S&V OBSERVER

The Difficulties in Evaluating A-Weighted Sound Level Measurements

John M. Masciale, Data Physics Corporation, San Jose, California

It has been known for a long time that the frequency response of human hearing is anything but linear. In 1933 Fletcher and Munson generated their Equal Loudness Curves. These curves compare sound at different frequencies and levels, and are plotted for different Phon levels. Each Phon level is defined by the decibel level at 1000 Hz. Hence the 40 Phon curve is a plot of the amplitude of single tones at different frequencies that sound as loud as a tone at 1000 Hz and 40 dB.

To improve on acoustic measurements, weighting curves were created to compensate for sound at different levels. The A-weighting curve was created to compensate for sound along the 40 Phon contour, the B weighting curve was created to compensate for sound along the 70 Phon contour, and the C weighting curve was created to compensate for sound along the 100 Phon contour.

To properly take a measurement using these weighting curves, the user was supposed to look at the overall sound pressure level, and then select the appropriate weighting curve. This is not a bad approach for highly tonal noise, or flat random noise, but there can be a lot of pitfalls trying to measure sound with different amplitudes at different frequencies (which is the case for most noise measurements).

When trying to standardize acoustic noise measurements, people found that this approach led to a lot of confusion. As a result, most noise measurement standards settled on the A-weighting curve to use in taking a measurement. There might be good accuracy in measuring things that are operating in a quiet room. But for any sound pressure measurements at or above the sound pressure level of a typical conversation, this can lead to measurements that have little to do with perceived noise levels.

A Weighting Versus Equal Loudness. Figure 1 shows the inverted A weighting contour plotted on top of the equal loudness curves at 40 Phons, 70 Phons, and 100 Phons. It is plain to see that at 40 Phons there is fair correlation, but the higher you go in loudness level the poorer the correlation, especially at lower frequencies.

In an effort to better correlate human hearing with measured sound pressure levels, various techniques of measuring loudness have been developed. ISO standard 532 Acoustics – Method for Calculating Loudness Level outlines two different methods for calculating the human perceived loudness of complex sound that has been measured in octave or 1/3 octave bands. Method A calculates loudness using the Stevens method. Method B (which is the more commonly used method) performs the calculations based on the work of Zwicker, and is referred to as Zwicker loudness.

The calculation of loudness is based on measurements in critical bands (denoted in Bark). Figure 2 is a graph of critical band number versus log frequency. The resulting amplitudes for each critical band are usually denoted in Sones/Bark. The area under the specific loudness curve results in a total loudness number in Sones. The convenience of measuring in Sones is that, unlike dB, they correlate to human hearing. Therefore, if measurement A is 20 Sones and measurement B is 40 Sones, measurement B will sound twice as loud as measurement A.

Example Measurement and Comparison. The best way to illustrate some of the difficulties in comparing A-weighted measurements is to compare measurements of similar sound pressure levels. I recently purchased a new snow blower. In comparing the sound of the old one with the new, I found that the older machine seemed to be significantly louder than the new. The sound of the old machine seemed to go right through me. Yet when I measured the A-weighted sound pressure level of the two machines there was only a 1 dB difference.

Figure 3 shows the 1/3 octave spectra of the sound pressure levels of the two snow blowers. Snow blower 1 resulted in a sound pressure level of 85 dBA. Snow blower 2 resulted in a sound pressure level of 84 dBA. A 1 dB difference in measurement is typically not considered perceivable in terms of overall loudness, yet my ears were telling me otherwise. Looking at the frequency content you can see that snow blower 1 has considerably more low frequency energy than snow blower 2. Figure 4 shows the same measurements with A-weighted 1/3 octave bands. Because of the propensity of the A-weighting curve to attenuate low frequency noise, the dBA calculation is dominated by the higher amplitude information at the higher frequencies.

I then decided to take a look at the specific loudness of the two machines (Figure 5). It is plain to see that the most substantial difference between the two machines is in both the lower and higher frequency range. The total loudness of 71 Sones versus 63 Sones indicates that the first snow blower is perceptibly louder than the second snow blower. The reason that the loudness measurement correlated better with what I was hearing is that the A-weighting curve over corrected the low frequency weighting, resulting in artificially low numbers. Even the linear sound level measurements (a 2 dB difference) did not really reflect what I was hearing.

Further analysis showed that in looking at loudness below 2 Bark the first snow blower had a loudness of 6.8 Sones, while the second snow blower had a loudness of 2.8 Sones. The first snow blower was nearly two and one half times as loud in the lower frequency range. Looking above 17 bark I found that the first Snow Blower had a loudness of 16.5 Sones, whereas the second snow blower had a loudness of 13.8 Sones. From these numbers, I can see that the low frequency noise content was the most markedly different and significant, which agrees with what I was hearing.

Conclusion. There is a place for the use of A-weighted measurements. A-weighting is a convenient standardized procedure that may be used for comparing simple measurements. It is unrealistic, however, in most circumstances to expect A-weighted measurements to correlate well with a subjective evaluation of loudness. Loudness is one of several psychoacoustic parameters that can be used to quantize the subjective evaluation of noise, and is readily available as a measurement in current acoustical instrumentation.

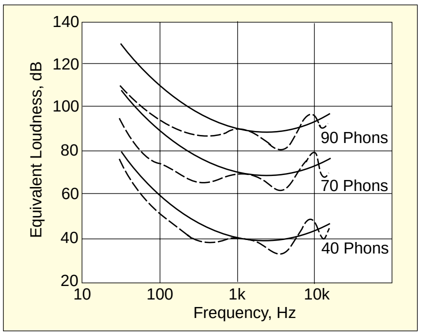

Figure 1. Comparison of three equal loudness contours with the A-weighted frequency response network.

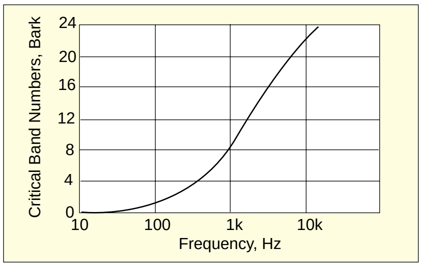

Figure 2. Critical band number vs. frequency.

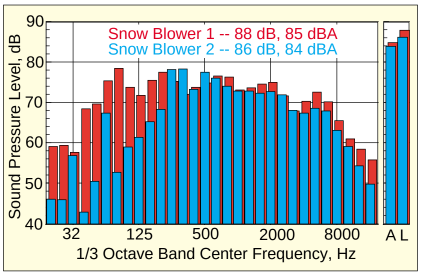

Figure 3. Sound pressure levels of two snow blowers.

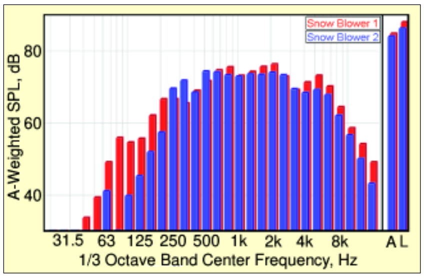

Figure 4. A-weighted sound pressure levels of two snow blowers.

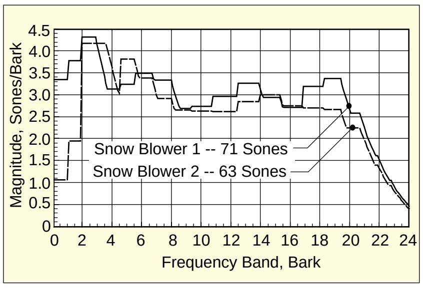

Figure 5. Specific loudness of two snow blowers.