived as sound. The pressure fluctuation (amplitude) determines the loudness and the number of fluctuations its frequency.

Sound waves travel in the air at a speed which is temperature dependent. The speed of sound is approximately 1130 feet per second at 70°F. The frequency of sound is measured in cycles per second, and is called Hertz (HZ). The human hearing range is 20 to 20,000 Hz.

The wavelength of a frequency is denoted by the Greek symbol λ and is calculated by dividing the speed of sound by the frequency.

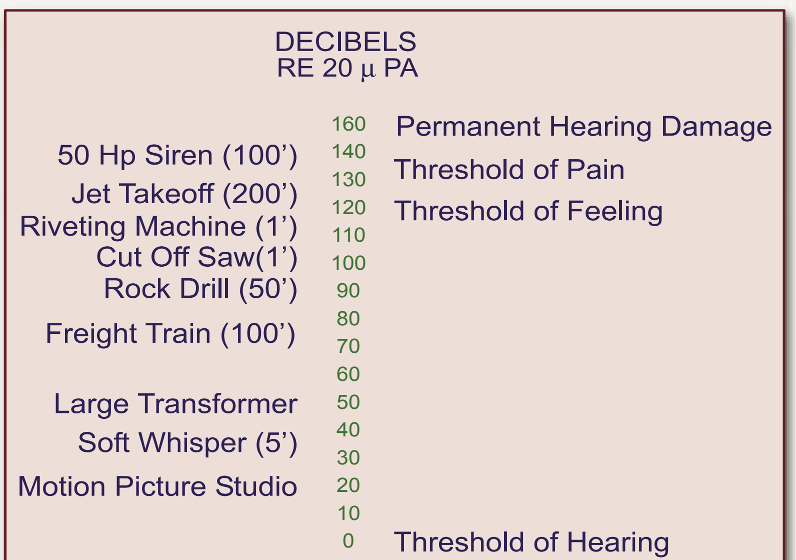
For comparison, the wavelength of 20 Hz at 70°F is 56.5 Ft. and 20,000 Hz at 70°F is approximately 11/16 In. long. Thus we see that high frequencies have short wavelengths and low frequencies have long wavelengths.

$$\lambda = C \div Hz$$

λ = Wavelength
Hz = Frequency
C = $49.03 \times \sqrt{(460 + F)}$
F = Degrees Fahrenheit

Wavelength Formula

The amplitude is another important aspect in describing the loudness of sound. A healthy human ear can detect as little as 20 Pascals but can withstand pressures a million times greater. Therefore, if sounds were measured in Pascals, the numbers would be unmanageable. Subsequently, the decibel or dB scale is used as the unit of measurement. By definition the decibel is 10 times the logarithm, to base 10, of the dimensionless ratio of a quantity to a reference quantity. The reference quantity being 20 micro Pascals (µPa).



Typical A-Weighted Sound Levels of Representative Noise Sources

The responsiveness of the ear to low energy noise is remarkable. The threshold of hearing for a typical adult is approximately 0 dB at 1000 Hz and increases proportionately with decreasing frequency. When sound levels approach 120 dB a prickling sensation is felt rather than heard and is known as the threshold of feeling. As sound levels increase to around 135 to 140 dB the prickling becomes painful and is known as the threshold of pain. Extended exposure to noise levels of this magnitude will result in permanent damage to hearing capabilities. Immediate and permanent hearing loss will occur if exposed to noise levels of 160 dB.

NOISE

Noise is any unwanted sound.
Noise may be continuous, intermittent, or erratic depending upon the source. It annoys, distracts and generally upsets the environment.

Noise measurements taken in the audible sound spectrum have been divided into frequency bands. The most common frequency bands are called octave bands. An octave is the interval between two tones having a frequency ratio of two. The bands typically used in industrial environments are the eight bands from 63 Hz to 8000 Hz center frequencies.

Center Frequency, Hz							
63	125	250	500	1000	2000	4000	8000
44-88	88-177	177-355	355-710	710-1420	1420-2840	2840-5680	5680-11360
Octave Band, Hz							

Standard Octave Bands

The decibel (dB) is the unit of noise measurement. It represents a relative value or ratio, not an absolute value. Decibels are combined logarithmically on an energy basis. The decibel level of a noise source is expressed in octave bands as either sound power level L_w(PWL) or sound pressure level L_p (SPL).

Sound power level L_w (PWL) is the measure of the total acoustic power radiated by a given source. It is constant for a given source and is independent of the acoustic environment. Sound pressure level L_p (SPL) expressed in decibels is a ratio of a sound pressure level to the reference level - L_w (PWL). It is dependent upon distance and the acoustic environment.

Sound power (L_w) is the cause. Sound pressure (L_p) is the effect. Consider the following analogy. A room is illuminated with a 200 watt light bulb. If the room is painted with white high gloss paint there will be more light reflected than if the room were painted a non reflective flat black. In either case the light would be brighter the closer you are to the light. If the bulb had a reflector type shade there would be more light in one direction than another. Regardless of its environment, the light bulb requires the same electrical power input. The relationship between sound power and sound pressure is similar. What we hear is sound pressure but it is caused by the sound power emitted from the source.

NOISE PROPAGATION

Simple noise sources radiate uniformly in all directions. However, in the real world, many factors affect the noise field such as walls, buildings, signs, piping, trees, or any object that becomes an obstacle in the sound path. In most cases, hard surfaces tend to reflect the noise and soft surfaces absorb the noise.

As noise emanates from its source, distance plays a major role in the amplitude that the ear perceives. The inverse square law states that each time you double the distance from the source, the noise level decreases by 6 dB. This phenomenon is termed divergence.

When a gas turbine engine is running or a reciprocating compressor blows down, the noise discharging from the stack (either vertical or horizontal) is higher directly in line with the discharge than to the side. This effect of directivity may be positive or negative depending on the angle and size of the discharge piping.

Other factors that effect the noise field include: multiple noise sources, back ground noise, temperature inversions, and atmospheric absorption.

The most commonly used expression for predicting noise levels for sound propagation outdoors for simple sources in a free field is:

$$L_p = L_w - 20 \text{ LOG } r + DI - Ae + 2.3$$

L_p = sound pressure level at a radial distance r from the source, dB
L_w = sound power level of the source, dB
r = radial distance from the source, ft.
DI = directivity correction
Ae = excessive attenuation due to air absorption, dB

Free Field Hemispherical Propagation

OSHA

The Occupational Safety and Health Act contains the most common noise control criteria used in industrial plants. It states that the maximum permissible noise exposure is 90 dBA for 8 hours, and for time periods less that 8 hours up to a maximum of 115 dBA.

Duration (hours) per Day	Sound Level (dBA)
8.00	90
6.00	92
4.00	95
3.00	97
2.00	100
1.50	102
1.00	105
0.50	110
0.25	115

Permissible Noise Exposure Limits (OSHA)

Octave Band Center Frequency, Hz	63	125	250	500	1000	2000	4000	8000
"A" Weight Correction (dBA)	-26	-16	-9	-3	0	+1	+1	-1

"A" Weighting Network

The most commonly used criteria of 90 dBA employs an "A" weighting network. This "A" weighting is applied to the sound pressure level L_p (SPL) resulting in an octave band spectrum that approximates human hearing response to noise.

HUMAN RESPONSE TO NOISE

Noise affects people in a number of ways. If sufficiently intense, noise may; damage hearing or health, interfere with work tasks, interfere with speech communication, interrupt sleep, or cause annoyance.

The ear is divided into three parts. The outer ear consists of a fleshy shell originally designed to gather sound. However, many evolutions of man have reduced the importance of the external ear. It is now used as an auditory canal to carry sound waves to the ear drum. The middle and inner ear make up the complex system that allows the ear to "hear".

Intense impact noise or continuous loud noise above 90 dBA can damage parts of the middle and inner ear resulting in permanent hearing loss.

Noise levels above 80 dBA interfere with normal conversational speaking making it difficult to communicate and perform work tasks.

Whether noise annoys or causes sleeplessness depends mostly on what it means to us, conditions in which it is heard, our mood, and how accustomed to it we are. The most disturbing and annoying sounds are those that are:

- **Loud** - The louder the noise, the more annoying it is.
- **High Pitched** - 1500 Hz and above.
- **Intermittent** - The more randomly the noise occurs, the more annoying it is.
- **Produced from a hidden or moving source** - The more uncertain you are about where a noise originates, the more annoying it is.
- **Inappropriate to your own activities** - We seldom object to the noise we make.
- **Unexpected** - Noise can startle.

Hearing loss due to aging is termed presbycusis, a progressive deterioration of hearing for frequencies between 3000 and 12000 Hz. Hearing loss due to excessive noise is similar to aging, but different in that noise causes loss of hearing acuity in a specific frequency range, approximately 4000 Hz (voice range)

Excessive noise can cause permanent hearing damage depending upon the frequency, intensity, and duration. It is impossible to reduce noise induced hearing threshold shift once it has occurred by reducing noise exposure. There is no way to restore normal hearing.

NOISE CONTROL

Noise control should reduce hearing risk to acceptable levels within cost effective parameters. Noise control can result in improved worker communication, increased productivity, higher quality of work output and a quieter, safer environment.

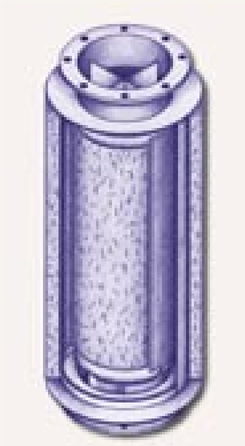
Effective noise control is usually achieved by (A) isolation, (B) dissipation, or (C) a combination of the two. This involves the use and application of sound absorption materials, acoustic shields and barriers, acoustic enclosures and/or silencers.

Silencers are divided into three distinct types:

- Reactive — Chambered
- Dissipative — Absorptive
- Combination — Chambered and Absorptive

Reactive Type Silencer

Basically a multi-chambered vessel generally restricted to low frequency applications on engines and reciprocating compressors, it functions upon a change in area, disruption of flow, pressure drop, and the dissipative affect of perforated internal tubes for effective broad band, low frequency performance. Performance is a function of silencer diameter, overall volume, and internal design.



Absorptive Type Silencer

Typically a straight through acoustically lined pipe, with or without an internal plug. It is essentially a high frequency, low pressure drop attenuator, applied to the intake and exhaust of centrifugal blowers, forced draft fans, and gas turbines. Performance is a function of absorptive material, length, and internal design.

Combination Type Silencer

Functionally a reactive-type silencer with an absorptive packed inlet and/or outlet to provide sound dissipation in both the low and high frequency ranges. The type of silencer is typically used in very stringent noise control applications.

Summary

Noise is any unwanted sound.

Noise can be controlled by addressing their source, path and/or receiver.

Noise control at the source. A noise source is created by the motion of a solid, liquid, or gas. A solid source me be quieted if its mode of operation is changed so that it moves less. Liquid and gaseous sources may be quieted by eliminating turbulence, reducing flow velocity, smoothing flow, and attenuating pressure pulsations. Control at the source by planning while the product is in the design stage is often the most cost effective and least expensive control measure.

Noise control in the path. Most corrective measure for an existing noise control problem utilizes changes in the path. Solutions for path noise control include barriers, enclosures, silencers, and mufflers, vibration dampening, and vibration isolation.

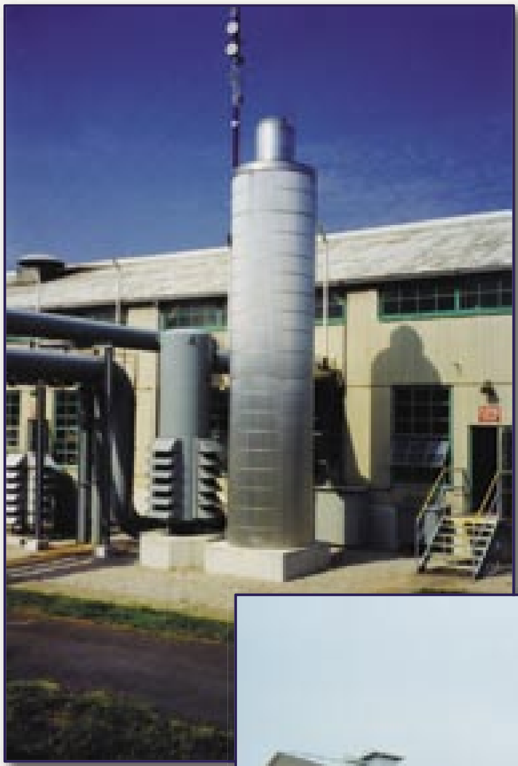
The demands of the receiver. The level to which a noise source should be reduced to be acceptable to human receivers often requires judgment on the part of the engineer and/or owner of the building or machine. A criterion for noise control for listeners depends on whether the goal is to preserve hearing, create space where conversation is easy, or to provide comfort in the home, or at work.

Mueller Environmental Designs, Inc. supplies noise path control equipment. Mueller has field proven noise control equipment for both rotating equipment and high pressure venting applications.

Mueller Environmental Designs, Inc. - Attention to Detail

Solar Saturn Intake and Exhaust; Designed to Meet 50 dBA at 50 ft. From Compressor Building

Cooper Bessemer Upgrade GMVH-10 MED Provided Intake and Exhaust Systems Designed to Meet 50 dBA at 50 ft. From Compressor Building



Cooper Bessemer GMW-10-TFT Intake and Exhaust Systems Designed to Meet 60 dBA at 50 ft. From Compressor Building

Compressor Station ESD Vent System Designed to Meet 50 dBA at 100 ft.

Solar Mars Intake and Exhaust System Designed to Meet 60 dBA at 50 ft. From Compressor Building

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