NUMBER 5
Applying Acoustics—Part 2

Acoustical Engineering Report

McGill AirSilence LLC
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Quantitative Analysis A-Weighting and Decibel Addition/ Subtraction

Introduction

Acoustical Engineering Report Number 4, *Controlling Industrial Noise Pollution*, introduced the concept of A-weighting sound levels (dBA) for the purpose of solving industrial noise problems. The single-number reading obtained using a standard sound level meter makes it easy to compare noise from various sources with OSHA standards. Since A-weighted sound levels are based on human perception of relative loudness and not the subjective quality of sound, it is not always desirable to establish design criteria in dBA. However, in the industrial environment where sound primarily differs in loudness, not frequency (spectral) content, dBA readings do offer a quick and easy means of quantifying sound that could cause potential hearing damage. Proper noise reduction techniques can then be applied quickly, at the source, path, or receiver.

A-Weighting

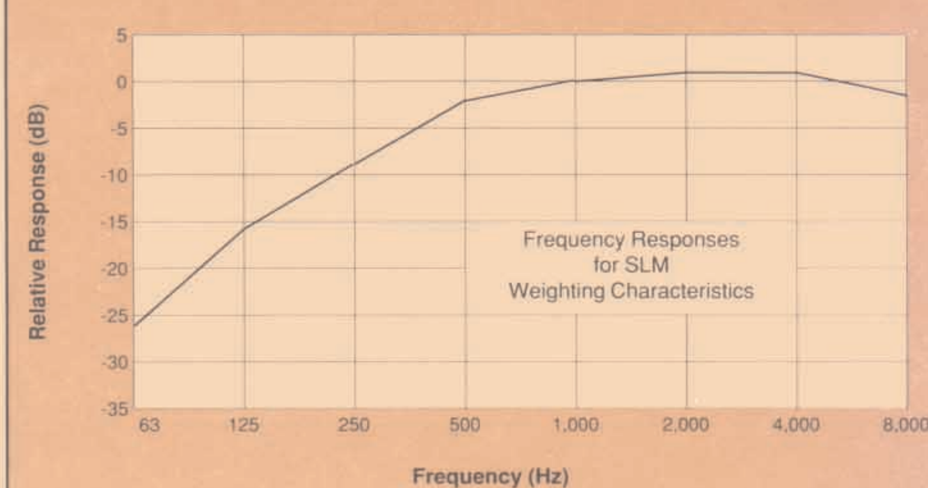
Figure 1 represents the A-weighted network designed into a sound level meter. **Table 1** provides the data for each octave band center frequency.

Table 2 illustrates the internal A-weighting adjustments made to each octave band center frequency by the

Table 1 A-Weighting

Octave Band/Center Frequency (Hz)	A-Weighted Filter Response (dB)
1/63	-26
2/125	-16
3/250	-9
4/500	-3
5/1,000	0
6/2,000	+1
7/4,000	+1
8/8,000	-1

Figure 1 A-Weighted Network



sound level meter to obtain the single-number dBA rating.

To obtain the single-number dBA rating, the sound level meter electronically adds the logarithms of the individual octave band sound pressure levels (Lp) as shown in **Equation 1.**

Equation 1

$$Lp_{1+2+\ldots+n} = 10 \log [(10)^{\frac{Lp_1}{10}} + (10)^{\frac{Lp_2}{10}} + \ldots + (10)^{\frac{Lp_n}{10}}]$$

where: Lp = sound pressure level

Decibel Addition

The graph in **Figure 2** was developed to simplify dB addition in manual calculations. Logarithmic dB addition results in smaller workable numbers. A doubling in loudness (3 dB increase) is obtained when adding dB values of equal magnitude (e.g., 100 dBA + 100 dBA = 103 dBA, not 200 dBA). Although sound levels of equal magnitude double in loudness when combined, the difference is barely perceptible to the human ear. The subjective effects that changes in sound pressure level have on the human ear are shown in **Table 3.**

Two options are available for obtaining single-number sound level ratings using linear dB addition. Option 1 combines the two lowest dB values first and adds the corrected dB value (shown in **Table 4**) to the next lowest dB value and so on until the single-number rating has been calculated. **Figure 3** illustrates this process as performed on the Lp adjusted values shown in **Table 2**. This single-number rating is accurate to ± 1 dB.

Option 2 consecutively pairs off the individual octave band center frequency values to obtain four corrected values, which are then paired and corrected to two values. Finally, these values are paired and corrected to the single-number rating. **Figure 4** illustrates this process using the Lp adjusted values shown in **Table 2.** This single-number rating is accurate to ± 2 dB.

The procedure in option 2 is generally used for manual dB addition because accuracy is maintained with simplicity and quickness. Either dB addition technique can be used for adding sound power or sound pressure levels.

Table 2 Sound Source A-Weighting Adjustments (dBA)

	Octave Band (Hz)							
	1	2	3	4	5	6	7	8
Actual Lp	110	107	103	101	99	89	78	65
A-Weighted	-26	-16	-9	-3	0	+1	+1	-1
Lp Adjusted (dBA)	84	91	94	98	99	90	79	64

Figure 2 dB Addition Correction for Combined Levels

Table 3 Apparent Change in Loudness

Change in Lp	Apparent Change in Loudness
3 dB	Just Noticeable
5 dB	Clearly Noticeable
10 dB	Twice (or half) as loud

Table 4 Adding Decibels

Decibel Difference	Decibel Correction (add to higher value)
0 to 1 dB	3 dB
2 to 4 dB	2 dB
5 to 9 dB	1 dB
10 dB plus	0 dB

Figure 3 Option 1—Linear dB Addition

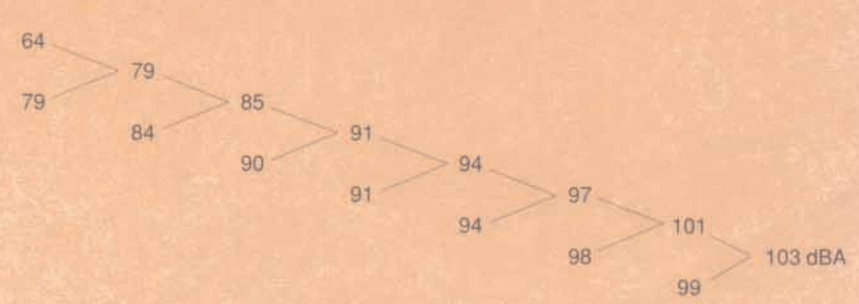
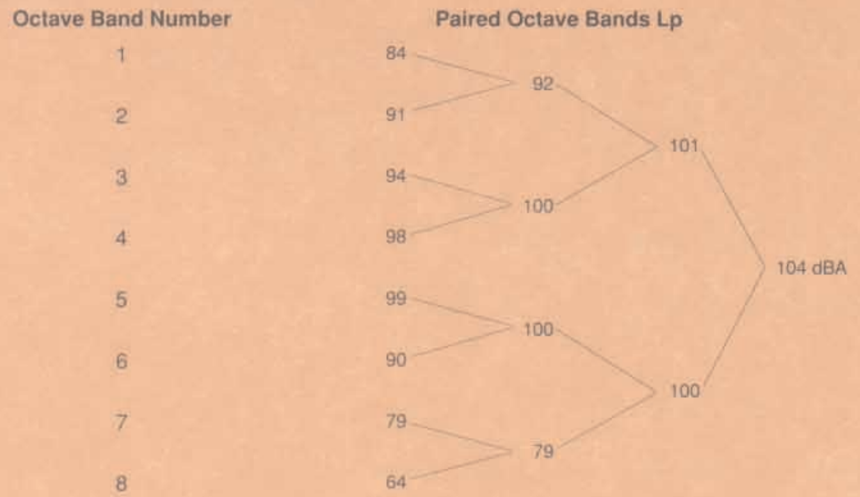


Figure 4 Option 2—Linear dB Addition



The previous illustrations show how dB addition is used to combine individual frequencies of a given sound source in order to generate a single-number dBA rating. Decibel addition can also be applied when determining the qualitative change between two noise sources having different spectral signatures, as is common in commercial air handling systems.

Qualitative sound evaluations are generally not addressed as single-number dBA ratings due to the variance in the spectral characteristics of the individual sound sources, but rather correlated against single-number noise criteria (NC) or room criteria (RC) ratings. Acoustical Engineering Report Number 6, *Qualitative Analysis: Establishing Acoustical Design Goals* will address qualitative sound evaluation.

Table 5 illustrates how dB addition is used to determine the combined spectral characteristics of two totally different sound sources. Notice that the fan has high lower frequency noise whereas the diffuser has high higher frequency noise when compared at the diffuser outlet. Combined, these two noise sources appear to balance across the entire spectrum. Effects of spectral noise balancing will be addressed in Acoustical Engineering Report Number 6.

Background Noise (Subtracting Sound Levels)

When using a sound level meter in noisy environments, background noise can often influence the accuracy of the measurements. The procedure for measuring the noise level of equipment subjected to background noise is as follows:

1. Measure the total noise level with the equipment running.
2. Measure background noise with the equipment off.
3. Determine the dB difference per octave band between readings in Step 1 and 2. If the difference is 3 dB or less, then the background noise level is too high for accurate measurement.
4. If difference is 3 to 10 dB, find the background noise correction using the chart shown in **Figure 5**.
5. Subtract the background noise correction value in Step 4 from the total noise level in Step 1 to determine the noise level of the equipment.

Figure 5

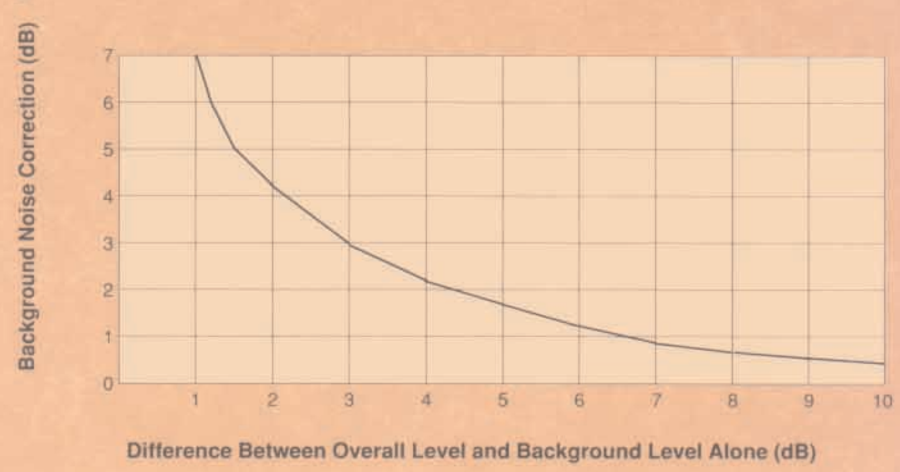


Table 5 Determining Combined Sound Levels of Sound Sources Having Different Spectral Characteristics

	1	2	3	4	5	6	7	8
Fan Noise @ Diffuser	52	53	51	44	38	31	25	17
Diffuser Noise	22	27	32	36	38	40	38	36
dB Difference	30	26	19	8	0	9	13	19
dB Correction (Table 4)	0	0	0	1	3	1	0	0
Combined dB @ Diffuser	52	53	51	45	41	41	38	36

Example 1: Determine the actual dBA rating of a piece of equipment located in a moderately noisy environment using a sound level meter and the procedure for eliminating background noise described above.

1. Measured total noise level = 85 dBA
2. Measured background noise level = 78 dBA
3. dBA difference:
   85 dBA - 78 dBA = 7 dBA
4. Background Noise Correction = 1 dBA (from **Figure 5**)
5. Equipment Noise:
   85 dBA - 1 dBA = 84 dBA

Summary

A-weighting of sound levels provides a quick and accurate means of quantifying sound based on the human response to the relative loudness of noise sources having relatively identical spectral content (typical of industrial environment). Decibel addition and subtraction techniques can either be used in quantitative or qualitative noise evaluations to combine individual sound levels.

A quantitative evaluation involves combining the individual sound level components of a single source by dB addition and subtraction into a single-number value, such as dBA, for correlation against a single-number value specification (e.g., OSHA). A qualitative analysis evaluates sound level spectral components. The dB addition and subtraction between two or more sound level sources is analyzed by octave band, then correlated against a spectral NC or RC curve specification. Qualitative sound evaluation will be addressed further in Acoustical Engineering Report Number 6.

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