Acoustical Engineering Report

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

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Sound

Sound is defined as "a variation in pressure, stress, particle displacement and velocity in a medium with internal forces." To many people, this definition is difficult to grasp, so we will approach it from a more basic level.

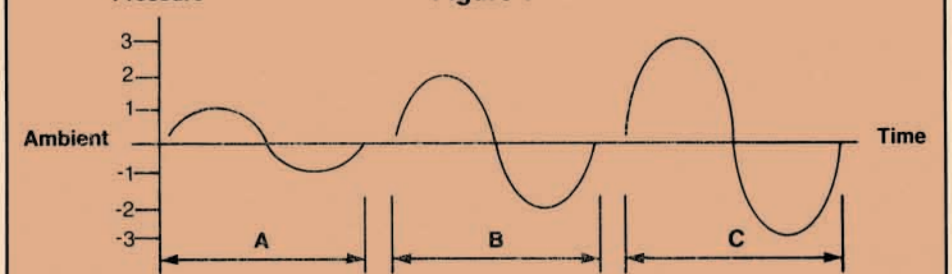
Everything on earth is subjected to the force of gravity, including the atmosphere surrounding us. The weight of a one-inch square column of air extending from any point on the earth's surface to the vacuum of space, is referred to as the barometric pressure or ambient pressure. This pressure is approximately 14.7 pounds per square inch (psi) at sea level.

When something causes the air pressure to fluctuate rapidly above and below the local ambient pressure, our eardrums respond by vibrating similarly, and we identify this as a "sound."

Noise

Noise is unwanted sound, whether it is a simple, short duration annoyance, or an extended duration sound. Particularly in an industrial environment there are many noise problems that can lead to permanent hearing loss.

Figure 1



Loudness

One of our subjective reactions to sound is what we sense as **loudness**. This sensation is related to the **amplitude** of the pressure fluctuation above and below the existing ambient pressure. This fluctuation generally is extremely small. Two things are important regarding our ear's reaction to the amplitude of pressure fluctuation:

1. For a given frequency, the greater the amplitude of the pressure fluctuation, the louder the sound is perceived to be.
2. For equal numerical changes in the amplitude of a pressure fluctuation, our ears become less and less responsive to the increase in loudness, as the amplitude increases.

Refer to Figure 1. Note that each of the three successive pressure wave fluctuations (A, B and C) have increased in amplitude by one unit. Each of these would sound louder than the previous pressure fluctuation.

When air pressure fluctuations are low, a specific numerical increase in the amplitude will be sensed as a specific increase in loudness. As the amplitude increases, our ears become less responsive to the increase in amplitude and we react by saying the sound did not increase in loudness as much as before. For example, our ears would tell us that the increase in loudness between A and B was greater than the increase in loudness between B and C, although the changes were numerically equal in magnitude.

Sound Pressure

To this point, we have discussed only concepts that deal with our subjective reaction to sound. Further discussion requires the introduction of our first "measurable" acoustical term, **sound pressure.**

Sound pressure is a numerical value for a pressure fluctuation in the atmosphere. Often, sound pressure is confused with another acoustical term, **sound pressure level**. These are different terms, and the difference between the two should be understood.

The accepted units of sound pressure are metric: newtons per square meter (N/m^2). To gain an understanding of what this unit represents, one newton per square meter is approximately the pressure that a slice of butter exerts on a piece of bread; it is approximately equal to 0.004 inches w.g. or 0.00015 psi pressure.

Our ears are extremely responsive to low amplitudes of air pressure fluctuations, and the lower "threshold of good hearing" (i.e. — the quietest sound an average person is likely to hear) has a pressure fluctuation amplitude of approximately 0.00006 N/m^2 (approximately 9 billionths of a psi).

Within the range of sound pressure that we typically would be subjected to, the amplitude of pressure fluctuation ranges from 0.00006 to 6.3 N/m^2. (The latter usually is referred to as the "threshold of discomfort.")

Pressure fluctuations above 6.3 N/m^2 can lead to pain, temporary hearing damage, or even permanent hearing damage if we subject our ears to these sound pressures for too long.

Table 1

Typical Sound Pressure Levels

Sound Pressure Level (dB)	Source	Subjective Reaction	Sound Pressure	
			N/m^2	Inch w.g.
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	63.2	0.2
140	Military jet takeoff at 100 feet	Danger	200	0.8

Sound Pressure Level

As mentioned, two important facts about our subjective reaction to sound are:

1. People are receptive to a very wide range of pressure fluctuations (0.00006 to greater than 6 N/m^2).
2. As the amplitude of the pressure fluctuation increases, our response to numerically equal changes in amplitude decreases.

Due to both the magnitude of the range, and the ear's diminishing response to increasing sound pressures, sound pressure is typically "quantified" in **decibels**, not newtons per square meter. When expressed in decibels, the value of air pressure fluctuation is termed **sound pressure level**.

Due to its logarithmic derivation, the use of decibels in acoustics lends itself well to correlating equal numerical changes in decibels with the perceived human response of equal changes in loudness.

For example, a **ten decibel increase** in sound pressure level corresponds closely to what is sensed as a **doubling** of the loudness of a sound, irrespective of the numerical value of the sound pressure level. Other good rules-of-thumb to remember are:

1. A **5 dB** increase in sound pressure level is clearly noticeable.
2. A **3 dB** increase in sound pressure level is barely noticeable.
3. Sound pressure level differences of less than 3 dB will generally be **undetectable**, even by those with very acute hearing.

Table 1 presents values of typical sound pressure levels in decibels, and the corresponding sound pressures in both metric and English units. By using sound pressure levels in decibels, we are provided with two or three digit integers instead of the more cumbersome multi-digit decimal representations for sound pressure.

By definition, sound pressure level can be determined by Equation 1 (see below) where:

Lp = Sound pressure level in dB. (Note: Many texts will abbreviate this as SPL.)

P = The root mean squared (RMS) value of the sound pressure fluctuation in N/m^2.

P_{ref} = A standard reference sound pressure equal to **$2 \times 10^{-5} N/m^2$.**

Equation 1 takes this form for the following reasons:

1. The use of a reference sound pressure is necessary to make the ratio inside the brackets unitless, so that a logarithm can be taken of that value. The value $2 \times 10^{-5} N/m^2$ (0.00002 N/m^2) is the threshold of excellent youthful hearing and is used as P_{ref} so that Lp = 0 when P = 0.00002 N/m^2, or is at the threshold of audibility.
2. The use of logarithmic math reduces the value of this ratio to a workable range between 1.0 and 14.0, for most of the commonly encountered sound pressures.
3. The external multiplier (10) brings the value to an easily written two or three place number which can be rounded off to zero decimal places without a loss of accuracy.

For easier calculation Equation 1 can be rewritten as Equation 2 (see below). The terms Lp and P remain the same.

Example: A fluctuating atmospheric pressure level has a root mean squared (RMS) value of 0.6 N/m^2. What is the sound pressure level in dB?

Using Equation 2 we have the following:

$$Lp = 20 \log_{10} \left[\frac{0.6 \ N/m^2}{0.00002 \ N/m^2} \right] dB$$

$$= 20 \log_{10} (30{,}000) \ dB$$

$$= 20 \ (4.477) \ dB$$

$$= 89.54 \ dB$$

The 89.54 dB value can be rounded off to 90 dB. This sound pressure level corresponds to an RMS sound pressure of 0.6 N/m^2 (see Table 1).

Subsequent reports will discuss **sound power/sound power level** and **sound frequency.**

Equation 1

$$\text{Sound Pressure Level} = Lp = 10 \log_{10} \left[\frac{(P)^2}{(P_{ref})^2} \right] dB \text{ re } (P_{ref})$$

Equation 2

$$Lp = 20 \log_{10} \left[\frac{P}{2 \times 10^{-5} N/m^2} \right] dB \text{ re } (2 \times 10^{-5} N/m^2)$$

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