Proceedings of The Institute of Acoustics 9C2

HEARING LOSS HAZARD ASSESSMENT - DO WE HAVE IT RIGHT?

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SUMMARY

For almost ten years, the authority for those in the U.K. involved in limiting occupational noise exposure has been the Department of Employment's "Code of Practice" (HMSO 1972). The fundamental aim of the Code is to reduce the incidence of Noise Induced Hearing Loss (NIHL) by reducing noise exposure.

It is evident that the noise measurement techniques described in the Code are intended to yield indices of the hearing loss hazard rather than to simply be measurements of the noise levels.

In this paper it is intended to examine the suitability of current noise measurement techniques as indices of the hearing loss hazard.

Validity of the assumptions implicit in the Code of Practice Like any hygiene standard, the Code makes a number of assumptions, the two most important being:
a) that an A weighted noise measurement correctly takes account of the relative harmfulness of the different frequencies to which the ear is sensitive, and
b) that the Equal Energy Concept (EEC) is valid.
It is necessary to examine the validity of these two assumptions.

Correctness of the A weighted frequency response The use of the A weighted frequency response has been universally adopted for noise measurement made with the purpose of identifying noise induced hearing loss hazards.

The origins of the A weighting lie in the FLETCHER and MUNSON (1932) equal loudness contours, the A weighting response curve being simply the inverse of the 40 phon contour.

It should be noted that the A weighting was designed to quantify noise annoyance at low intensity levels but that it is now also used to define hearing loss hazard due to exposure to high intensities.

Examination of the equal loudness contours indicates that the frequency response of the ear is highly dependent upon noise intensity; at low intensities the ear is less sensitive at low frequencies than at middle frequencies, as the intensity increases this difference in sensitivity becomes less apparent. If a weighting based upon perception data is adopted, it is clear that the weighting should be a function of intensity.

A corollary to the use of a weighting based upon perception data is the assumption that the hearing loss at any given frequency is caused only by noise exposure at that frequency, i.e. the hearing loss at, say, 1kHz is caused only by exposure at 1kHz. However, it is well documented that the maximum temporary threshold shift (TTS) due to exposure to narrow band noise occurs approximately half an octave higher than the exposure frequency(BURNS, 1973). KYLIN (1960) has published data which indicates that narrow band noise causes TTS at frequencies above and below, as well as at, the frequency of exposure.

It appears unreasonable to assume that this effect is confined only to narrow band noise.

In their study BURNS and ROBINSON (1970) examined the A, ½A, B and C weightings to determine which gave the best correlation between noise exposure and the consequential NIHL. They found that for falling spectra the B weighting tended to give the best correlation. Apart from the BURNS and ROBINSON report there has been no evidence produced which indicates that the A weighting is optimal for identifying hearing loss hazard.

One indication that the A weighting may not be optimum is the apparent lack of correlation between the spectrum of the noise exposure and the audiogram showing the consequential hearing loss. In addition it has been observed that narrow band noise or pure tones are relatively more damaging than wideband noise of the same 'A' weighted energy, (BURNS 1973).

Thus the implicit assumption that an A weighted noise measurement correctly takes account of the relative harmfulness of the different frequencies to which the ear is sensitive is cast in doubt.

Validity of the equal energy concept (EEC) The equal energy concept has been adopted into the noise standards of most countries, although one major exception has been the U.S.A. If the EEC were valid, the incidence of hearing loss would be maintained constant if an increase in noise intensity were "balanced" by an equivalent decrease in duration of exposure and vice versa. For example, the hazard over twelve years at 90 dB(A) should be essentially the same as the hazard over four years at 95 dB(A) (5 dB is equivalent to a factor of c. 3.2).

From BAUGHN's (1973) data the validity of such "balancing" can be examined in 5 dB steps of SPL. Table 1 shows the incidence of Noise Induced Hearing Loss for various combinations of exposure intensity and duration exposures. It can be seen that the risk of suffering a mean hearing loss of ≥ 25 dB over the audiometric frequencies is 3.5 per cent over twelve years at 85 dB(A) and 3.5 per cent over four years at 90 dB(A), so that for these particular exposure intensities and durations the EEC is shown to be valid.

However, the risk over twelve years at 90 dB(A) is 11.5 per cent whereas the risk over four years at 95 dB(A) is 6.5 per cent - in this instance the EEC would appear not to be valid although the overall noise energy is the same in both instances.

Table 2 shows the effect of "balancing" an increase of 5 dB in intensity of exposure with a threefold reduction in exposure duration. From these data it would appear that the EEC is only valid for exposure intensities of less than 90 dB(A) for periods not exceeding twelve years.

As intensity increases the EEC becomes increasingly less valid, and the ratio of the risk at the higher and lower intensities appears to decrease systematically with increasing SPL.

It is therefore contended that neither the A weighted frequency response nor the equal energy concept are valid indicators of hearing loss hazard under all conditions of noise exposure.

Examination of the literature suggests that the non-validity of the EEC may, in part, be due to the operation of the Aural Reflex (AR)which changes the transmission characteristics of the middle ear.

Operation of the Aural Reflex The AR is a mechanism by which the transmission of sound energy through the middle ear is reduced at high intensities so protecting the inner ear.

It has been shown that the aural reflex has an elicitation threshold, for healthy ears, of 75-85 dB(A) for wideband noise and 90-100 dB for pure tones (MARGOLIS and FOX 1977) and that the protection afforded to the inner ear varies from 2 to 30 dB depending upon frequency and noise intensity (SESTERHENN and BREUNINGER, 1978).

If it is assumed that the EEC is valid in terms of exposure of the inner ear to noise, it is possible to explain the effects shown in Table 2 in terms of the action of the AR as it will increasingly attenuate sound in the middle ear as intensity increases above the elicitation threshold and so reduce damage to the inner ear. It is also possible to explain the ears greater sensitivity to damage due to exposure to narrow band noise as the higher reflex threshold will result in less protection to the inner ear.

One of the difficulties in quantifying hearing loss hazard is the person-to-person variability in response. If it is assumed that the AR protects the inner ear against industrial noise, it could be expected that those with higher elicitation thresholds would gain less protection and therefore suffer greater hearing loss.

Examination of the available data indicated that those suffering from permanent threshold shift tend to have higher reflex thresholds (MARGOLIS and FOX, 1977). The authors imply that the higher reflex thresholds are as a consequence of the hearing loss, however, an equally valid interpretation could be that the greater hearing loss is as a result of reduced protection due to the higher threshold.

General Discussion It is concluded that neither the A weighted frequency response nor the Equal Energy Concept are valid indicators under all noise exposure conditions. It is contended that the action of Aural Reflex can account for these effects and that the Aural Reflex offers protection against industrial noise.

REFERENCES

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TABLE 1. Relation between Leq during work in 2-32 years and risk of impairment for conversational speech (≥ 25dB Average Hearing Loss (AHL))

Leq dB(A)	Years of Exposure 2	4	6	8	12	16	18	32	36
85	0.5	1.0	1.5	2.5	3.5	5	5	7.5	9
90	1.5	3.5	5.5	8.0	11.5	14	15	18	21
95	3.0	6.5	9.5	13.5	20	25	26	31	31
100	5.0	10.5	17	24	34	38	42	44	44
105	7.0	15	24	36	47	53	55	61	59
110	10.0	22	36	47	63	72	75	73	67
115	13.0	27	46	58	78	84	-	-	-

From BAUGHN (1973)

TABLE 2. Effect on risk of suffering 25dB AHL of maintaining equal noise immission

Leq dB(A)	Years of Exposure	Percentage at risk (Ratio)	Years of Exposure	Percentage at risk (Ratio)
85	12 (12)*	3.5 (1)	18 (18)*	5 (1)
90	4 (12)	3.5 (1)	6 (6)	5.5 (1.1)
95			2 (4)	3.0 (0.6)
90	12 (12)	11.5 (1)	18 (18)	15 (1)
95	4 (7)	6.5 (0.6)	6 (9)	9.5 (0.6)
100			2 (6)	5.0 (0.3)
95	12 (12)	20 (1)	18 (18)	26 (1)
100	4 (7)	10.5 (0.5)	6 (10)	17 (0.7)
105			2 (7)	7.0 (0.3)
100	12 (12)	34 (1)	18 (18)	42 (1)
105	4 (8)	15 (0.4)	6 (11)	24 (0.6)
110			2 (7)	10 (0.3)
105	12 (12)	47 (1)	18 (18)	55 (1)
110	4 (8)	22 (0.5)	6 (10)	36 (0.7)
115			2 (7)	13 (0.2)
110	12 (12)	63 (1)	18 (18)	75 (1)
115	4 (8)	27 (0.4)	6 (11)	46 (0.6)

Note * Shows actual time at higher Leq to maintain risk