inter·noise 96
25th Anniversary Congress – Liverpool

INCE: 36.1

ASSESSING HEARING PROTECTORS FOR USE IN IMPULSIVE NOISE

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1. INTRODUCTION

There are no standards for assessing whether hearing protectors (muffs) are capable of providing adequate protection in impulsive noise. Muff attenuation in impulsive noise is either measured during use or it is estimated from manufacturer's data for continuous noise. Muff attenuation during gunfire was measured and estimated. The methods used to measure and estimate peak attenuation are described here. A comparison of the measured and estimated peak attenuation is also given for the different types of muffs tested ie traditional passive, passive level-dependent and sound restoration level-dependent.

2. MEASURING MUFF ATTENUATION

Attenuation measurements

Muff attenuation can be obtained by measuring the insertion loss (the difference between the sound pressure level (SPL) at the ear with and without the muff worn) or the transmission loss (the difference between the SPL outside and under the protector). The insertion loss method gives results closest to the real ear attenuation at threshold (REAT) method described in BS EN 24869-1: 1993 [1]. However in high SPLs it is not safe to make measurements at the unprotected ear and transmission loss measurements are preferred. Previous laboratory measurements have shown that in high levels of impulsive noise the differences between the insertion loss and the transmission loss are within 3 dB for traditional passive, passive level-dependent and sound restoration level-dependent muffs.

Measurement of the peak SPLs outside and under the muff

A free field quarter-inch microphone capable of measuring up to 164 dB was used to measure impulsive noise outside the muff. It was positioned at grazing

incidence, ie the microphone was perpendicular to the sound field, to limit the effects of ringing that can lead to incorrect measurements of peak pressure.

For measurements on human subjects, a miniature microphone fitted in the cavum of the concha measured the SPL under the muff. The microphone has been used to measure peak SPLs up to 143 dB without overloading. The signals from the microphones outside and under the muffs were recorded digitally using a DAT recorder.

3. ANALYSES

The peak pressures recorded outside and under the muff were measured directly from the time history of the pressure variations. The peak SPL measured under the muff was subtracted from the peak SPL outside the protector to give the peak attenuation.

The SPLs under the muff are higher than those that would exist in an equivalent unobstructed sound field because sound is reflected and diffracted around the head and ears. Laboratory measurements have shown the SPL at the microphone positioned in the cavum of the concha is increased by up to 2 dB which results in an underestimate of the peak attenuation. However these differences are small compared to those that can occur between individuals due to fit etc and so no corrections were made to compensate for the increased SPLs under the muff.

The signals recorded outside and under the muff were analysed into one-third octave band levels using a one-second linear averaging time triggered by the start of the impulse. This data was used to estimate the peak attenuation from BS EN 24869 attenuation data.

4. ESTIMATING PEAK ATTENUATION OF MUFFS

Method using BS EN 24869 attenuation data

In the absence of standards, the peak attenuation of a muff is estimated by subtracting the BS EN 24869 assumed protection from the unweighted octave band levels measured outside the muff. The peak attenuation is taken as the difference between the summed octave band levels outside the muff with and without the BS EN 24869 assumed protection subtracted.

BS EN 458 [2]

A method for estimating the peak SPL at the ear when hearing protection is worn is described in Annex B of BS EN 458: 1994. It is valid for impulsive noise that is dominated by middle-to-high frequencies, not low frequency impulsive noise.

The frequency characteristics of the noise source are determined by measuring the maximum rms values of the C-weighted (L_{CFmax}) and A-weighted (L_{AFmax}) SPLs with a sound level meter with a FAST time constant. When

L_{CFmax} - L_{AFmax} < 5 dB, the peak SPL under the muff is estimated by subtracting the muff M-value from the measured peak value. (The M-value is obtained from the BS EN 24869 octave band attenuation data of a muff using the method described in BS ISO 4869-2: 1994 [3].)

The BS EN 458 method was tested with impulsive noise from rifles that was dominated by frequencies between 250 and 500 Hz (L_{CFmax} - L_{AFmax} ~ 4 dB). For sound restoration level-dependent muffs the BS EN 458 predicted peak attenuation was higher than the measured attenuation. Therefore using this method it would be possible to overestimate muff attenuation which could result in people being exposed to higher peak sound pressure levels than was estimated. For the traditional passive protectors and the passive level-dependent protectors the estimated peak attenuation was lower than the measured peak attenuation.

5. MUFF PERFORMANCE IN IMPULSIVE NOISE

The transmission loss values for a range of muffs (traditional passive, and passive and sound restoration level-dependent protectors) were measured during normal use in impulsive noise from firearms. Measurements were made with handguns on indoor ranges, shotguns and rifles outside, and during the proof-firing of shotgun cartridges. The peak SPLs of the different firearms ranged from 135 to 162 dB, with dominant frequencies between 250 and 2000 Hz. The measured and estimated peak attenuation values are given in Table 1.

TABLE 1: Measured and estimated peak attenuation

Impulsive Noise		Peak Attenuation dB					
Peak sound pressure level dB	Dominant Frequency Hz	Traditional Passive		Passive level-dependent		Sound restoration level-dependent	
		Measured	Estimated[1]	Measured	Estimated[1]	Measured	Estimated[1]
153 - 162	250 - 500	36	15 (24)[2]	25	12 (21)[2]	26	17 (28)[2]
135 - 143	500	31	19	17	17	26	23
154 - 156	500	29	23	20	19	28	23
156 - 158	1000	22	21	21	15	23	18
143 - 146	2000	33	26	19	19	28	24
150 - 154	2000	30	24	24	19	31	27

Notes: [1] Estimated using BS EN 24869 attenuation data
[2] Estimated using BS EN 458 method

Traditional passive muffs

The measured peak attenuation for the traditional passive muffs was between 22 and 36 dB. These protectors generally gave higher attenuation in impulsive noise than the level-dependent muffs. The peak attenuation estimated using BS EN 24869 assumed protection was close to or lower than the measured peak attenuation for all impulsive noise sources.

Passive level-dependent muffs

Currently there is only one passive level-dependent muff commercially available. This muff gave consistently lower peak attenuation than the traditional passive and the sound restoration level-dependent muffs. The measured peak attenuation was between 17 and 25 dB. The peak attenuation estimated using BS EN 24869 assumed protection was close to or lower than the measured peak attenuation for all sources of impulsive noise.

Sound restoration level-dependent muffs

The measured peak attenuation for the sound restoration level-dependent muffs were between 23 and 31 dB. These peak attenuation values were similar to those obtained for the traditional passive muffs. The estimated peak attenuation calculated using BS EN 24869 assumed protection was close to or lower than the measured peak attenuation for all sources of impulsive noise.

Measurements with rifles showed that sound restoration level-dependent muffs with large volume cups gave higher peak attenuation than those with small volume cups; the peak attenuation was between 19 and 23 dB for small volume cups, and between 23 and 31 dB for large volume cups.

When sound restoration level-dependent protectors are worn in high peak sound pressure levels, the level under the muff is dominated by attenuated sound and the electronic muffs behave as traditional passive muffs. Measurements showed that there is less than 3 dB difference between the attenuation measured with the volume control off and with the volume control full on.

6. CONCLUSIONS

In the absence of standards, the most accurate way of determining the effectiveness of a muff in a particular impulsive noise environment is to measure the attenuation in-situ. However if it is not possible to measure muff attenuation, then it can be estimated using one of two methods: using BS EN 24869 assumed protection data or the method described in BS EN 458. Both methods generally give estimated peak attenuation close to or lower than the measured attenuation. Therefore users will be over rather than underprotected by estimating the muff attenuation. Additional work is planned to investigate further the BS EN 458 method since so far it has only been tested using impulsive noise from rifles.

References

[1] 'Sound attenuation of hearing protectors. Part 1: Subjective method of measurement', BS EN 24869-1: 1993

[2] 'Hearing protectors - Recommendations for selection, use, care and maintenance - Guidance document.', BS EN 458: 1994

[3] 'Acoustics - Hearing protectors. Part 2: Estimation of effective A-weighted sound pressure levels when hearing protectors are worn.', BS ISO 4869-2: 1994