The Noise Reduction Rating — Fact and Fiction

NRR's Checkered Career

The Noise Reduction Rating, popularly known as the NRR, had a lot to recommend it when it first appeared on the scene in the 1970s. Prior to that time the attenuation of hearing protectors had to be assessed using a lot of complicated calculations. The NRR, however, offered a simple, single-number method that manufacturers were required to print on the hearing protector's package. Even those who were totally unfamiliar with acoustics could get an idea of how much attenuation (noise reduction) a protector afforded and compare that with the amount of attenuation that was needed in the user's workplace.

But problems with the NRR have developed over the years. First, consumers have taken the NRRs too literally, expecting them to provide exactly that amount of attenuation in the workplace, which they do not. Then, in an effort to compensate for the NRR's lack of realism, the purchasers often adopt a "bigger is better" mentality, selecting a protector with an unnecessarily large NRR when only a few decibels of attenuation may be necessary. The trick is to understand what the NRR does and doesn't do so that it may be used in a realistic and practical manner.

How the NRR Came to Be

The NRR is based on a laboratory method to evaluate the attenuation of hearing protection devices developed by the National Institute for Occupational Safety and Health (NIOSH) and published in 1975. Around that time the U.S. Environmental Protection Agency (EPA) had been charged with setting labeling standards for products that emitted high levels of noise and for products that were designed to protect people from noise. The EPA chose the latter type of product for its first (and, it happens, its only) noise labeling regulation.

Accordingly, EPA notified hearing protector manufacturers that they must test their products in a suitable laboratory, arrive at a Noise Reduction Rating, and print that rating on a prescribed label on the hearing protector package. Figure 2 shows the label for the 3M 1260 reusable ear plug, with its NRR, along with the other wording required by the EPA. Note that the NRR is 25 dB "when used as directed," indicating that the user may not receive this much attenuation if the plug is not inserted and worn correctly.

Laboratory Procedures for Arriving at the NRR

The standardized procedure required by the EPA is detailed in its regulation (40 Code of Federal Regulations, Part 211, Subpart B). It uses a well established method for testing hearing protector attenuation called "real-ear attenuation at threshold" or REAT. The laboratory procedures are outlined in an ANSI standard, the latest version of which is ANSI S12.6-1984. Noise signals at a variety of sound frequencies are presented to trained listeners in the laboratory, and hearing threshold levels with and without hearing protectors are obtained. The difference between the two conditions reflects the hearing protector's attenuation. The examiner combines the attenuation results obtained over a series of tests for each frequency for a group of at least 10 listeners, and calculates mean attenuation values and standard deviations.

At this stage the evaluator may use the "long method" (NIOSH method #1) to estimate the protector's attenuation in a particular noise environment. Some individuals prefer to use the long method rather than the NRR because it yields the most accurate information for a particular noise spectrum. It is especially useful for noises with unusual spectra, such as noises with strong low-frequency components. One must remember, however, that the way the protector is fitted, inserted, and worn usually has a much greater effect on the actual sound level arriving at the ear drum than the method one has used to calculated its attenuation.

To use the long method, the evaluator first measures the noise levels at certain octave-band center frequencies in the wearer's environment using a sound level meter with an octave-band analyzer. The range of frequencies measured extends from 125 Hz to 8000 Hz. Standard adjustments for A-weighting are then applied to these measurements and the hearing protector's mean attenuation values and two standard deviations are subtracted at each frequency. The two standard deviations are subtracted to account for variations in anatomical shapes and sizes as well as individual response in the laboratory. They are not intended to reflect the differences in wearing practices encountered in actual use. Finally, the resulting levels are added logarithmically to obtain the estimated A-weighted sound level beneath the ear protector in the user's environment.

The NRR simplifies this procedure considerably. First, a noise with a standard spectrum ("pink" noise) is substituted for the real thing, and a small adjustment is made in the calculation for "spectral uncertainty."

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Because these stages are performed in the laboratory, the consumer does not need to make so many measurements or calculations in the field. As in the long method, the NRR incorporates the two-standard-deviation subtraction, and the values for each frequency have been summed logarithmically to produce a single number.

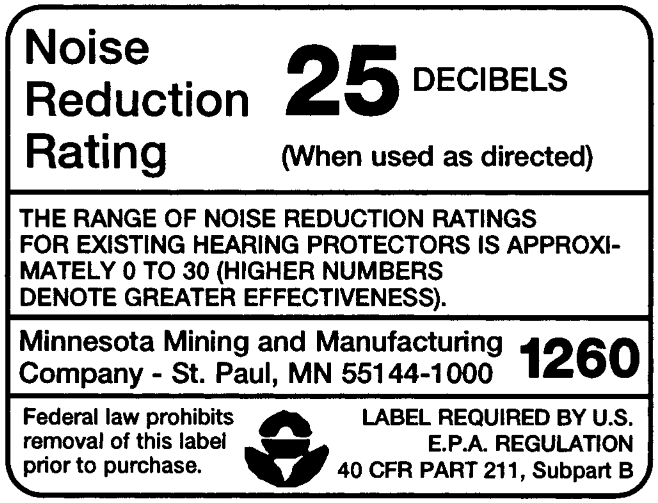

Figure 2.
The EPA requires hearing protector package labels to list a Noise Reduction Rating.

Using the NRR on the Job

Use of the NRR does not avoid the need to evaluate a worker's noise exposure in his or her particular environment, but octave-band measurements are no longer necessary. The employer or purchaser must subtract the NRR from the C-weighted noise exposure level in the worker's environment to obtain the estimate A-weighted sound level under the protector. There is a good reason this seeming inconsistency. The sound level meter's A-weighting network acts as a filter, causing most mid- and high-frequency sounds to pass through and be measured at their actual levels. Low-frequency sounds, however, are increasingly attenuated as the frequency spectrum becomes lower. One way of saying it is that the A-weighting network "discriminates" against low-frequency sound.

The C-weighting network, on the other hand, allows most low-frequency sounds to be measured at their actual levels. The difference between A-weighted and C-weighted measurements provides a good estimation of the relative contribution of low frequencies in a particular noise.

Most hearing protectors attenuate the high frequencies significantly more than the low frequencies. Because of this fact, and also because most industrial noise tends to have either a low-frequency emphasis or a relatively flat configuration, both the EPA and OSHA recommend that the NRR be subtracted from the C-weighted noise level in the user's environment. This is especially true when the noise appears to be predominantly low-frequency or if the A-weighted exposure levels are relatively high (above about 95 dB).

In some cases the employer may not have access to C-weighted measurements. While most sound level meters provide the option to take C-weighted measurements, many noise dosimeters do not. In cases where only A-weighted measurements are available, the OSHA standard requires that employers subtract 7 dB from the NRR before subtracting it from the worker's environmental noise level. Take the example of the employer who wishes to use the 3M 1110 Corded Foam Ear Plug, which has an NRR of 29 dB, and the individual who will use the plugs, and who has an A-weighted noise exposure level of 97 dB. The estimated level under the plug would be 75 dB(A). (29-7=22, 97-22=75.) The reader must remember that the 7-dB adjustment is necessary because of the lack of information about the noise spectrum and not because of the difference between laboratory and real-life use of the protector.

Many employers, who have designated "noise hazard" areas, will choose to measure noise levels with sound level meters and estimate the A-weighted protected level on the basis of C-weighted levels in these areas. In situations where workers move around quite a bit, where the noise levels fluctuate, or where there is a significant component of impulsive noise in the environment, employers will have to conduct personal noise monitoring. In these cases, a dosimeter is the measuring instrument of choice and the result will be displayed in terms of time-weighted average exposure level (TWA) or noise dose in percent, which can be converted easily to TWA. Although dosimeters did not formerly have this capacity, some modern dosimeters can display the noise dose or TWA both in dB(C) and in dB(A), a very convenient feature. The employer then subtracts the NRR from the C-weighted TWA. If the dosimeter does not have C-weighting, the NRR is reduced by 7 dB and the remainder is subtracted from the A-weighted TWA.

Practicalities

As mentioned above, hearing protectors seldom give the same results in actual use that they do in the laboratory, so the result is that the NRR gives a highly optimistic picture of the actual attenuation.

Hearing conservation professionals have used special equipment in the field to mimic the procedures for evaluating hearing protector attenuation in the laboratory. A series of studies using a variety of hearing protectors has shown that the average attenuation that people receive in the workplace is only about one-third to one-half the attenuation that laboratory subjects receive. In addition, the variability among wearers, as shown by the standard deviation, is two to three times greater than in the laboratory. It appears that the differences between field and laboratory results are greater for plugs than for muffs, although the foam plugs appear to perform somewhat better than most of the other plug varieties.

One of the consequences of this disparity between the NRR and actual field attenuation is reflected in a 1983 enforcement memo issued by the federal* OSHA's Office of Health Compliance Assistance. The memo instructs federal OSHA inspectors not to issue citations to a company for failing to use feasible engineering controls when workers have TWAs of 90 dB(A) to 100 dB(A) unless the company fails to have "an effective hearing conservation program." Unfortunately, OSHA has never explained exactly what it means by an effective hearing conservation program. OSHA does, however, instruct its inspectors to derate the hearing protector's NRR by 50 percent, or divide the NRR in half, when using these enforcement guidelines.

For example, an employee in a factory might have an A-weighted TWA of 102 dB and a C-weighted TWA of 104 dB. Wearing the 3M foam plug with an NRR of 29 dB would yield an estimated A-weighted level under the plug of 75 dB(A). This would appear to be more than ample protection. If the 1983 enforcement guideline were employed, the plug would be derated by 50 percent to an NRR of 14.5 dB, and the estimated A-weighted level under the plug would be 89.5 dB(A). According to the OSHA memo, the company would be in compliance and engineering controls would not be required.

If, however, the factory worker had experienced a standard threshold shift in hearing (STS) sometime during his tenure with the company, the company would not be in compliance because OSHA requires that employees who have incurred an STS must have hearing protectors that attenuate to 85 dB(A) or below.

The situation becomes still more complicated if the employer does not have access to instruments that measure with the C-weighting network. If the operator of the factory mentioned above had to use the employee's A-weighted sound level, 7 dB would need to be subtracted from the NRR before it was derated and the resulting estimated level under the protector would be a too-high 91 dB(A). (29-7=22/2=11, 102-11=91.) This company would probably be required to use a protector with more attenuation (or a muff and a plug), or institute engineering controls.

What Next?

The reader must bear in mind that the OSHA enforcement policy is just a guideline and not a regulation. But that would not solve the problem of the NRR. The fact is that the NRR does a relatively poor job of predicting attenuation in actual field use, although it does give the purchaser a little information about the relative attenuation of one device versus another.

Recently a new ANSI working group, S12/WG11, has undertaken the task of developing a new method for evaluating the attenuation of hearing protectors. This group is attempting to find a laboratory method that will correlate reasonably well with the results found in the field studies. The chances are that any new NRRs resulting from their procedures would be considerably lower than the present ones. In the meantime, purchasers of hearing protectors will need to follow the requirements of OSHA's noise standard. For most, this will mean continuing to use the NRR in the prescribed way. They should, however, view the NRR with a certain amount of healthy skepticism.

For Further Reading

American National Standard Method for the Measurement of the Real-Ear Attenuation of Hearing Protectors, ANSI S12.6-1984.

Berger, E.H. Hearing Protection Devices. In E.H. Berger, J.C. Morrill, L.H. Royster, and W.D. Ward (Eds.), Noise and Hearing Conservation Manual (4th ed.) American Industrial Hygiene Assoc. Akron, OH, 1986. (Now located in Fairfax, VA).

Gasaway, D.C. Chapter 8 in Hearing Conservation: A Practical Manual and Guide. Prentice-Hall, Inc.: Englewood Cliffs, NJ, 1985.

U.S. Dept. Labor (1981). Occupational Safety and Health Administration. Occupational Noise Exposure; Hearing Conservation Amendment. Fed. Reg. 46, pp. 4078-4179 (especially pp. 4151-4155).

U.S. Code of Federal Regulations, 29 CFR 1910.95. (OSHA noise regulation). U.S. Code of Federal Regulations, 40 CFR Part 211 Subpart B. (EPA regulation for the NRR).

* While many state OSHA programs have followed suit, the reader should be aware that some states do not use this compliance policy.