HEARING PROTECTORS – CALCULATIONS OF THE NOISE LEVEL AT THE PROTECTED EAR

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ABSTRACT

The risk of noise induced hearing loss, when wearing a hearing protector, can only be calculated with the knowledge of the noise level at the protected ear. Several methods are available for calculating this level, from the hearing protectors' attenuation data. However, most available data are obtained from procedures not usually found in real world situations. Therefore, the results from the calculations are corrupt. This paper reviews some existing methods for the attenuation measurements and noise level calculations. Some ways to overcome the use of non-realistic attenuation data are suggested in the paper.

RÉSUMÉ

Le risque de perdre l'ouïe à cause de bruits excessifs, lorsque qu'un protecteur auditif est utilisé, ne peut être que calculé en connaissant le niveau de bruit à l'oreille protégée. Plusieurs méthodes sont disponibles pour effectuer ce calcul en utilisant les données de l'atténuation du bruit du protecteur auditif. Toutefois, les données disponibles sont obtenues grâce à des méthodes fort éloignées des situations que l'on retrouve dans la réalité de l'environnement de travail. C'est pour cette raison que les résultats sont erronés. Cet article revoit les méthodes existantes pour les calculs des mesures d'atténuation et du niveau du bruit. Il suggère aussi différentes façons pour éviter l'utilisation de données inexactes d'atténuation du bruit.

1. INTRODUCTION

In October 2003, as a part of a Noise Control Seminar organized by the Occupational Hygiene Association of Ontario (OHAO), this author made a presentation on the subject of hearing protectors. Members of the audience suggested that a tutorial on the use of the protectors' attenuation values would be useful for professionals and users alike. This paper is the result of this suggestion.

Hearing protectors are the most frequently used devices for reducing the hazard of hearing loss in the industry as well as in construction. The reasons for this choice are: their relatively low cost; the ease and speed of introducing the protectors in the workplace (even though in many occasions this is not done properly); and the urgent need of showing that something has been done to protect workers from excessive noise.

Hearing protectors are intended to reduce the noise level reaching the inner ear. Therefore there is strong need to know the level of noise reduction provided by the hearing protector, i.e., their attenuation, so that the noise level at the protected ear can be calculated. Noise level at the ear, resulting from donning a protector is the level that is effective when the HPD is worn, i.e. the diffuse field level that would have created that level in the ear canal, minus the attenuation of the device

The objectives of this paper are: to review the different ways of calculating this level; to highlight the pitfalls associated with these calculations; and to suggest ways to overcome the use of non-realistic attenuation data.

2. BACKGROUND

attenuation of hearing protectors is the measurement of the shift of the threshold of hearing of a subject, resulting from donning a protector. The method is known as REAT: Real-Ear Attenuation at Threshold. For this procedure, a person (the subject) "lends" his head to have the protector donned and uses his hearing to detect the minimum sound level that he can perceive (his hearing threshold). Two thresholds are measured: one with and one without the protector in place. The difference between the two thresholds is, by definition, the attenuation of the protector. The signals that the subject is to hear are third-octave band filtered white noise, centered at the audiometric frequencies between 125 and 8000 Hz. The reason for testing at different frequencies is because the attenuation of protectors is frequency-dependant.

When the protector is worn sound reaches the inner ear following three paths:

a) Through the body of the protector,
b) Through cracks between the protector and the skull (in the case of a muff), or between the protector and the ear canal (in the case of a plug), and

c) Through the skull bone (bone conduction).

For all practical purposes, only the first two paths are of importance (unless a protector is very well fitted or unless a combination of an earmuff and earplug is worn), and can reduce considerably the attenuation offered by a protector. The attenuation through the bone is approximately 45 dB, much higher than that of commercial protectors as typically worn [1, 2].

Standards require that between 10 and 20 subjects are used for the measurements to account for the anatomical differences among people. To avoid false results, the attenuation is measured at least twice for the same subject. The results are treated statistically and presented as a table or graph of the mean values and standard deviations of the individual results at each of the above-mentioned frequencies as shown in Figure 1. The convention for the graphs in Figure 1 is that attenuation always appears as negative, while the standard deviation is positive.
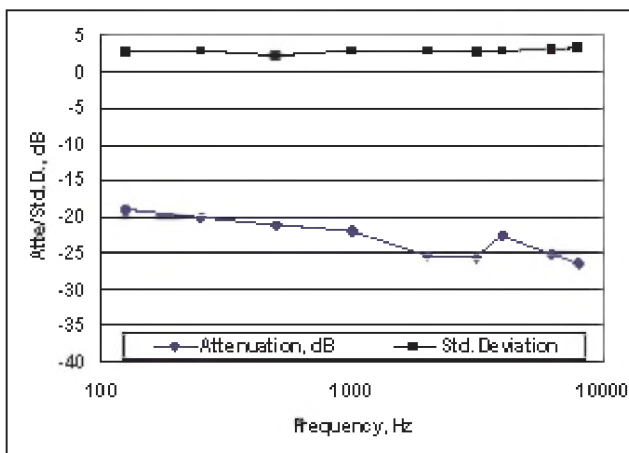

Figure 1. Performance of Hearing Protectors.

Several standards deal with the procedures to be followed when measuring the attenuation, as well as with the instrumentation and environment required for the tests. The most important among them, due to their wide usage, are the ISO 4869-1 and the ANSI S12.6 – 1997 [3, 4]. The ANSI standard contains two measurement procedures. The first of them, Method A, is similar to that in the ISO Standard with small differences, mostly in operational details. Both Standards make use of subjects that are familiar with this kind of tests. The procedure is designed to measure the maximum attenuation that can be achieved using the protector under test. For this purpose, if a test results in an unexpected, low attenuation value, the measurement is repeated. The role of the subject is limited to just fitting the protector under the operator's supervision and to indicate when the signal is perceived.

The second measurement procedure in the ANSI S12.6 – 1997 Standard (Method B) requires the subject to don the protector following the manufacturer's written instructions.

The operator is not allowed to intervene in the process, or to provide help or instructions. Also, subjects are naïve: they are not allowed to have previous experiences wearing or testing hearing protectors.

A new ISO Standard, 4869 – 7 is presently in preparation [5]. It follows closely the procedures in the ANSI 12.6 – 1997, Method B. The reason for the ANSI method B and for the new ISO standard will be further discussed in this paper. This reason is based on the fact that the attenuations measured following the Method A or the existing ISO standards are significantly larger than those obtained in realistic work conditions.

4. THE ATTENUATION DATA

There are several procedures for the calculation of the sound level at the protected ear using the results from the attenuation measurements. All of them make use of mean attenuation values and their standard deviations. Following are some of the available calculations.

The ISO 4869 -2 Standard contains three different calculation procedures [6]:

a) The Octave-Band Method: The noise level in the workplace is measured in Octave bands. Then, at each frequency, the attenuation of the protector is subtracted from the noise level. Finally, the difference is corrected according to the percent protection performance, correction that is included in the Standard. The percent protection performance is the percentage of situations for which the A-weighted sound pressure level is equal to or less than the predicted value. The result of the calculation is the sound level of the protected ear in octave bands. Considered as the most accurate calculation, it has not been adopted by users, probably because of the complexity of interpreting the results without converting them to dBA.

b) The HML Method: Relatively popular among the Northern countries in Europe, this method requires the ambient noise to be measured in dBA and dBC. Three coefficients, H, M and L are supplied by the manufacturer. They are calculated using the protector's mean attenuation values and standard deviations. The noise level of the protected ear is calculated in two steps using the above data.

c) The Single Number Rating (SNR): This method requires the measurement of the ambient noise in dBC. A coefficient, SNR, is calculated by the manufacturer using protector's mean attenuations and standard deviations. The noise level at the protected ear is calculated using the ambient noise level, measured in dBC, and the SNR, corrected according to the specific protection performance.

There are other computational procedures that also are used

extensively. They are:

a) The NRR. This is the single number rating most often used on this side of the Ocean. It has gained popularity mainly because of the ease of use and also because the USA Environmental Protection Agency EPA requires NRR to be printed on every hearing protector's package [7].

As with the previously described indices, the NRR is calculated from the mean value of the measured attenuations at all audiometric frequencies and the calculated standard deviations of the measurements. Because two standard deviations are subtracted from the mean value of the attenuation, in theory 98% of users will have the calculated noise level of the protected ear or higher. Only 2% of users will have attenuation lower than the calculated. The inherent assumption is that the attenuations are normally distributed. Although this is not a proven fact, it is a working tool used across the hearing protection community.

By definition, the sound level of the protected ear is obtained as follows:

$$SL = SL(dBC) - NRR, \text{ or}$$
$$= SL(dBA) - NRR + 7 \text{ dB},$$

where SL(dBC) and SL(dBA) are the ambient sound levels measured in dBC and dBA.

b) The NRR(SF) [8]: This is a rating calculated with results from measurements following procedures in the Method B of the ANSI 12.6-1997 Standard [4]. The sound level of the protected ear is calculated in a similar way as with the NRR with some small differences. For the calculation of the NRR(SF), only one standard deviation is subtracted from the mean value. The resulting noise level at the protected ear applies, therefore, to 84% of the wearers.

Results from studies indicate that the calculated sound level at the protected ear using the Octave Band method, the NRR and the HML, is approximately the same [9, 10].

5. PROBLEMS WITH THE CALCULATION RESULTS

Extensive studies have demonstrated, that attenuation values measured in laboratories and reported by manufacturers are significantly higher than those measured in the field [11, 12]. The main reason for the field lower performance appears to be the poorer fitting of the protectors due to lack of training and motivation, poor choice of size in the case of plugs, lack of attention while fitting, etc. Berger quotes the following reasons: comfort, utilization, readjustment, fit, compatibility, deterioration and abuse [13].

Figure 2 is from Reference 14 and shows a comparison between protectors' NRR measured in laboratories and in the field. The field NRRs are calculated using one (1) standard deviation and not two (2) as is the case with the laboratory
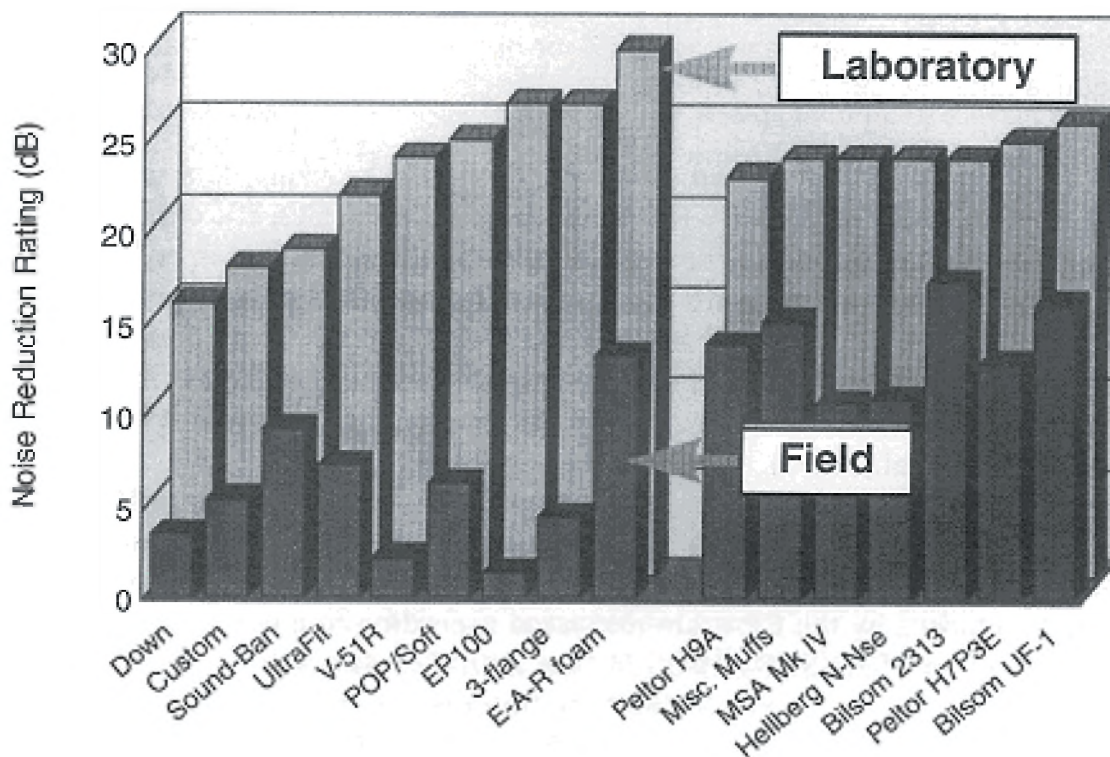
Figure 2: Comparison of NRRs published in North America (labeled values based upon laboratory tests), to real-world "field" attenuation results derived from 22 separate studies.

NRRs. It can be seen that not only the field attenuations are much lower, but also, that there is no relation between both attenuations. For example the laboratory result of the EP100 plug is one of the highest among plugs, while the field one is one of the lowest. The same applies to muffs: see the results for the MSA Mk IV.

There is no need to stress the consequences of using overly optimistic NRR values for the noise exposed population: users would think that they are protected, while, in reality they are not.

However, it must be pointed out that the problem is not inherent to the calculation of the NRR, nor that manufacturers are to be blamed for reporting high NRR values. The problem resides in the data obtained through laboratory measurements that are intended to yield optimum performance values for the protectors. Those are the data used for calculations of the sound level in the protected ear using any of the above-described procedures: the "long" octave band method, the HML, the SNR or the NRR. Using any of them will yield abnormally high attenuation values for the protectors and non-realistic, low values for the sound level at the protected ear.

Therefore, the solution is not in the calculation method, but in the way the attenuation data is obtained. This is why the ANSI 12.6-1997 measuring method B was devised as an alternative to the Method A. This also is the reason for the new ISO 4869-7 (5). As mentioned above, when measuring hearing protectors following the method B, the resulting attenuations are similar to those obtained in field tests in establishments with well-managed hearing conservation programs.

6. DERATING SCHEMES

The disparity between laboratory and field attenuation results has been long recognized. Also, it has been recognized that there is no straight relation between both values. Therefore, there is no mathematical operation that would allow for the calculation of one using the results from the other. In view of the above, several derating schemes have been proposed.

As per OSHA to calculate the noise level of the protected ear, the NRR should be derated by 50% before it is subtracted from the sound level measured in dBC [15]. For example, if the sound level is 100 dBC, and the nominal NRR of a given protector is 30, the noise level of the protected ear will be 100 − 30/2 = 85 dBA.

NIOSH recommends derating NRR by a factor of 75%, 50% and 30% respectively for muffs, slow-recovering plugs and all other plugs [16]. As an example, a muff with a nominal NRR of 30 will be derated to NRR = 20. However, if the protector is a foam plug, it will be reduced to NRR = 15.

Behar recommends a variable scale, similar to that of NIOSH, where 7 will be subtracted from muffs' NRR, 10 from plugs and 13 from cap-mounted muffs [17].

7. POTENTIAL SOLUTIONS

The present situation regarding the attenuation values of hearing protectors can be summarized as follows:

a) The NRR is still the best known and most used rating scheme
b) Very few manufacturers have their products tested as per the ANSI method B, therefore there are few data available for the calculation of NRR(SF).
c) There are no approved standards, other than ANSI12.6-1997 (4) that includes measurement methods that result in attenuation similar to the field attenuation data.

Until the NRR(SF) (or some alternative value) becomes available, the best alternative for users is to derate the nominal NRR using any of the previously described methods. . It will also be extremely useful if users (especially large manufacturing facilities) begin requesting their suppliers and manufacturers for attenuation data obtained using the ANSI method B procedure. Only the users' pressure will force manufacturers to start providing meaningful data for their products.

However, one needs to stress the fact that the simple use of hearing protectors, should not be considered as an alternative to a well-managed hearing conservation program that deals with all issues regarding the use of protectors.

8. ACKNOWLEDGMENT

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