THE DEGREE OF PROTECTION AFFORDED BY HEARING PROTECTORS IN INDUSTRIAL NOISE: VARIATIONS WITH NOISE SPECTRA AND WITH PEOPLE

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The overall attenuation provided by any pair of hearing protectors depends on the noise in which they are worn and on how well they fit. Hearing protectors afford vastly different degrees of protection under different circumstances; this may result in insufficient protection for some people and over-protection for others.

The approach to both the assessment and the limitation of the risk of occupational deafness has been greatly simplified by the findings of recent research. Robinson (1968) has shown that injury to hearing can be considered to be a function of the cumulative acoustical energy that passes into the ears of those exposed. The work of Atherley and Martin (1971) suggests that this "energy principle" holds for most industrial noises no matter how the energy is distributed in time. The present study is based on the "energy principle". In the study laboratory determinations of the attenuation provided by glass down earplugs have been applied to one hundred industrial noises. The aim has been to estimate the variation in the degree of protection provided by the earplugs when people wear them in different noises and when different people wear them in the same noise. The study highlights the danger of unintentionally over-protecting some people whilst insufficiently protecting others.

Method of Estimating the Protection Afforded by Hearing Protectors

Estimates of the attenuation of a particular type of hearing protector are usually available as a set of six or eight values: these having been obtained from measurements made with pure-tones or with one-third octaves of random noise centred at octave band centre frequencies. Attenuation data are often available for the frequencies between 62.5 Hz and 8 kHz.

The attenuation data have to be applied to the equivalent continuous noise level (ECNL) of the particular noise hazard. Unless both the noise and the exposure to the noise are continuous, for eight hours per day, the attentuation figures must not be applied directly to the measured A-weighted sound level. The method used to estimate the ECNL to which the ears are exposed, when hearing protectors are worn, begins with an octave band analysis of the noise hazard. From each of the octave band sound levels are subtracted the A-weighting corrections shown in Table I. The ECNL for each individual octave band can then be computed; these ECNLs are then combined in an estimate of the overall ECNL for the unprotected condition. To obtain an estimate of the overall ECNL for the protected condition the attenuation data are subtracted from the corresponding octave band ECNLs and the resultants added according to the usual rules governing the addition of sound levels.

The calculations can be simplified if the spectrum of the noise does not vary markedly throughout the period of exposure. It is then not necessary to compute individual octave band ECNLs and the overall ECNL for the unprotected condition can be computed from the measured A-weighted noise level.

A further simplication can be made if both the exposure and the noise are also continuous: the measured noise level in dB(A) is then identical to the overall ECNL. Table I illustrates the calculation for this simple case. The attenuation data, used in this example, are the median results obtained with glass down earplugs as measured in accordance with the American Standard Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold Z24.22 (1957).

Table I - Example of the method of estimating the protection afforded by hearing protectors

Octave band centre frequency Hz	62.5	125	250	500	1000	2000	4000	8000
Noise from electric motor dB	82	87	88	90	90	87	84	77
A-weighting corrections dB	-26	-16	-9	-3	0	+1	+1	-1
A-weighted electric motor noise dB(A)	56	71	79	87	90	88	85	76
Median attenuation glass down earplugs dB	3	3.5	7.5	10.5	13.5	24.5	27.5	23.5
A-weighted levels: occluded condition dB(A)	53	67.5	71.5	76.5	76.5	63.5	57.5	52.5

Overall levels - unoccluded: 94 dB(A) unoccluded: 80 dBA

The noise spectrum chosen for the example was that produced by an electric motor. The protection provided by the glass down earplugs is the difference between the overall equivalent continuous noise levels for the unoccluded and occluded conditions; in this case it is 14 dB(A). Protection of 14 dB(A) or greater would be obtained by 50% of the people wearing glass down in the electric motor noise.

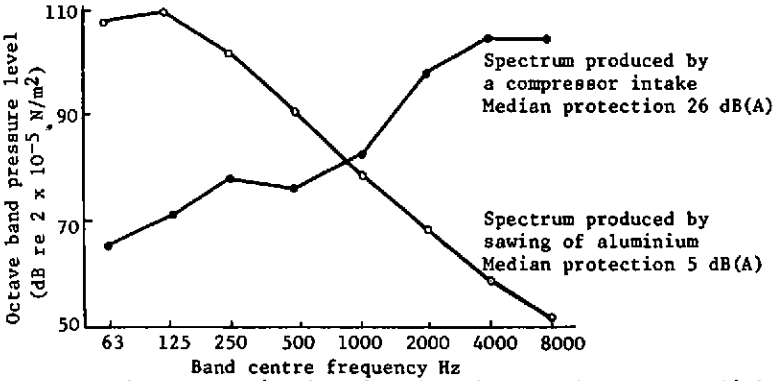
There are errors inherent in this system for estimating the protection afforded against a noise. In particular the attenuation data determined with pure-tones or one-third octaves of random noise are applied to octave band levels. It must also be remembered that the median attenuation data have been used in the calculations; for 50% of the population our estimates of the protection provided are therefore optomistic.

Variation in the protection afforded by hearing protectors when worn in different industrial noises

Most hearing protectors attenuate high frequency sounds more efficiently than low frequency sounds. It is therefore reasonable to expect the degree of protection afforded by any hearing protector to vary according to the spectral shape of the noise in which it is worn.

Two noise spectra are shown in Figure I; they represent a fast rising spectrum and a fast falling spectrum taken from a study of 100 industrial noises. The 100 spectra included noises from the plastics industry, the steel industry, weaving and mining.

Figure I - Fast rising spectrum and Fast Falling Spectrum



The median attenuation data for glass down earplugs were applied to the above spectra in the method of the previous section. The estimated protection against the noise with the fast falling spectrum was 5 dB(A); the corresponding estimate for the fast rising spectrum was 26 dB(A). These are the extremes of the 100 spectra that were studied and values of protection between 5 dB(A) and 26 dB(A) were obtained for the other ninety-eight noises. Table II illustrates the approximate degree of protection afforded against 25%, 50% and 75% of the noises.

Table II - The approximate degree of protection afforded by glass down against 100 industrial noises

Lowest protection	5 dB(A)
Protection afforded against 25% of noises	less than 12 dB(A)
Protection afforded against 50% of noises	14 dB(A)
Protection afforded against 75% of noises	less than 17 dB(A)
Highest protection	26 dB(A)

It can be seen that in 50% of the noises studied, 14 dB(A) of protection is provided by glass down earplugs; based on median attenuation data. In 75% of noises greater than 12 dB(A) of protection is given, and in 25% of noises greater than 17 dB(A) of protection is provided. Therefore for 50% of the noises that were studied a reduction of at least 14 dB(A) in the overall equivalent continuous noise level could be achieved for 50% of the people by wearing glass down earplugs.

The study has only been concerned with glass down earplugs; however, approximate estimates of the median, upper bound and lower bound protections afforded by good quality fluid-seal earmuffs are shown in Table III. These have been calculated using the median, upper and lower bound spectra of the glass down study, with median attenuation data.

Table III - Approximate estimates of the protection afforded by fluid-seal earmuffs against the 100 industrial noises

Protection afforded against fast falling spectrum	21 dB(A)
Protection afforded in approximately 50% of noises	28 dB(A)
Protection afforded against fast rising spectrum	35 dB(A)

Variation in the protection provided by glass down ear plugs when worn by different people

So far only the median attenuation data have been applied to the noise spectra. However, some people may receive vastly more protection and others substantially less than that estimated from the median attenuation data. The former may be over-protected with possible

consequent difficulty with the perception or localization of warning or monitoring signals. The problems of localization when wearing earmuffs have been discussed by Atherley and Noble (1970) and Atherley and Else (1971). For the people for whom the protection is inadequate, the risk of noise-induced hearing loss may be present even when wearing the glass down earplugs.

It would be useful to be able to specify the attenuation provided to 99% of people since this would enable the British Occupational Hygiene Society Standard for Wide Band Noise (1971) to be used to estimate the percentage of the population at risk from occupational deafness when wearing hearing protectors. However, most determinations of the attenuations of hearing protectors are taken from small samples, for example the ASA Z24.22 requires ten people and three repetitions. Great difficulty is encountered when estimating the ninety-ninth percentile from the attenuation distributions at particular frequencies, especially the lower octaves for which the distributions appear to be skew. For this reason Table IV only gives estimates of the protection afforded by glass down earplugs calculated from the quartile and median attenuation data.

Table IV - Variation in a protection afforded by glass down owing to fit

Protection provided to 75% of wearers	fast falling spectrum	> 2 dB(A)
	median spectrum	> 9 dB(A)
	fast rising spectrum	> 20 dB(A)
Protection provided to 25% of wearers	fast falling spectrum	> 13 dB(A)
	median spectrum	> 19 dB(A)
	fast rising spectrum	> 31 dB(A)

The variations in protection, owing to fit, for other types of hearing protectors will of course be different. The greater standard deviations associated with prefabricated earplugs would probably result in even larger variations in the degree of protection; earmuffs and the new individually moulded earplugs may produce more constant protection from person to person.

It has been shown that the degree of protection afforded by any hearing protector can vary greatly from noise to noise, and from person to person. Also the protection provided any person will vary from occasion to occasion depending on the goodness of fit of the hearing protectors.

Estimates have been given for the protection provided by glass down earplugs; even with these relatively well fitting plugs variations between 2dB(A) and 30 dB(A) have been obtained. Whenever hearing protectors are given to a group of people, some will receive greater protection than others and if due regard is not made for the spectrum of the noise there will be a danger of over-protection for some people and under-protection for others.

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