THE ACOUSTICAL CONSULTANT

The Decibel – An Acoustical Yardstick

by R.J. Weisenberger

As I have taken an entirely new approach to the art of organ building, it is important that acoustical terminology be understood more fully.

I hope to clear up any misunderstandings, by explaining the meaning of acoustical terms in this and future articles. I invite questions from the reader to clarify any misunderstandings, as well as questions dealing with any acoustical or solid state problems of any given installation.

I can advise against getting too much, or too little, organ from anything from a home installation to one in a stadium. I will need to know the number of ranks, their operating pressure, the working dimensions of the largest pipe in each rank, and the dimensions of the auditorium. I can also give specialized tips on revoicing flue pipes for a different pressure, and how to preserve the original tonality as best as possible, or to give it an added high end brilliance or low end punch to compensate for a dull auditorium, if given the dimensions of the 8'C pipe of each rank. I will also advise against revoicing if the figures supplied indicate that the pipework is already well-suited for a given installation. Since one unfamiliar with pipe voicing could ruin an organ, I will restrict such information to professionals.

This article is intended to familiarize the reader with the decibel (DB), what it is, how it is measured, conditions affecting it and how the ear responds to sound.

Since the ear is sensitive to sounds over a frequency range of 20 Hz to 20,000 Hz (cycles per second) and to a power range as great as one billion to 1 (0 DB to 120 DB), the decibel represents a more convenient means of expressing power ratios. The decibel was named in honor of Alexander Graham Bell (decibel meaning 1/10 Bel) and is abbreviated as DB.

The DB scale is a logarithmic scale used to express the ratio of a given level as referenced to some standard level. In the absolute DB scale, 0 DB is referenced to the threshold of acute hearing at a frequency of 1 KHz (1,000 cps), which is 10^{16} W/cm^2 (watts per square centimeter), or .0002 uBar (millionths of barometric pressure). Every increase of 10 DB is an increase of power of 10 to 1, or an increase in voltage or pressure of about 3.2 to 1.

As can be seen, a modest increase in DB means a large increase in sonic pressure, and an astronomic increase in acoustical power. The dynamic range (ratio of loudest to softest sound) of a large pipe organ is typically 40 to 50 DB, although a dynamic range of 60 DB can be achieved in high pressure organ designs.

One acoustical watt may not seem like a very large amount of power, but considering a 2% efficient speaker (most home speaker systems are from 2 to 5% efficient) operated below 200 Hz, where its output is for all practical purposes, nondirectional, it would take a 50 watt RMS amplifier in order to produce one acoustical watt (a level of 108 DB at a distance of one meter from a non-directional source in free space).

Through tests I have found that a single, well-voiced flue pipe is capable of producing this level on a pressure of 10" WP. I also found that by making the proper modifications to the design of the pipe's mouth that the pipe could be operated efficiently over a pressure range of 16 to 1. Test equipment recorded and verified the expected change in output of 24 DB,

$$DB = 10 \log \frac{P\ output}{P\ input} \text{ for power}$$

$$DB = 20 \log \frac{E\ output}{E\ input} \text{ for voltage or pressure}$$

	DB	POWER RATIO	PRESSURE RATIO	PHYSIOLOGICAL EFFECTS
	0	1	1	silent (anechoic room)
	20	100	10	quiet (watch ticking-3')
	40	10,000	100	quiet room (ambient noise)
Pipe Organ Range	60	1,000,000	1,000	soft (music or conversation)
Pipe Organ Range	80	100,000,000	10,000	moderately loud (music)
Pipe Organ Range	100	10,000,000,000	100,000	loud (music)
	120	1,000,000,000,000	1,000,000	very loud (danger — can cause permanent hearing loss)

with an error of less than 6 DB in every design of pipe tested. This is a ±3 DB tolerance, about as good as can be expected from a high fidelity speaker over its frequency range!

I have proved that pipes definitely follow a predictable pattern of behavior and can be analyzed objectively — apparently something never before actually proved or attempted.

I also found that a large pipe of the closed variety, when placed near the corner of a room, would have its output substantially increased, just as the bass output of a speaker may also be increased in this manner.

All measurements of decibels will be meaningless unless some standards are rigidly adhered to.

First, the international reference of .0002 uBar must be always used as 0 DB, and secondly, the distance from the source should always be 1 meter (39.37") unless otherwise specified. One yard (3") will be close enough for most purposes.

Sound levels will decay by 6 DB every time the distance from the source is doubled, or by 3 DB if the power is halved. If a sound level meter (SLM) is used to measure *music*, the flat response "C" weighting must be used for an accurate measurement, also the meter must be set to fast response to include peak levels of complex waveforms.

In reverberant rooms and auditoriums a point will be reached where a further increase in distance does not appreciably affect the overall sound level. This is known as the critical distance, and it is typically at a distance of 1/3 the length of most rooms from the sound source. At this point the direct sound level will balance with the reverberant sound level. (Incidentally, this is one of the best positions from which to listen to or record a concert.)

The power required to produce a given sound level will be directly proportional to the cubic volume of a room.

The ear, although extremely sensitive, hears sounds in their true perspective and balance only at the higher levels of sensation (90 DB to 110 DB). Levels in excess of 110 DB are again unbalanced, produce pain, and are dangerous to your hearing. Below 90 DB, it takes considerably more power to produce low bass tones of 32 Hz than it does to produce sounds in the range of voice frequencies (200 to 2000 Hz). Organ chambers provide a natural compensation for this odd property of hearing, because the short wavelengths of high frequency sounds are much more easily attenuated (reduced) by passing through swell shades than are the low frequency sounds, having wavelengths over double the length of the open pipes, and over quadruple that of the closed pipes. The large offset pipes being located near the walls and floors of the chamber receive the increased output they need to achieve tonal balance with the rest of the organ.

The most successful installations are those where the organ is capable of producing maximum levels between 100 DB to 110 DB in the auditorium. Obviously, large installations require considerably more power than small ones.

An organ built for a large theatre or auditorium, would be deafening if installed in a home, unless the pipework is installed in the nonliving quarters of the home, separate from the console. The reason for this is simple. The *sound level* is *inversely proportional* to the cubic volume of a room for a given *power*, while the *power* is *directly proportional* to the cubic volume of a room for a given *sound level.*

At all levels of sensation the ear is most sensitive to sounds over the frequency range of 2 to 4 KHz (the approximate top octave of a 4' stop). A large organ can achieve an excellent tonal balance with only a couple of powerful stops in this range or above. A moderate number of less-powerful stops at these pitches will also give good results.

Lord Kelvin, in 1883, said, "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it."

For further reading, the reader may consult the following source. *Acoustical Engineering,* by Harry F. Olson, Ph.D., Copyright 1957, D. Van Nostrand. Chapter II — Section 2.2 (will show the effects of chamber walls on closed offset bass pipes). Chapter XI — Architectural Acoustics. Chapter XII — Speech, Music, and Hearing.

A future article will explore power requirements of pipe organs. □