Technical Perspective

Sound Measurement and Attenuation

INTRODUCTION:

Noise pollution has become a serious issue and is a concern for residential, commercial and industrial environments. This Technical Perspective will explore what noise is, how it is generated, how it is measured, how to estimate what the noise levels will be when measured values are not available, and how to reduce noise sources to acceptable levels.

KEY POINTS:

- Measurement of Sound
- Sound Attenuation Options

MEASUREMENT OF SOUND

Sound in a physical sense is the vibration of gas or air particles that causes pressure variations within our eardrums. These pressure variations are translated by our hearing senses into what we call sound.

The variation in normal air pressure that is part of a sound wave is characterized by the rate at which the variation occurs and the extent of the variation. This rate is called the frequency, measured in hertz. In a normal adult, the audible frequency range is from 20 to 18,000 hertz. The extent of the variation in pressure is measured in microbars, which is one millionth of the normal atmospheric pressure. The difference between the threshold of hearing and the threshold of pain corresponds to a pressure differential of 10^6 or one million microbars. Because of this wide range, sound pressure measurements are made on a logarithmic or decibel (dB) scale. A decibel is a logarithmic ratio of two values, with the base value being the threshold of human hearing (0 dB). The second part of the ratio is the actual sound pressure measurement.

We know that human ear sensitivity varies with frequency. A low frequency sound at a certain pressure ratio (dB) does not seem as loud as a higher frequency sound of the identical pressure ratio (dB). To account for this difference, a weighting scale that takes into account the way the human ear responds was developed. This scale is called the A weighting scale and provides results which conform approximately to the response of the human ear. The A weighting scale is abbreviated dBA

Following are sound pressure levels for some common everyday sounds.

Typical Sound Pressure Levels

dBA	Source	dBA	Source
140	Engine exhaust – no muffler @ 3 ft.	60	Large store or office
130	50 HP Siren @ 100 ft.	50	Average residence
120	Jet takeoff @ 200 ft	40	Soft whisper
110	Riveting machine	30	Quiet office on Saturday
100	Large Diesel Engine @ 10 ft.	20	Mouse walking across a wood floor
90	Train @ 20 ft.	10	
80	Inside a sports car @ 60 mph	0	Threshold of hearing (young person)
70	Inside a luxury car @ 60 mph		

Source: Handbook of Noise Measurement, General Radio Company

Another term that is commonly used in evaluating sound levels is sound power or sound intensity. Sound power is the acoustical energy emitted by the sound source and is an absolute value; that is, it does not change value as the distance from the source increases. Think of sound power as the wattage of a light bulb. Sound pressure would then correspond to the brightness of the bulb in a particular part of the room. Sound pressure is what our ears hear, what sound meters measure and what ultimately determines whether a sound source is acceptable.

Noise originates from any source that vibrates or can cause the air around it to vibrate. This can come from a metal blade striking the air as in a fan or the expansion of hot gas as in an engine exhaust. What our ears hear is the combination of all the noise sources added together.

Theoretically, if noise originates from a point source and is a single frequency, the mathematics are simple. However, real world noise is very seldom simple, and thus the mathematics becomes infinitely more complex. Variations include geometrical spreading, air absorption, ground absorption, ground reflection, diffraction attenuation of a barrier, weather variability, complex acoustical structures and reflections. A complex sound can be expressed as a combined value as in the "A" weighing scale. The frequencies can also be broken down into full octave (60 hz, 120 hz, 240 hz, etc.) or 1/3 octave or even smaller bands to evaluate the intensities of the sound and where the individual frequencies are originating from. This becomes critical when developing sound attenuation because different frequencies require different methods of attenuation.

As an example, noise sources from a typical engine generator set are exhaust, mechanical noise from the rotating and reciprocating parts, fan noise, intake air and turbocharger noise. The exhaust noise is the most predominant. The type of muffler and the position of the exhaust exit will have the most effect on radiated noise. The second most predominant noise source is the engine cooling fan and the associated air flow. Additional noise sources from the alternator fan and mechanical noise from the engine and engine accessories add to the overall noise level.

The most predominant problem in controlling a noise source is that a high degree of noise reduction is required to make a difference that is perceptible to the human ear. Using a simple listening test with everyday sounds, a 2 to 3 dB difference is about the smallest perceptible difference that we can hear. To achieve a 3 dB reduction requires a 50% reduction in sound energy. A 10 dB reduction would require a 90% reduction in sound energy.

Government regulatory bodies are concerned about the amount of noise emitted for overall health reasons and for short and long term protection of our hearing ability. OSHA is very specific about the noise level the human ear can tolerate over time.

OSHA Sound Exposure Limits

Hours	dBA (continuous)	Hours	dBA (continuous)
8	90	4	95
6	92	1	100

Source: Handbook of Noise Measurement, General Radio Company

In addition to federal control, local ordinances establish a tolerable or safe sound level in dBA at a specific distance from the source or at the perimeter of an individual property where the sound source originates. Measuring techniques are almost always in a straight line from the source at a specific distance, and the standard distance used for most equipment is 1, 3 and 7 meters.

When the sound level at a specific distance is not available, how can one estimate these sound levels at required or specified distances? Since sound pressure is inversely proportional to the square of the distance from the source, a formula can be developed to determine the dB values at any specific distance from the sound source. These estimations are not totally accurate, but can approximate sound levels in lieu of actual measurements.

$$\mathbf{12\ Log_{10}\ (D2 / D1)}$$

D2 = Distance from the source for the 2nd sound source
D1 = Distance from the source for the 1st sound source

Example:
D1 = 1 meter from the noise source
D2 = 7 meters from the noise source

$12 \log_{10}(7) = 10$ dBA reduction from 1 to 7 meters from the sound source

When adding two noise sources the following table can be used:

When 2 decibels values differ by	Add the following amount	When 2 decibels values differ by	Add the following amount
0 to 1 dB	3 dB	4 to 9 dB	1 dB
2 to 3 dB	2 dB	10 dB or more	0 dB

Source: Handbook of Noise Measurement, General Radio Company

If more than 2 sources are to be added, add two at a time and continue until only one value remains.

SOUND ATTENUATION OPTIONS

The three most important methods of noise attenuation are sound barriers, sound absorbers, and vibration dampers. Sound barriers are the most effective for reducing noise, but not always the most cost effective. Sound absorbers such as foam padding, resonant tunnels and baffles cost less but are generally not quite as effective. Vibration control can reduce or even eliminate specific frequencies, which may have a major effect on the total sound level. In addition, sound measurement in a sound laboratory might yield totally different results from a field sound test. In any situation where sound parameters are important, it's necessary to consider not only where the source is, but when it will be emitting noise. What is tolerable at 1:00 pm might not be so tolerable at 2:00 am. What is the area around the noise source like? Have variables such as geometrical spreading, air absorption, ground absorption, ground reflection, diffraction, attenuation barriers, weather variability, complex acoustical structures and reflections all been taken into account? Who will be affected by the noise? Is it near a hospital, nursing home, residential area or a manufacturing facility?

Another consideration is tonal quality and consistency. The noise from a ventilation system is hardly noticeable unless it stops, or starts whining or squealing. Machinery that is unbalanced or has repeated impacts, or pulsating flows of liquids or gases are almost always objectionable. Noise features that make us take notice are annoying tones and abrupt changes in sound level. The more prominent the tone and the more abrupt the change in sound level, the more noticeable the noise is. The lower frequencies tend to be less annoying and thus can be of a higher intensity than the higher frequencies. Knowing the type of noise helps in identifying the method of sound attenuation and often the simplest method is to use our ears to pinpoint annoying features of the noise before attempting to attenuate it.

Lastly, does the additional cost of sound attenuation justify the reduction in noise? This is not always a consideration when federal or local noise standards are enforced. Typically, to reduce an engine generator set from a standard enclosure at 78 - 82 dBA to a sound attenuated enclosure at 73 - 75 dBA will add 20% additional cost to the enclosure. To reduce the sound pressure levels to the 65 - 68 dBA range will add 35%. To reduce the levels to the 55 - 60 dBA range can easily double or triple the cost of the enclosure as well as cause significant dimensional increases.

It is also important to consider any pre-existing noise levels before additional equipment is installed. These existing noise sources could be close to the maximum dB levels defined by a local code. Then, additional equipment, even with specifications within the requirements of the code, would exceed the maximum noise level permitted on site.

Loud and objectionable noises polluting our environment can have serious physical as well as economic consequences. Having an understanding of sound measurements and the basic principles of sound attenuation can simplify noise reduction efforts and eliminate potential site problems and the additional costs associated with those problems.

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