ON NOISE AND NOISE MEASUREMENT

Certain questions have been raised by owners and users of HJ3100 fume extractors regarding the noise made by the things, and why the muffler or silencer don't 'cut the noise in half, but just reduce it 6 to 9 db.'

Second things first. The decibel is properly a measurement of sound *power*, not sound *amplitude*; it is the only way we have to quantify a subjective phenomenon; it is an ineluctable fact of the mathematics of the case that a difference of 6 dB does in fact represent a difference of exactly half the sound power. A 9-decibel difference, then, represents an even lower level of sound power. Audio equipment is advertised and sold on the basis of sound power, as most of us know[1].

When your unmuffled HJ3100 emits, say, 60 dBA at wherever you elect to measure it, and the muffled one emits 54 dBA[2] at the same point, the muffler is acting as it was designed to do; please don't expect the new reading to be 30 dBA. That is unrealistic. The average noise level in an office is around 50 dBA; in an average living room, 45-50 dBA (depending upon whether or not the lobotomy box is on); in your car, 60 - 65 dBA; in an average shop, 60 - 70 dBA; at a movie, 80 - 90 dBA and at a rock 'concert', 100 -120 dBA.

Amplitude is one aspect that can make a sound annoying; frequency, or the amplitude of noise at certain frequencies, is another. A high-pitched sound is much more annoying, subjectively, than a low-pitched one[3].

If the noise is still objectionable (you are in a quiet room, for example), the cause of your discomfort is the frequency of the sound generated by the blower and the air passing through the case. This tells you the machine is working, but its high-frequency characteristic can be annoying. Place the HJ3100 on a carpet square (use a nice shaggy one, not a piece of cheap indoor-outdoor carpeting) or other padding and you will notice an immediate improvement. This works because, like the silencer, the pad absorbs the high-frequency sounds.

For those who want more information, and there may be such, the following note will tell you more about linear and logarithmic scales than seems absolutely necessary.

The magnitude of X(f) measured in **decibels** is defined by $A_{X(f)} = 20 \log |X(f)|$. A 6 dB increase corresponds (approximately) to doubling the magnitude, and a 20dB increase corresponds to a tenfold increase. If ψX denotes the angle of X(f), it follows from Y(f) = H(f) X(f) that $A_{Y(f)} = A_{H(f)} + A_{X(f)}$; correspondingly, $\psi_{Y(f)} = \psi_{H(f)} + \psi_{X(f)}$. That is good to know.

By measuring sound amplitudes in decibels, we can account for the amplitude and phase relationship of two signals X and H by merely adding their dB values and phase values. In addition, graphs that show how the magnitudes and phase angles change with frequency are usually plotted on a logarithmic frequency scale. Thus a doubling of frequency (called an octave, from musical terminology) has the same horizontal displacement for all frequencies.

This is not only convenient mathematically, but also fits pretty well with the facts of human hearing. Human hearing is more or less logarithmic, responding to ratios rather than differences. Roughly speaking, 1 dB is about the smallest perceptible change in loudness, no matter what the starting intensity level, and a one-octave frequency change sounds like the same musical interval, no matter what the starting frequency.

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[1] Many of us know this to our regret - if we have a Young Person in the house, or up the street, with a predilection for playing popular 'music' slightly above the threshold of pain. Most modern music is just noise with a copyright. And so is Wagner.

[2] If you are still dissatisfied, we do have a 'silencer' - check the catalog or seek elsewhere on this page - that reduces the racket by at least 8 dBA; this gives an average noise of 52 dBA. It makes all the difference, believe me. This silencer is specially configured to get rid of the higher pitched sounds emitted by the HJ3100 - you know, the ones that make you want to kick something.

[3] That is why commercials feature high-voiced shriekers. The sponsor hopes for your attention.

The purpose of this note is to introduce you to the concept of logarithmic scales, and in particular to the decibel scales commonly used in acoustics to measure loudness.

LOGARITHMIC VERSUS LINEAR SCALES.

Wherein we explain the difference between linear and logarithmic scales, and indicate conceptually why logarithmic scales are used as the measurement method in stimuli/sensation situations such as quantifying loudness.

First, we must clearly understand the idea of a *linear* scale. A simple example is a ruler used to measure distance. Each inch on the ruler is equal to every other inch; that is, the distance between 0 and 1 inch is the same as the distance between 117 and 118 in. This should be obvious to the cat.

Now, contrast this with an example of a *logarithmic* scale **-** say, the frequency separation of the octaves on a piano keyboard.

Like the increments on a ruler, the keys on a piano are equally spaced; thus playing two notes an octave apart requires the same spread of the hand no matter where you are on the keyboard. Now consider the frequency difference between the lowest and highest octaves on a piano. To raise a note an *octave* we must double its frequency. This is a *multiplicative* process, not an *additive* process. What difference does this make? Consider the frequencies of the successive octaves of the lowest note on a piano. On most pianos the lowest note is A; it is four octaves below the A above middle C. Now, if A above middle C has a frequency of 440 Hz., the lowest A should have a frequency of 27.5 Hz (divide 440 by 2 four times). The octaves of the notes A thus have frequencies given by the sequence 27.5, 55, 110, 220, 440, 880, 1760, and 3520 Hz. At the bass end, the frequency difference between the notes of an octave is 55-27.5=27.5 Hz.; per contra, at the highest octave the frequency difference is 3520-1760=1760 Hz. Even though we *perceive* each interval as an octave, unless we have a singularly tin ear, the frequency difference between the notes in the two cases is vastly different because of the multiplicative relation between the notes in an octave. The point of all this is that the difference between a logarithmic and a linear scale rests upon whether the natural steps increase in an additive fashion (linear scale) or in a multiplicative fashion (logarithmic scale).

LOGARITHMIC NATURE OF LOUDNESS.

It happens that our senses respond in a fashion that is more or less logarithmic. (Trust me on this; it happens to be true, and has been studied to death by generations of physiologists and psychologists. Most good composers know it[4], too, intuitively if not scientifically, and make use of it incessantly.)

Sensation is the reaction of our ear/brain to an incoming stimulus, e.g. a sound. It is possible to measure sound stimuli precisely because the size of the stimulus is related to the pressure amplitude of the sound wave. A microphone, for instance, translates these pressure variations into an electrical signal that can be measured to the nearest femtovolt. Per contra, the *sensation* produced by a sound is a *subjective* quantity. Sensation can only be determined by asking a human test subject questions such as 'Which of these sounds is louder?'; watching to see if he jumps out of his chair when the volume is cranked up or a rap record is played is helpful but less accurate. These experiments are in the realm of *psychophysics*[5], the combination of psychological testing methods with physics, and a wonderful subject for the Sunday supplements.

The relation between stimulus and sensation, sometimes called 'Fechner's law', states that 'as stimuli are increased by multiplication, sensation increases by addition.' For example, if a series of sounds are played with quantitatively measured stimuli that increase logarithmically in the ratio 1, 2, 4, 8 et. seq., our ear/brain combination would measure a loudness increase that went up in equal steps. That is, the last sound would be perceived as roughly 5

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[4] The bad ones don't, which may account for the fact that most popular 'music' sounds like a train full of pigs on fire smashing into a huge pile of old aluminium cans.

[5] One of the early natural philosophers who explored the psychophysical relation between sensation and stimulus was Gustav Theodor Fechner. He documented the logarithmic nature of the senses in The Elements of Psychophysics, published in Liepsic in 1860. He is dead, now.

times as loud as the first sound, rather than the 16 times that would be implied from the quantitative measurement. The important point here is that our perception of loudness is logarithmic, not linear.

You may wonder why man would evolve with a logarithmic response to loudness. One reason is related to the fact that our ability to hear spans an enormous range of pressure amplitudes - a very large dynamic range. So-called 'primitive man' needed to be able to hear the scuff of a bare foot upon grass - and distinguish between the footstep of his hunting partner and a hunting beast - and also hear (and hence act upon) the sounds of an avalanche, an approaching mammoth, or a flood. A logarithmic response helps to compress this range so that the response to variations in weak sounds is similar to the response to variations in loud sounds. Other reasons may be advanced, but until the higher animals are studied we must take this, like so many other things we know to be so, on faith, and not be too disappointed when they turn out not to be so after all.