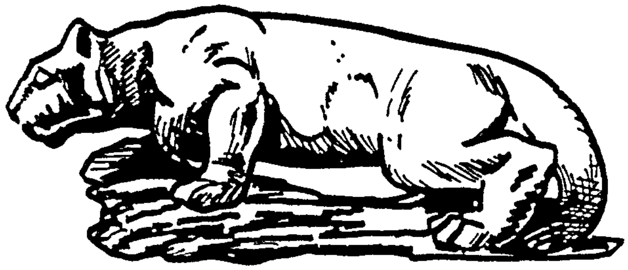

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MEASUREMENT OF HEARING PROTECTOR ATTENUATION AT ULTRASONIC FREQUENCIES

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INTRODUCTION

Health hazards resulting from exposure to ultrasound such as nausea, vertigo and fatigue (collectively called ultrasound sickness) have been recognized for many years, both in situations where the energy is transmitted directly to human tissue and by means of air transmission. The recognition of these hazards is reflected in the existence of several standards and regulations issued by governmental and health agencies in various countries. Some of these set limits for exposure to air-transmitted ultrasound intended to minimize the risk of sustaining ultrasound sickness (1,2). In contrast to the usual rating procedure for sound exposure which involves A-weighted sound levels, these usually specify acceptable at-ear levels in high-frequency one-third octave bands, typically over the range of 12.5 to 20 kHz.

In general, the minimization of hearing loss and other negative effects of sound exposure are achieved either through a reduction in noise level to which an individual is exposed, or through a reduction in the duration of exposure. The former is preferrably achieved by appropriate engineering controls, but more often through the use of personal hearing protection. The preferred method for assessing the attenuation of hearing-protective devices (HPDs) involves Real Ear Attenuation at Threshold (REAT) determinations usually obtained in accordance with ASA Standard 1-1975 (3) or ISO Standard 4869-1 (4), where measurements are made in the range 125 - 8000 Hz. Experience has shown that REAT thresholds obtained above 8000 Hz are highly variable, primarily due to decreased hearing sensitivity and to the complexity of high-frequency wave patterns. In certain circumstances, the use of an acoustic test fixture (ATF) with built-in artificial ears is an acceptable substitute for subjective testing (5).

The proliferation of ultrasound sources in the workplace has served to emphasize the requirement to quantify the attenuation properties of protective devices and materials at ultrasound frequencies. Although the transducers of ultrasound sources such as immersion cleaners typically operate at about 20 kHz, the interaction of the transducer with the cleaning fluid often produces potentially hazardous audible noise in the 10 - 20 kHz region. With an ATF, measurements may be carried out over this frequency range while minimizing the problems associated with subjective evaluations.

In this study, the high-frequency attenuation of two earmuff and three earplug HPDs was measured with an ATF at frequencies up to 22.4 kHz. In addition, two barriers, one a sheet of copier paper, the other a sheet of polyurethane foam, were evaluated for high-frequency noise reduction.

1/3 Oct. Freq.	Bilsom Viking	Peltor Comfort	E-A-R Classic	E-A-R E-Z-Fit	Willson Silencer	Copier Paper	Poly Foam
6.3 kHz	46.9	45.5	53.2	52.6	43.2	8.7	3.1
8 kHz	45.1	43.0	54.2	56.5	39.8	12.2	4.7
10 kHz	44.8	45.2	48.9	53.3	31.4	11.2	4.5
12.5 kHz	48.3	42.7	42.0	54.8	41.0	13.4	7.6
16 kHz	53.8	48.9	43.9	61.1	46.3	13.4	3.4
20 kHz	49.9	48.2	46.3	62.7	44.4	16.3	3.7

Table 1. HPD Mean Attenuation and Material Insertion Loss in dB with Direct Sound Incidence.

1/3 Oct. Freq.	Bilsom Viking	Peltor Comfort	E-A-R Classic	E-A-R E-Z-Fit	Willson Silencer	Copier Paper	Poly Foam
6.3 kHz	27.0	31.4	46.5	50.4	38.9	10.2	2.5
8 kHz	28.7	21.2	43.1	47.8	28.8	10.7	4.8
10 kHz	37.5	38.8	52.2	52.1	33.2	13.4	4.4
12.5 kHz	41.4	43.4	43.0	61.6	43.4	13.1	5.5
16 kHz	38.0	38.4	41.2	60.9	40.0	10.9	4.4
20 kHz	31.5	35.7	45.1	60.1	33.3	13.9	5.5

Table 2. HPD Mean Attenuation and Material Insertion Loss in dB with Grazing Sound Incidence.

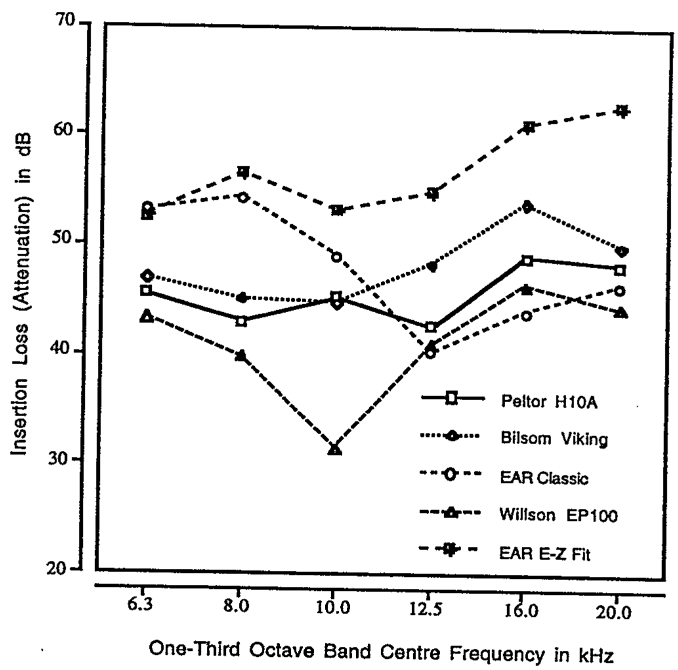

Figure 1. Mean high-frequency hearing-protective device attenuation with direct source incidence.

DISCUSSION

HPD Attenuation. A review of the data presented in Figures 1 and 2 shows a considerable variation in the attenuation across devices and across direction of incidence. Nonetheless, in this study, the Cabot Safety E-A-R E-Z-Fit earplug consistently appeared to provide the greatest overall attenuation, regardless of frequency or direction of sound incidence. Across HPDs, there was also a general trend toward higher attenuations with direct incidence and relative independence of attenuation with frequency, whereas with grazing incidence, there was a trend towards maximum attenuation at 12.5 kHz.

Insertion Loss Due To Barrier Materials. Of the two barrier materials selected for insertion loss measurements, the sheet of paper proved to be the more effective attenuator, providing about 10 -15 dB of insertion loss over the frequency range of measurement. The sheet of foam, on the other hand, provided only 3 - 5 dB of insertion loss, presumably due to its open-cell construction. Although these results may be of academic interest, the practical value for shielding against ultrasound is clearly minimal when compared with other available methods.

Implications For Hearing Protection From Ultrasound Sources. The effect of protection on ultrasound exposure can be calculated as shown in the example of Table 3. In this instance, the actual noise spectrum produced by the Lewis L/C 136H ultrasonic cleaner at the operator's position (7) has been reduced by using the mean attenuation obtained for one of the less effective HPDs assessed in this study. The resulting levels can be compared with hearing conservation criteria intended for use with ultrasound. For example, Parrack (1966) (8) has suggested that no exposure be permitted if the 20 kHz one third octave band level exceeds 105 dB (considering that a hazard may exist due to sub-harmonic energy accidentally generated by ultrasound equipment), whereas, the hearing damage threshold is thought to be about 140 dB. For avoidance of the symptoms of ultrasound sickness (vertigo, nausea, fatigue, etc.) Acton and Carson (1967) (9) have proposed that the power summation of the levels in the 12.5 and 16 kHz one-third octave bands should not exceed 78 dB. Comparison with modelled data given in Table 3 shows that although the unprotected levels are considered sufficient to cause symptoms of ultrasonic sickness, the chosen HPD should provide more-than-adequate ultrasound protection in this instance. Paper sheeting of the weight used in this experiment, however, would not provide sufficient protection for the user.

1/3 Octave Band Cenrte Frequency	Lewis Cleaner Noise Emission	Willson Silencer Mean Attenuations	Estimated At-Ear Levels
6.3 kHz	64	41.1	22.9
8 kHz	71	37.7	33.3
10 kHz	75	32.3	42.7
12.5 kHz	56	42.2	13.8
16 kHz	97	43.2	53.8
20 kHz	103	38.9	64.1

Table 3. Estimated At-Ear Sound Levels in dB at the Operator Position of a Lewis Type L/C 136H Ultrasonic Cleaner, assuming the use of Willson Sound Silencer Earplugs

CONCLUSIONS

The efficacy of using an ATF for the measurement of HPD attenuation at ultrasonic frequencies has been demonstrated in this study. It has also been shown that any one of the HPDs evaluated in this study is capable of providing sufficient protection against the noise produced by the Lewis L/C 136H ultrasonic cleaner. However, improvised noise shielding e.g., paper or foam products, may not provide sufficient protection.

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