NUMBER 2
Acoustical Terminology — Part 2

Acoustical Engineering Report

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

2400 Fairwood Avenue
Columbus, Ohio 43207-2700
614/443-5520, Fax: 614/542-2620
Web site: mcgillairsilence.com
E-mail: acoustics@mcgillairsilence.com

Authored and Published by
United McGill Corporation's
Engineering Department

Frequency, Broadband Sound Levels, and Octave Bands

Introduction

The first engineering report in this series (AER Number 1) pointed out that what we sense as sound is only a rapid fluctuation in ambient air pressure above and below the local barometric pressure. One of the variables of this phenomenon, the amplitude of the pressure fluctuation, was also discussed.

To fully understand what we sense as sound, another variable needs to be discussed — the "speed" or "rate" of pressure fluctuation. Although the apparent loudness of a sound is a function of the amplitude of the pressure fluctuation, both the rate and amplitude of pressure fluctuation must be considered simultaneously in judging the true loudness of a sound.

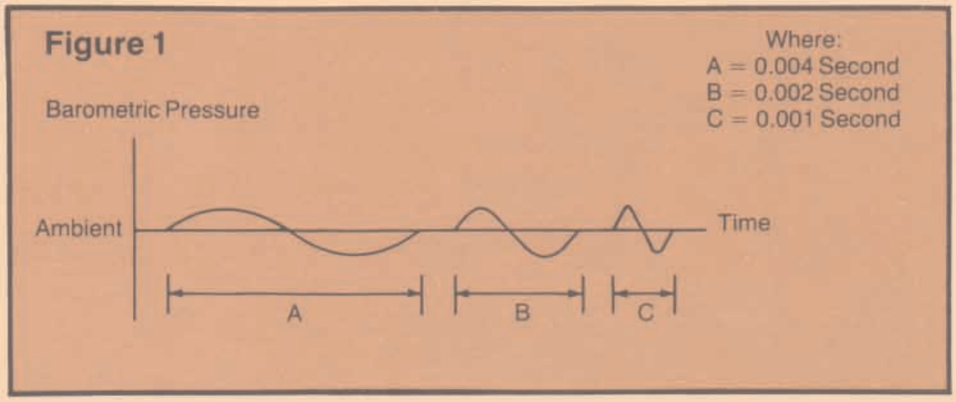
Pitch—Tone

Subjectively, we react to the rate of pressure fluctuation by assigning a certain *pitch* to it. What is sensed as a low pitched sound, such as a foghorn or bass singer's voice, is composed of relatively *slow* pressure fluctuations. What is sensed as a high pitched sound, such as a police whistle or a soprano's voice, is composed of relatively *fast* pressure fluctuations.

We also subjectively classify sounds as a function of their *tonal* quality. Examples of this are when we characterize sounds as hissing, rumbling, roaring, whistling, or other similar words.

Both the pitch and tone of a given sound will be discussed, but first we need to quantify the rate of pressure fluctuation.

Figure 1



Frequency

Let us assume that air pressure is fluctuating in a purely sinusoidal pattern above and below the ambient barometric pressure, as shown in **Figure 1**. The pressure fluctuations A, B, and C are traveling through one complete cycle in 0.004, 0.002, and 0.001 second, respectively. If they were to continue fluctuating at these rates, they would repeat themselves 250, 500, and 1,000 times, respectively, in 1 second.

The *frequency* of a pure tone is defined as the number of cycles per second at which the ambient air pressure is fluctuating. The unit of frequency measurement is Hertz (Hz). One Hz corresponds to 1 cycle per second.

The human ear responds to a wide

range of sound frequencies. A young person with excellent hearing may be able to discern sounds between 20 Hz and 20,000 Hz. As we get older, the audible-range width has a tendency to shrink at both the low and high frequency ends.

Loudness

As we stated earlier, the true *loudness* of a sound is a function of both the amplitude and frequency of the air pressure fluctuation, and both of these must be considered simultaneously.

To better understand this phenomenon, consider an experimental scenario in which we have the following:

(1) A pure-tone generator, amplifier, and speaker system that is operating at a pre-measured and constant sound pressure level and at a frequency of 1,000 Hz. This can be called the "control tone."

(2) A similar system, in which we can independently vary the frequency and/or amplitude, and in which we have a way of measuring the resultant sound pressure level. This can be called the "variable tone."

(3) A group of representative listeners to judge the loudness of the variable versus the control tones.

We would conduct the experiment by setting the 1,000 Hz control tone to a specific sound pressure level, and then setting the variable tone at a specific frequency and low amplitude. Next, we would start increasing the variable-tone amplitude (volume) and ask the listeners to respond when they believed the variable tone had the same loudness as the control tone. This would be repeated at numerous variable-tone frequencies and control-tone sound pressure levels.

When the experiment was completed, the following trends would result:

(a) To sound equally loud at frequencies below 1,000 Hz, the sound pressure levels of the variable tone would be higher than the sound pressure level of the control tone.

(b) To sound equally loud at frequencies from 1,000 Hz to around 7,000 Hz, the sound pressure levels of the variable tone would be equal to, or lower than, the control-tone sound pressure level.

(c) At frequencies above 7,000 Hz, the same phenomenon as (a) would be noticed, namely that the variable-tone sound pressure levels would be higher than that of the control tone.

If we were to plot the results of our experiment, they would be similar to **Figure 2**. These types of plots typically are referred to as *equal loudness* curves or contours.

Broadband Sound Levels

In reality, very few of us are ever exposed to many *pure-tone* sounds. Even something that sounds pure, such as the sound when a guitar string is plucked, is actually a combination of various frequency components. In the case of the plucked guitar string, what we hear is actually a combination of the basic frequency of the string, along with one or more of its harmonic frequencies (i.e., integral multiples of the basic frequency).

Most of the sounds that we are subjected to on a daily basis are a combination of thousands of frequency components. These are all *broadband sounds* and, although we may be able to characterize them by their pitch or tonal qualities, they are not pure tones.

We should understand that the various amplitudes of the frequency components of a broadband sound level may differ significantly among sound sources. For example, it is not enough to say that a fan produces a certain type of noise, since different fan types exhibit differing sound spectra. If we consider this, along with the fact that the sound reduction properties of various noise controlling equipment also are a function of frequency, we easily can see that the components of a broadband sound level need to be quantified in some form before we can effectively solve or prevent a noise problem.

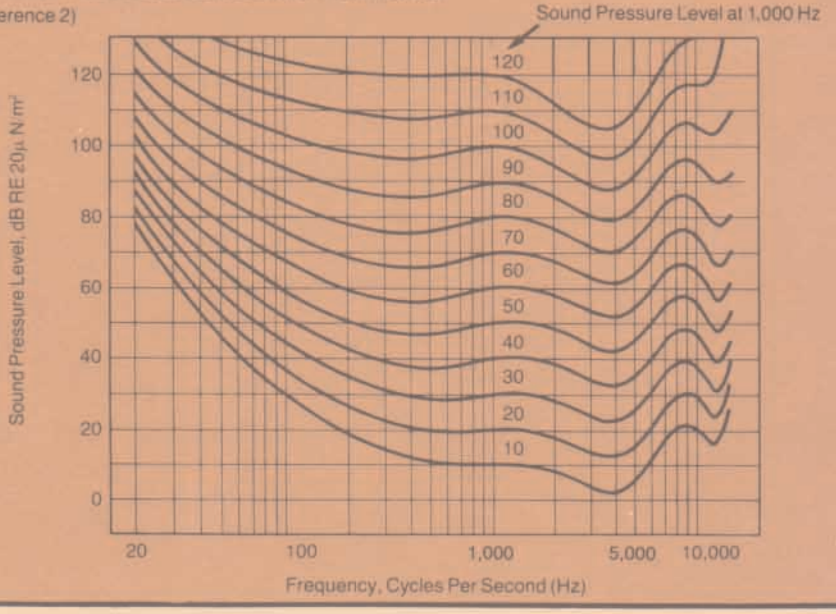
Octave Bands

The most common way of expressing the amount of sound in various fre-

Figure 2

Free-Field Loudness Contours for Pure Tones

(Reference 2)



quencies is by the use of *octave bands*. An octave band is a frequency band in which the highest frequency in the band is two times the lowest frequency in the band. This results in a geometric progression whereby the actual bandwidth increases as frequency increases.

It is easier to hear the difference between two low frequencies than between two high frequencies. Since our ears have the effect of compressing frequency ranges as frequency increases, the use of octave bands is an effective way of simulating this phenomenon.

Octave bands generally are expressed in one of three ways: (1) as an octave band number, (2) as a center frequency, or (3) as a listing of the upper and lower frequencies of the octave band. **Figure 3** provides a comparison of these.

Octave Band Numbers and Center Frequencies

Octave band numbers represent frequency segments usually evaluated in an acoustical design. *Center frequencies* are the geometric center frequency of each of the respective octave bands.

A good rule of thumb exists for remembering the corresponding center frequencies and octave band numbers. First, remember that the eighth octave band has a center frequency of 8,000 Hz. For each octave band lower than the eighth, the center frequency is one half of the previous center frequency (i.e., the seventh octave band has a center frequency of 4,000 Hz, the sixth octave band has a center frequency of 2,000 Hz, and so forth).

Occasionally, one will see acoustical data listed for different octave band frequency ranges. This type of data is antiquated and not in widespread use. Use of such data is only suggested when more up-to-date information is not available, since extensive improvements and modifications have been made in both testing standards and acoustical measurement equipment in the last decade.

Evaluation of Broadband Sound Levels— Design Goals

There are two major ways of evaluating broadband sound levels. These two methods can be separated into a *quality* versus a *quantity* type of rating procedure.

The typical quality rating procedure evaluates the noise spectrum of a given sound and compares it with standardized curves. Examples of this procedure are the familiar NC, PNC, and RC noise criteria curves. These rating procedures usually are applied to indoor areas, such as offices, hallways, etc. Depending on the use of the area, various curves are applied as design goals.

The typical quantity rating takes the apparent loudnesses of the frequency components, weights them appropriately, and then recombines the weighted components to give an overall single-value reading. An example of this procedure is the familiar A-weighted sound pressure level (dBA). This procedure typically is applied in factory environments where the concern is not *how* something sounds but rather *how loud* it sounds.

Our next Acoustical Engineering report will discuss the concept of *sound power.*

Reference 1 **AER, Number 1, "Acoustical Terminology—Sound Pressure — Sound Pressure Level," United McGill Corporation**

Reference 2 **D.W. Robinson and R.S. Dadson: "A Redetermination of the Equal Loudness Relations for Pure Tones," (British Journal of Applied Physics, Vol. 7, May 1956, p. 166)**

Figure 3

Comparison of Methods that Express Sound Pressure Levels of Octave Bands

Octave Band #	1	2	3	4	5	6	7	8
Center Frequency (Hz)	63	125	250	500	1,000	2,000	4,000	8,000
Frequency Range (Hz)	45-90	90-180	180-355	355-710	710-1,400	1,400-2,800	2,800-5,600	5,600-11,200

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