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THE DANGER OF EVALUATING HEARING PROTECTORS ON THEIR ATTENUATION ALONE.

"THE BEST HEARING PROTECTOR IS THE ONE THAT GETS WORN."

To the above oft-quoted saying we would add: "all the time it is needed".

Clearly a hyper-effective protector that is too uncomfortable to use defeats its purpose. We would, however, go a step further: it is far better to use a comfortable protector with somewhat less attenuation during a high proportion of a noise exposure than reluctantly wear a high-attenuation protector now and then.

The danger of wearing hearing protectors for only part of the noise exposure time is not readily appreciated. The fact that the unit of sound level, the decibel, is based on a logarithmic scale is perhaps the main reason for this. We cannot add or subtract decibels as we do ordinary linear units. A more obvious danger is that unless you know exactly when they will happen, intermittent periods of extremely harmful high-energy noise may occur while the ears are unprotected.

This publication aims to illustrate that the attenuation of a hearing protector has little bearing on the actual or effective protection given, unless the protector can be worn for the full duration of the noise exposure.

THE RISK OF INJURY DEPENDS ON THE TOTAL NOISE DOSE.

When we assess the risk of permanent hearing damage for people exposed to noise, we work with a number of simplifications.

One such simplification is to measure the overall intensity of sound in dB(A). Another is to estimate the risk criteria of non-uniform noise conditions from the durations and dB(A)-levels of the different noise exposures. Taking a typical working day as a sample, we calculate the equivalent continuous sound level (Leq) that would give the same risk of injury as the actual exposure.

EQUIVALENT CONTINUOUS SOUND LEVEL (Leq).

In calculating equivalent continuous sound levels we make use of a generally accepted trading relation between dB(A) levels and exposure time. This relation is based on the approximation that the risk of injury depends on the total sound energy reaching the ear, regardless of how the energy is distributed in time. This is known as the equal energy rule and implies that if the exposure time is doubled, the permissible energy level must be halved. And, as a logarithmic scale is used, halving the energy corresponds to a decrease in sound level of 3 dB(A).

Simply stated, then, we can find the Leq for non-continuous exposure by measuring the different sound levels and durations of the exposures and calculating the average noise dose spread over an eight-hour day.

TWO VASTLY DIFFERENT NOISE EXPOSURES THAT CARRY THE SAME HEARING DAMAGE RISK.

A man is subjected to the pattern of sound shown in fig. 1, namely:

Sound level dB(A)	Duration of exposure/day
115	10 mins
105	45 mins
95	5 hours

For the remainder of the day the sound level is 70 dB(A) or below and can safely be ignored.

Using the method of calculation recommended by ISO (International Organization for Standardization) the Leq works out at 100 dB(A) to the nearest decibel.

In fig. 2 the harmful exposure is restricted to a sound level of 115 dB(A) for a duration of 16 minutes. The Leq in this case also works out at 100 dB(A).

The situation in fig. 2 can be likened to that where a man wears hearing protectors practically the whole day in a steady sound level of 115 dB(A). The protectors are capable of attenuating the sound to the maximum permitted level, but are uncomfortable. The man removes them for a few minutes at a time—in all 16 minutes per day. He would then be exposed to the same hearing damage risk as if he went with unprotected ears in a continuous sound level of 100 dB(A) during an 8-hour day.

The actual or effective protection achieved in this case amounts to a reduction in the Leq from 115 to 100 dB(A)—still a dangerous level by any criterion.

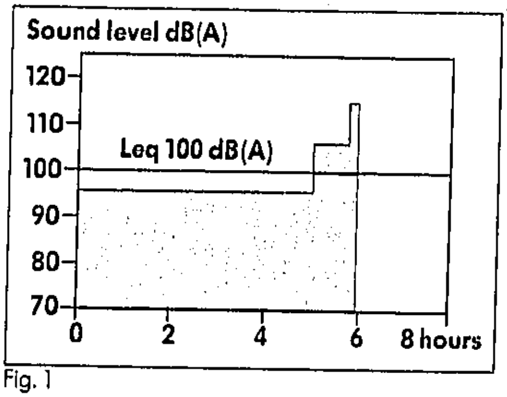

Fig. 1

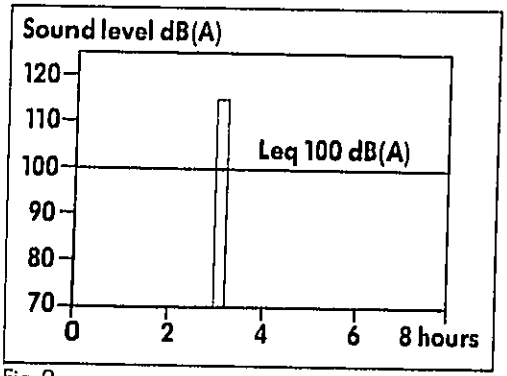

Fig. 2

THE DRAMATIC EFFECT OF REMOVING HEARING PROTECTORS DURING NOISE EXPOSURE.

From the foregoing examples, we have seen that relatively short exposures to high noise levels involve a serious hearing damage risk. We have also seen that the effective protection of hearing protectors can be expressed in terms of the reduction in Leq achieved by the wearing of them.

The effect of removing hearing protectors during a noise exposure is simply illustrated in fig. 3. Here the protectors are assumed to give infinite attenuation–no sound energy at all reaches the ears while they are worn. And yet even these 'ideal' protectors would have to be worn for a very high proportion of the exposure time to give adequate on-the-job protection.

In practice, of course, hearing protectors do not provide infinite attenuation. Some sound energy reaches the ears while they are being worn.

The graph has been constructed from the expression:

$$\text{Effective protection dB(A)} = 10 \log \left(\frac{100}{100 - \%\ \text{time worn}}\right)$$

(After D. Else)

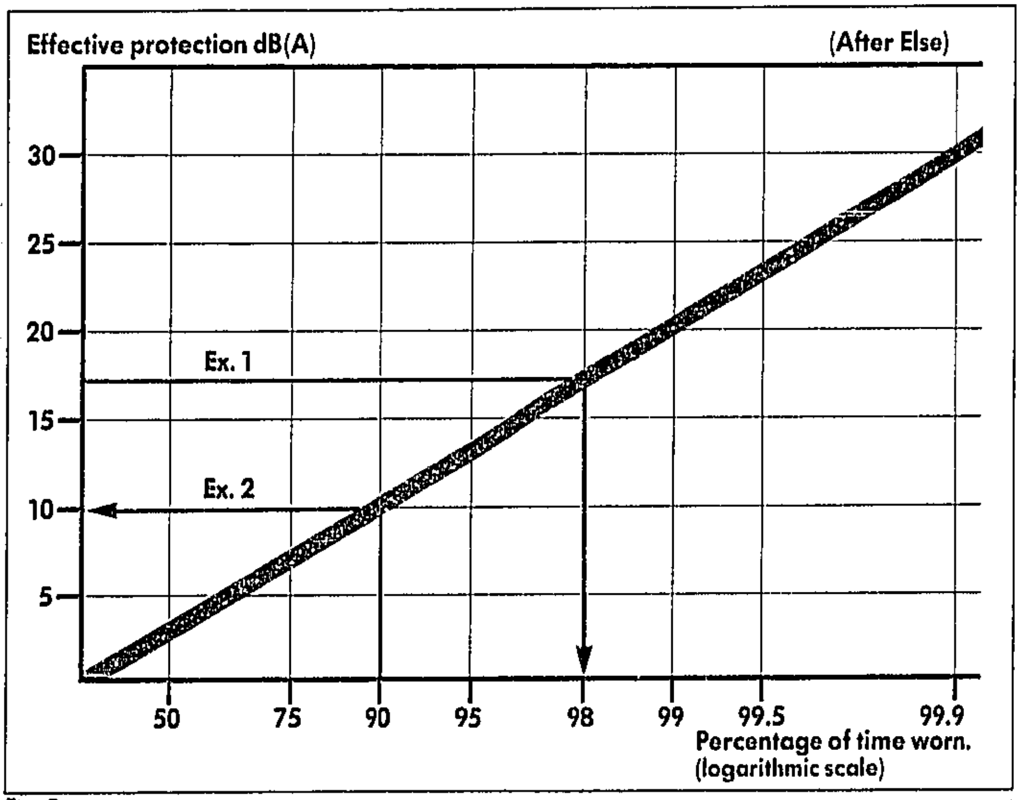

Fig. 3

EXAMPLE 1

Take an exposure with an equivalent continuous noise level (Leq) of 107 dB(A). From the graph we see that to reduce the Leq to 90 dB(A)—or by 17 dB(A)—infinite-attenuation protectors would have to be worn for as much as 98% of the total exposure time.

EXAMPLE 2

Consider a situation where the Leq is 105 dB(A) and our theoretical protectors are used for 90% of the exposure time. The graph shows that despite the infinite attenuation of the protectors the actual protection achieved is insufficient—no more than 10 dB(A).

A REALISTIC COMPARISON BETWEEN TWO TYPES OF HEARING PROTECTORS.

For this comparison we have chosen two protectors with widely differing characteristics. One is a 'super' muff with high attenuation, particularly in the low frequency range.

The other is of the insert type. For convenience, we have used the attenuation data for a mineral down earplug, which is generally accepted as a comfortable protector.

The effective protection curves for the respective protectors are shown in figs 4 and 5.

We see from fig. 4 that if the 'super' muffs were to be removed for 10% of the noise exposure, the effective protection would be no more than 10 dB at all frequencies. And there is every reason to assume that they would be removed–frequently and for long periods. To begin with, high attenuation muffs–practically by definition–are uncomfortable to wear for any length of time. Moreover, because of their high attenuation at the speech frequencies, there would be a tendency to take them off during conversations.

As the mineral down plugs (fig. 5) have none of the inherent disadvantages of 'super' muffs, there is every chance of their being used for the entire exposure time. Their nominal attenuation values would then be the same as the effective protection given in practice, with high attenuation of the high-frequency components of the noise. True, performance at low frequencies is limited. But as we will see later, high attenuation at low frequencies–as afforded by the 'super' muffs–is of doubtful value in practical noise situations.

'SUPER' MUFFS

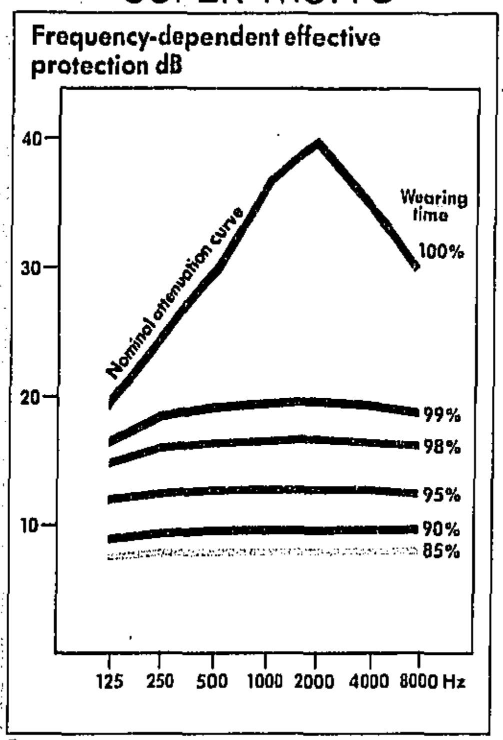

Fig. 4

The attenuation values for both protectors are as tested by Karolinska Institutet in Stockholm, the upper limit of the lower quartile being taken as the nominal attenuation.

The formula used to obtain the frequency-dependent effective protection in relation to the time worn is as follows:

MINERAL DOWN PLUGS

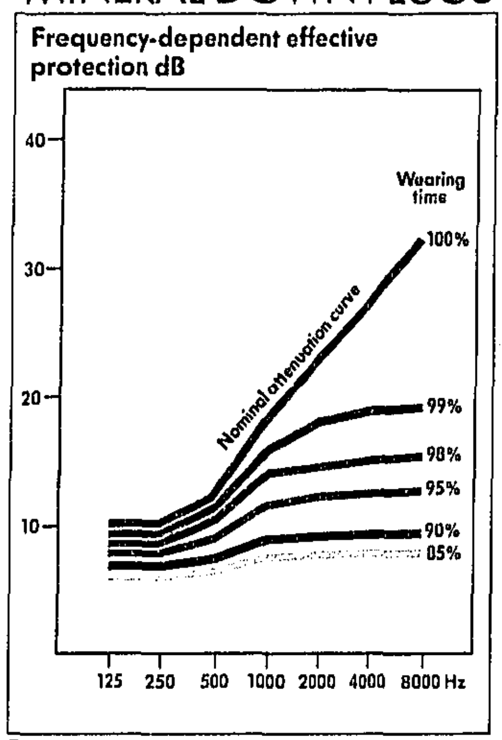

Fig. 5

$$\Delta L_{eff} = -10 \log \left(\frac{t2}{T} \cdot 10^{\frac{-\Delta L}{10}} + \frac{t1}{T}\right)$$

where:

ΔL_{eff} = the effective protection
ΔL = the nominal attenuation of the hearing protector
$t1$ = exposure duration without hearing protector
$t2$ = exposure duration with hearing protector
T = $t1 + t2$ = total duration of noise exposure.

THE PRACTICAL NOISE SITUATION.

Frequency spectra (distribution of sound energy with regard to frequency) vary greatly in industry. Consequently the protection provided by a given protector will also vary.

In fig. 6 the A-weighted sound levels of 100 noise spectra have been plotted against the difference between their C-weighted and A-weighted sound levels (L_C–L_A). The greater the difference, the more powerful the low–frequency components and vice versa.

The spectra are those selected by the National Institute for Occupational Safety and Health (NIOSH) as being typical for industry in the USA. It is therefore safe to assume that they are also typical for other industrialized countries.

The first thing we see from a study of these spectra is that the vast majority represent sound levels below 100 dB(A). Also clear is that the high sound levels apply predominantly where the L_C–L_A value indicates powerful high frequency components.

The next stage is to evaluate the performance of the two types of protector (figs 4 and 5) in the context of the 100 typical spectra.

100 A-WEIGHTED NIOSH SPECTRA

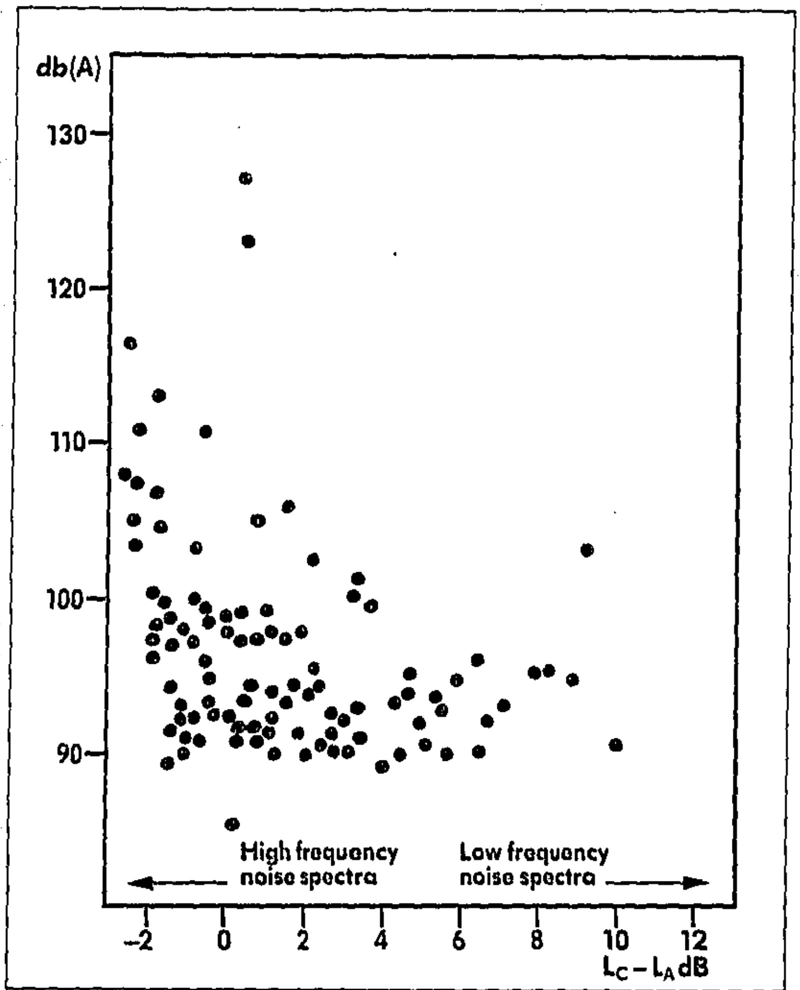

Fig. 6

THE POTENTIAL DANGERS OF OVERPROTECTION.

Figures 7 and 8 show the influence of wearing time on the performance of hearing protectors in practical noise situations. The curves were arrived at by calculating the percentage of the 100 NIOSH spectra reduced to an Leq below the risk criteria of 85 and 90 dB(A) respectively by the wearing of hearing protectors for different fractions of the exposure time. The red curve represents the 'super' muffs and the blue curve the mineral down earplugs (see figs 4 and 5).

From the diagram we see that in practice the benefit of the 'super' muffs' high nominal attenuation will be nullified if the mineral down plugs are worn as little as 1–3% more of the total exposure time. And as very high attenuation and comfort appear to be incompatible characteristics in hearing protectors, the chances are that the mineral down plugs would be worn considerably longer than the 'super' muffs and thereby give better overall protection.

The implication of this clear: the use of protectors with higher attenuation than necessary involves a serious hearing damage risk.

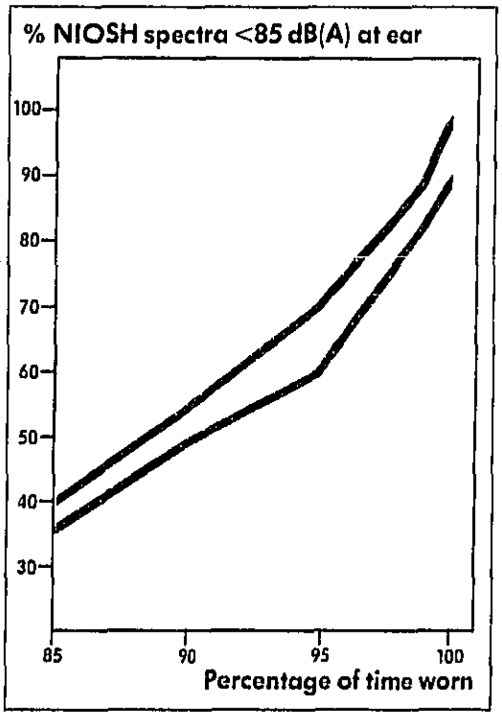

Fig. 7

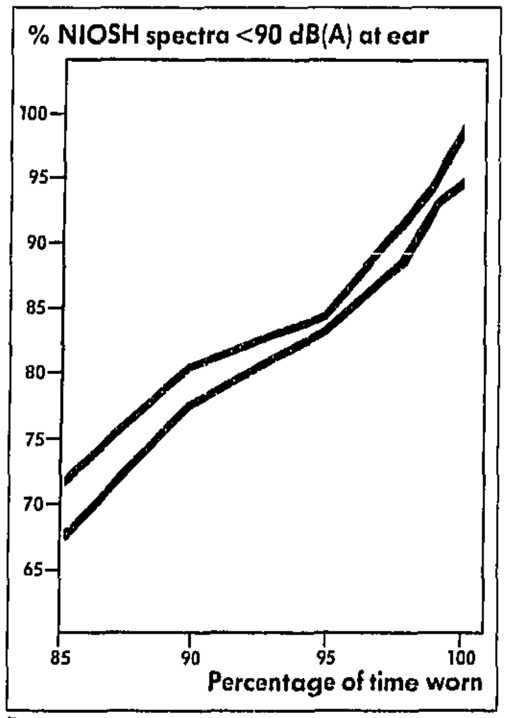

Fig. 8

'SUPER' MUFFS

MINERAL DOWN PLUGS

CONCLUSIONS.

As shown by Robinson in 1968, the risk of occupational deafness can be predicted from the total A-weighted noise dose received by the exposed person. Clearly, then, the effectiveness of a hearing protector is governed by its ability to reduce A-weighted noise dose rather than instantaneous sound level.

We hope we have been able to show that this ability is dependent on the extent to which the hearing protector is worn during a noise exposure. If a high-attenuation protector is not worn for the full duration of a noise exposure, the same degree of protection or greater may be obtained with a protector which affords less nominal attenuation, provided it is comfortable enough to be worn for a greater proportion of the exposure duration.

A recent comparative investigation of hearing protectors carried out by the University of Lund in a large Swedish shipyard provides statistical support for our contention. The results indicate that the workers who wear protectors with relatively high attenuation (earmuffs fitted to helmets) have generally more severe hearing impairment than those who use more comfortable earplugs with 10–15 dB less nominal attenuation.

The study concludes that this paradoxical situation arises from the fact that the high attenuation protectors are often removed during a noise exposure.

REFERENCES

Robinson, D.W. Relations Between Hearing Loss and Noise Exposures, Teddington, England. National Physical Laboratory, 1968.

Else, D. 1973. A Note on the Protection Afforded by Hearing Protectors–Implications of the Energy Principle. Annual of Occupational Hygiene, 16,81.

Erlandson, B., Håkanson, H., Ivarsson, A., Nilsson, P. Earplugs versus earmuffs; a comparative investigation of hearing protectors. Draft report, 1978.

Lundin, R. The effectiveness of hearing protectors in practical situations. Bilsom internal report 1978.

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