E•A•RCAL[SM] Laboratory

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Re: Comparing hearing protector ratings – NRR, SNR, SLC_{80}, and others

The noise reduction capabilities of hearing protection devices (HPDs) are most easily specified by the use of single number ratings. Common ones in use today are the Noise Reduction Rating (NRR, as mandated by the U. S. Environmental Protection Agency, 1979), the Single Number Rating (SNR, specified in an International Standard, ISO 4869-2), and the Sound Level Conversion (SLC_{80},specified in an Australian/New Zealand standard, AS/NZS 1270).

For each rating, the value is based on a computation utilizing real-ear attenuation at threshold results for the HPD measured over a range of seven or more test frequencies, from 125 Hz, or sometimes lower, up to 8000 Hz. However, each of the three ratings call for attenuation results measured using a different real-ear attenuation standard. Thus, there are two causes of differences that may be found when comparing the values for a given HPD using the three rating systems.

1) Differences in the computations between the three rating methods,
2) Differences in the attenuation data that are the input to the computational procedures.

Differences in the computations

In devising simplified number ratings various techniques have been proposed over the years. In all cases the "gold standard" against which the accuracy of the ratings are adjudged is an octave-band computational approach that utilizes the actual noise reduction data from the laboratory test. These data are in the form of mean or average attenuation values across a group of test subjects, and the associated variability factors or standard deviations. One of the single-number approaches that most closely approaches values predicted using the gold standard, is to compute a number that is subtracted from the C-weighted sound level to predict the A-weighted exposure. Thus, instead of the seemingly straightforward procedure of measuring unprotected A-weighted exposures to predict protected A-weighted exposures as presented below in Equation (1), the labeled value should be correctly used with C-weighted measurements as in Equation (2). Note the prime (or apostrophe) after the dBA indicates that the results are predicted values when the hearing protector is worn. In our example below the SNR is used, but the math applies equally to the NRR and the SLC_{80} .

Wearer's estimated exposure (dBA') = workplace noise level (dBA) – SNR (1)
Wearer's estimated exposure (dBA') = workplace noise level (dBC) – SNR (2)

All three approaches, NRR, SNR, and SLC_{80}, should be applied as shown in Equation (2), i.e. the value is subtracted from a dBC measurement. In that regard the mathematics for the three approaches is similar, however, there are certain details that give rise to important differences. Key aspects are listed in Table I.

The most substantive computational issue is the number of standard deviations (SDs) that are subtracted from the mean attenuation values in the computation of the rating. The U.S. uses 2 SD, whereas AS/NZS and Europe use only 1 SD. The ISO standard that specifies how to compute the SNR allows the user to choose the number of SDs they will utilize. The use of the 2-SD correction in the NRR is theoretically intended to predict the protection that is achieved by 98% of wearers. This can only be true if the test data are representative of actual use. They aren't, and thus the 98% protection factor is a misleading in the degree of safety that it implies.

With the 1-SD corrections the intent is to predict what about 84% of the users achieve, and since the AS/NZS test data are more representative of field performance (see next section), the degree to which the 84% number is achieved is much closer than the degree to which the 98% value is achieved with the U.S.-based NRR. The subscript "80" on the SLC_{80} explicitly indicates that it intends to predict the protection achieved by 80% of users.

The more SDs that are subtracted in the computation, the lower the rating will be. This is offset in computation of the NRR since the SDs are so small that about two of the ANSI SDs is often equivalent to one SD using either the ISO or AS/NZS measurement procedures. The other computational differences listed in Table I are of minor consequence with the exception of a constant 3-dB "spectral safety factor" that is subtracted when computing the NRR.

TABLE I – Key issues differentiating the prominent single-number rating methods in use today

	NRR	SNR	SLC_{80}
Specified attenuation test standard	ANSI S3.19	ISO 4869	AS/NZS 1270
Type of attenuation data	experimenter fit	exp. supervised fit	subject fit
Standard deviation (SD) correction	-2 SD	-1 SD*	-1 SD
Spectral safety factor	- 3 dB	0	0
Presumed noise exposure spectrum	pink	pink	shaped**
Frequency range included in computation	125 Hz – 8 kHz	63 Hz – 8 kHz***	125 Hz – 8 kHz
Comparison using different types of data for each rating			
High-attenuation foam plug	29	28	24
Medium-attenuation muff	25	31	30
Comparison using AS/NZS data for each rating			
High-attenuation foam plug	14	25	24
Medium-attenuation muff	22	29	30

* The standard allows the user to select the appropriate value; however, -1 SD is typically utilized.

** The shaped noise is similar, but not identical to the flat spectrum of the pink noise.

*** Few 63-Hz data are available. Adding this band yields no useful gain in the accuracy of the computations, but does affect the SNR by about 0.5 dB compared to leaving those data out of the computation altogether.

Differences in the attenuation data that are use in computation of the ratings

Of even greater importance than the actual computational procedure is the data upon which the computations are based. The three ratings each utilize data from a different attenuation test standard as listed in Table I. With respect to the real world, the ANSI standard provides the most unrealistic data, whereas the AS/NZS standard provides the most useful estimates. The ISO values fall somewhere in between. The effects in all cases are more substantial for earplugs than for earmuffs. For additional information on laboratory test procedures and the real-world attenuation of hearing protectors see EARLogs #20 and #21 referenced as the end of this article.

Sample comparison of the ratings

The second section of Table I provides a comparison of the three ratings for a representative foam earplug and a representative medium attenuation earmuff. In making the computations, the appropriate type of test data (ANSI S3.19 for the NRR, ISO 4869 for the SNR, and AS/NZS 1270 for the SLC) were utilized. The fact that the NRR is based on optimum-fit S3.19 data is offset by its negative 3-dB correction and the inclusion of a subtractive 2-SD correction instead of one SD. For the earmuff, where the type of test procedure has less effect on the outcome, the NRR (with the data derived from the optimized S3.19 fitting procedure) is in fact lower, by 5 to 6 dB, than the SNR or SLC_{80}.

The last section of Table I compares the three ratings using just one type of data, in this case from the AS/NZS standard. Now the effects of the computational methods themselves become clear. The NRR is substantially smaller, by 10 to 11 dB, for the plug because of the 2-SD and negative 3-dB corrections. For the muff the effect is not as large, amounting to only 7 to 8 dB, since the SDs are typically smaller for muffs than for plugs.

Additional ratings in common use

Two other ratings are in use today, one being more complex and potentially more accurate and the other being even simpler to use than a single number. The more complex procedure is the HML method, which stands for High-Medium-Low (also specified in the same ISO standard 4869-2 as the SNR), and the other is a Class scheme (specified in the same AS/NZS standard 1270 as the SLC_{80}).

The HML is a 3-number method that provides attenuation ratings for sounds with dominant energy in the high-, middle-, or low-frequency range. Because of its additional complexity and amount of data that are involved, the HML procedure is potentially more accurate for predictive purposes and a closer approximation to the “gold standard” octave-band approach. However, the underlying data (both the hearing protector attenuation values and the employee noise exposure measurements) are sufficiently imprecise as to partially undermine the potential improvements in predictions that it affords.

Class systems, such as the one specified in the AS/NZS standard, assign a class to a device based upon its laboratory-measured attenuation values. The advantage of classes is that they simplify hearing protector selection, potentially de-emphasize the importance of attenuation, and eliminate the possibility that the user will be tempted to make unwarranted “precision” 1-dB estimates of protection. However specifiers are tempted to always use the “best” class. Another shortcoming is that differences of 0.1 dB in the attenuation in a single octave band can cause a hearing protector to be moved from one class to another. According to AS/NZS 1270 classes are assigned based upon the device SLC_{80} as shown in Table II and then hearing protectors are specified based upon the noise level measurements, also as shown in Table II.

The Class scheme, in spite of its seeming imprecision, may provide sufficient accuracy for certain applications and allow hearing conservationists to focus on other more important aspects, such as motivation, training, and supervision of employees to wear their HPDs correctly and consistently for proper hearing protection.

TABLE II – Determination of the AS/NZS Class and specification of allowable noise levels*

SLC_{80}	Class	May be used up to this noise level (dBA)
10 to 13	1	90
14 to 17	2	95
18 to 21	3	100
22 to 25	4	105
26 or greater	5	110

* Specification of allowable noise levels includes a built-in safety factor since noise risk is based upon both the level and duration of exposure (i.e. noise dose), and the standard specifies noise in terms of level only. For example, a Class-3 HPD can be used up to a sound level of 100 dBA, but if that noise level is present for only 1 hr./day that amounts to (based on 3-dB exchange rate) an equivalent daily exposure of only 91 dBA.

Summary

All of the ratings described herein include features in their computation or required data that vary from one procedure to another, thus none are directly comparable to each other. The specifier should be sure to select the HPD data that are appropriate to the regulation in the market in question. However, regardless of the rating selected, users should be aware that even the most accurate of the ratings are only a statistical estimate of the protection that any given individual will obtain. Without individual fit-test data on users it is simply not possible to reliably make individual predictions; at best these data provide general indications for groups of users.

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