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THE EFFECTS ON THE ACOUSTICAL PERFORMANCE OF SOME EARMUFFS OF NORMAL INDUSTRIAL USE

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INTRODUCTION

It is generally assumed that the performance of hearing protectors when worn in industry is predictable from laboratory-based measurements on new protectors. Such tests do not consider the effects of poor fitting of hearing protectors when worn in the factory nor the deterioration of the protectors performance due to normal wear and tear.

The study that is described here examined the effects of normal wear and tear on the protectors' acoustical performance. The study was one part of a larger, more general, investigation. Although only a few samples of earmuff were tested, the results indicate that earmuffs are more durable than is generally assumed.

BACKGROUND

Hearing protectors that are used in the United Kingdom are normally tested according to two British Standards BS 5108 (1) and BS 6344 (2).

The first standard, BS 5108, employs trained subjects tested in laboratory conditions wearing the protectors. It is these results which are used to predict the noise levels at the ears of industrial users using the methods described by the Health and Safety Executive (3). This states that the "assumed protection" is the group mean attenuation minus one standard deviation, and as such 84% of the wearers would receive at least the assumed protection or greater.

The second standard, BS 6344 (1984) describes a series of objective performance tests for earmuffs two of which test the insertion loss provided by individual cups of a protector and the headband tension. Other parts of this standard test for seal leakage, resistance to impacts, etc.

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When this small study was planned it was proposed to test 15 samples of Racal Ultramuff II earmuffs before and after 6 weeks of normal industrial use. The choice of 6 weeks was arbitrary but it enabled each device to be given a reasonable period of service without being lost or damaged beyond use. At a later date six samples of the same model, which had been used for one year, and six Bilsom Viking defenders, which had been heavily used for 4 weeks in a foundry, were obtained for testing. Even later still, a single Racal Ultramuff II was obtained which was still being worn despite tears in the seals. All the used protectors were tested in the laboratory and the results were compared with those for unused protectors of the same model tested on the same subjects.

EXPERIMENTAL PROCEDURE

The real-ear test procedure described in BS 5108 (1983) requires at least 10 subjects to be tested in a purpose built test facility when they are wearing the protectors. A test signal is played to the subject through an array of loudspeakers. The test signal is pulsed 1/3-octave band pink noise. The level of the test signal is varied by a switch controlled by the test subject. He presses the switch when he can hear the signal and releases the switch when the signal is inaudible. This causes the test signal to rise and fall in level. The mean value of the test signal indicates the subjects threshold of hearing. He is tested wearing the protector and with his ears unoccluded, the difference in the two hearing thresholds indicates the subjective attenuation of the protector. The acoustical attenuation of the protector is described by the group mean attenuation and the standard deviation across the sample of subjects.

The insertion loss measurement procedure described in BS 6344 (1984) is carried out using an Acoustic Test Fixture. This comprises a body and base on resilient mounts designed to accommodate a pressure microphone and pre-amplifier. It enables the insertion loss of each cup to be measured separately by recording the microphone outlet when the microphone is covered by the cup then uncovered in the same acoustic field.

The headband tension meter enables the headband tension to be measured when the cups of the protector are a pre-determined distance apart.

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The 15 Racal Ultramuff II protectors which were chosen for the initial study were each tested once on only one subject. Each protector was marked and the names of the subjects and the protectors they wore were noted. Insertion loss and headband tension measurements were also measured. The company nurse in the firm that assisted in this exercise was asked to issue the protectors to people who habitually wore protection and to return them to the laboratory after the sixweek period. When the devices were returned from the factory they were tested objectively, cleaned, tested objectively again and then tested subjectively. The only obvious signs of wear were a small split on the inside of one seal and one headband was deformed.

The second batch of protectors that were used comprised six Racal Ultramuff II defenders, used for 1 year in a press shop, and six Bilsom Viking defenders which had been used for four weeks in a foundry. All these protectors were considered to be no longer effective by the safety officers.

Despite the dirt, grease and stiffened seals, the protectors were in reasonably good condition. One of the Bilsom Viking protectors had a seal missing so for the purposes of this study one seal was tested on two earmuffs.

The last protectors used in the study were a single Racal Ultramuff II with badly torn seals and a new Bilsom Viking. The Ultramuff was being worn up to the moment it was acquired for these tests.

When only one protector was available then all six subjects were tested wearing it. When six protectors were available which had a similar history then each device was tested once on one subject only.

None of the devices tested was found to have any damage to the protector shells other than scratches.

It should be stressed that there was no significance in the choice of protectors used in the study.

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RESULTS

The group mean attenuation values and standard deviations averaged over six sets of data are given in tables 1 and 2. The Racal Ultramuff II results are also shown graphically in figure 1.

Tables 3 and 4 give the insertion loss measurements for the new and used earmuffs.

The headband tension measurements are summarised in table 5.

DISCUSSION

The mean attenuations for the four groups of Ultramuff data show a small and progressive loss in attenuation with usage. After 6 weeks of use the attenuation appears to stabilize, provided neither the seals nor the cups are damaged. The protector with the torn seals shows a considerable loss in performance of up to 10dB at some frequencies.

The standard deviations for six protectors after 6 weeks use and 1 years use are similar and generally greater than the standard deviations for the unused protectors.

An analysis of variance was carried out on the test results with and without the "torn-seal" data included. When the "torn-seal" data was not included then there was no statistically significant difference between the sets of data for protectors having had different degrees of usage. With the "torn-seal" data included statistical significance was obtained at the 1% level due to different degrees of usage.

A multiple comparison test (Fisher LSD test) confirmed there was no significant difference between the first three sets of data although there appears to be a trend for the frequency averaged mean protector attenuation to deteriorate slightly with initial use then stabilize. This is illustrated in figure 2. The loss in mean attenuation between groups 1 and 2 is about 3dB, which is the order of magnitude of the standard deviation for this protectors when tested according to BS 5108.

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The Bilsom Viking earmuffs show a small loss of attenuation at low and high frequencies due to use. A t-test was carried out on these results which gave statistical significance at the 5% level at 3.15kHz and 4kHz where the loss in attenuation was only 3 to 4 dB. The reduction in the frequency averaged mean attenuator performance due to use was 2.6dB.

Since the average reduction in real-ear attenuation with use for these types of protectors is about 3dB for undamaged seals, it might be reasonable to re-define the "assumed protection" to be the group mean minus two standard deviations.

The insertion loss measurements for both types of earmuff do not show an obvious trend after 6 weeks use. The Ultramuff protectors which had 1 years use show a loss over the whole frequency range, when compared to new protectors, with more than 10dB reduction at some frequencies. This maybe due to hardening of the seals. A further reduction in attenuation occurred when the seals were torn.

The Racal Ultramuff II earmuffs had an average reduction in headband tension of 18.5% after 6 weeks use from 10.18N to 8.25N. After 1 years use the average headband tension was 8.1N.

The Bilsom Viking protectors had no deterioration in headband tension after 6 weeks use.

CONCLUSIONS

1. The real-ear attenuation of protectors appears to reduce slightly, but not significantly, with initial use and then stabilize provided the seals and cups are not punctured.

2. Puncturing of the seals gave a considerable loss in low and mid-frequency attenuation of up to 10dB at some frequencies.

3. After 1 year of use Racal Ultramuff II protectors gave good attenuation in spite of hardening of the seals.

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4. The primary factor controlling real-ear attenuation appears to be physical damage to the cups and seals. Headband tension appears to be of secondary importance.

5. The average loss in real-ear attenuation with use when neither the cups nor the seals are punctured is about 3dB.

6. A re-definition of the "assumed protection" might be the group mean minus two standard deviations to allow for normal wear and tear.

7. The objective insertion loss measurements show a progressive loss in performance with use.

ACKNOWLEDGEMENT

This study was carried out with the support of the Health and Safety Executive. The opinions expressed are those of the authors and are not necessarily shared by the sponsor.

REFERENCES

1. BS 5108 (1983) Measurement of Sound Attenuation of Hearing Protectors. British Standards Institution. London

2. BS 6344 (1984) Industrial Hearing Protectors. Part 1 - Specification for Earmuffs. British Standards Institution. London

3. Department of Employment (1972) Code of Practice for Reducing the Exposure of Employed Persons to Noise. HMSO. London

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		1/3 Octave Band Centre Frequency, Hz									
		63	125	250	500	1k	2k	3.15k	4k	6.3k	8k
6 New, Unused Protectors:	Mean	16.3	9.3	15.5	23.3	34.2	33.5	34.2	32.0	27.5	31.8
:	Standard Deviation	3.9	3.7	3.8	5.8	4.0	4.5	1.8	3.0	4.8	4.3
6 Protectors, 6 Weeks Use:	Mean	12.7	9.0	13.3	20.3	29.0	31.5	32.5	28.0	23.7	26.5
:	Standard Deviation	6.0	5.0	8.2	6.1	5.7	5.3	3.2	5.6	7.3	6.6
6 Protectors, 1 Years Use:	Mean	10.8	8.2	12.2	20.8	30.3	32.2	33.7	31.0	22.8	24.5
:	Standard Deviation	6.8	5.0	6.7	6.7	6.2	3.9	1.8	2.5	6.5	4.9
1 Protector, 1 Years Use,: Torn Seals	Mean	8.2	3.8	4.5	10.5	20.8	25.0	30.5	34.0	21.0	24.7
:	Standard Deviation	5.8	3.0	4.0	3.3	2.3	2.9	3.0	2.0	5.5	5.5

TABLE 1: Real-ear Attenuation of New and Used Racal Ultramuff 11 Earmuffs.

		1/3 Octave Band Centre Frequency, Hz									
		63	125	250	500	1k	2k	3.15k	4k	6.3k	8k
1 New, Unused Protector:	Mean	14.8	11.7	19.3	30.8	38.3	30.2	37.8	41.8	38.2	38.3
:	Standard Deviation	2.7	2.9	1.7	2.1	2.1	1.5	2.1	5.6	3.3	4.7
6 Protectors, 4 Weeks Use:	Mean	11.8	11.0	17.0	26.5	35.2	32.3	34.3	37.7	35.3	34.2
:	Standard Deviation	4.8	3.9	3.0	3.1	4.5	3.2	2.1	2.6	5.0	3.8

TABLE 2: Real-ear Attenuation of New and Used Bilsom Viking Earmuffs.

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		1/3 Octave Band Centre Frequency, Hz									
		63	125	250	500	1k	2k	3.15k	4k	6.3k	8k
12 New, Unused Cups:	Mean	13.2	8.1	16.0	31.5	44.5	47.8	37.9	33.1	36.1	34.6
:	Standard Deviation	2.1	1.5	0.8	1.2	0.5	3.2	2.4	1.8	1.6	1.1
12 Cups, 6 Weeks Use:	Mean	11.9	5.3	18.8	33.2	46.5	49.5	39.9	32.9	36.1	36.2
:	Standard Deviation	1.6	1.8	1.1	0.9	1.0	3.3	1.7	1.8	2.1	2.0
12 Cups, 1 Years Use:	Mean	4.1	4.6	6.9	21.3	34.9	47.7	36.8	28.2	25.9	26.2
:	Standard Deviation	7.1	5.4	8.2	8.5	8.0	5.7	5.6	7.6	4.9	7.9
2 Cups, 1 Years Use, Torn Seals:	Mean	6.5	2.1	6.5	20.0	30.9	43.8	32.9	24.1	19.7	25.7
:	Standard Deviation	-	-	-	-	-	-	-	-	-	-

TABLE 3: Insertion Loss of New and Used Racal Ultramuff II Earmuffs.

		1/3 Octave Band Centre Frequency, Hz									
		63	125	250	500	1k	2k	3.15k	4k	6.3k	8k
2 New, Unused Cups :	Mean	14.7	12.0	23.1	33.8	47.6	36.3	44.1	43.2	39.5	41.8
:	Standard Deviation	-	-	-	-	-	-	-	-	-	-
12 Cups, 6 Weeks Use:	Mean	13.8	13.6	20.4	33.1	43.8	41.3	37.7	39.9	39.1	37.1
:	Standard Deviation	2.1	1.4	2.2	2.4	3.1	2.9	2.2	2.2	2.7	2.9

TABLE 4: Insertion Loss of New and Used Bilsom Viking Earmuffs.

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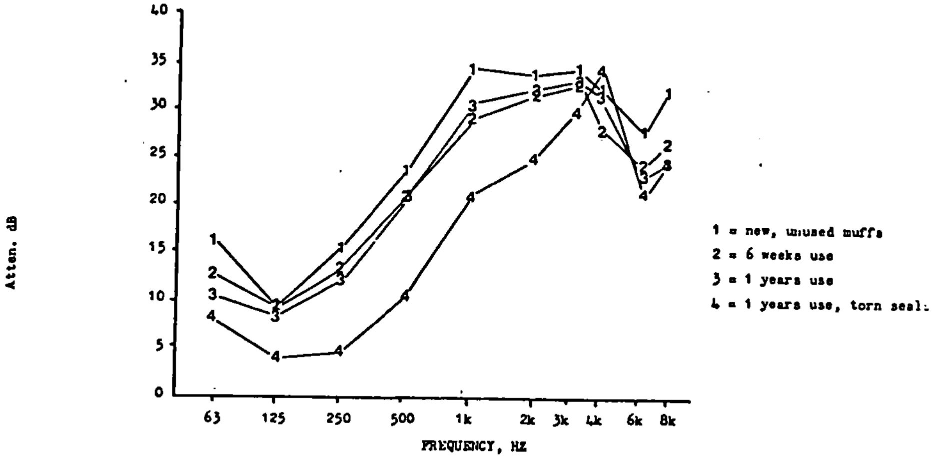

Fig. 1: Real-Ear Attenuation of Racal Ultramuff II Earmuffs. Ageing of Protectors.

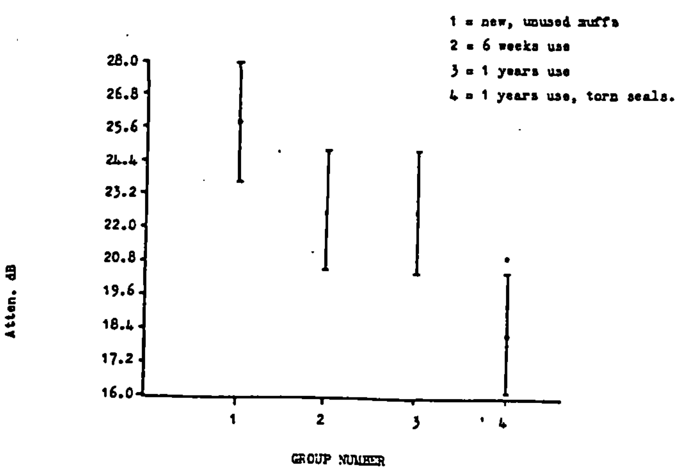

Fig. 2: Multiple Comparison Test Results for Racal Ultramuff II Earmuffs.