Proceedings of the Institute of Acoustics

REAL FINGERS IN REAL EARS

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1. INTRODUCTION

Following on from a warning of an impending short noise event or when suddenly exposed to a loud noise, for instance by the opening of a door in a factory, the natural instinct of most persons is to cover their ears in some way usually by use of their hands. There is of course, for most people, a limit to the length of time that the hands can be held in such a protect position and instinct based perhaps on past experience usually dictates the way in which the hands are used and the protection effected. For instance some people cup their hands over their ears and this appears to be a common response (see test procedure). Some place their fingertips in the entrance of the ear canal, to a greater or lesser extent, and some, using their finger tips, depress the tragi over the entrance to the ear canal.

Although some measurements have been reported on the attenuation provided by these actions we are not aware of any that have been carried out in a systematic manner using the detailed procedure laid down in a European standard BSEN 24869-1[1] for the measurement of the performance of ear protectors. This procedure provides a standardised method of determining the sound attenuation in terms of the mean value and standard deviation in octave bands over the audio frequency range using a statistically valid group of sixteen people with normal hearing. Data from these tests are used to select hearing protectors for use in both continuous, quasi continuous and impulsive noise and, at present, provide the best available means for such selection. The method appears the most pertinent one to use to assess the use of hands as protectors, not least, because the results can be compared directly with published data for purpose made protectors.

2. DESCRIPTION OF TEST

The BS EN 24869 test is essentially an "insertion" loss test using the hearing of real persons as the detector system. It is therefore subjective method depending upon the judgement of individuals. The advantage is that real ears with realistic physical differences not only of the ears but of the surrounding body structure and tissues are used so that practical "fitting" situations are accounted for to some extent. To ensure a proper statistical assessment is made sixteen subjects are used and a mean of the responses taken.

Essentially the subject's head is placed in a uniform sound field and the level of that sound field is incresed until the subject indicates that it can be heard i.e. the sound field has been reduced to the subjects threshold of hearing. The hearing protector or in this case the hands are placed in position

and the process repeated. The difference between the two thresholds gives the sound attenuation of the protection. It is essential that the sixteen subjects are a representative cross-section of the adult population at large and great care is taken during their selection. The first requirement is that each subject shall have a hearing threshold level by earphone listening in either ear of no more than 15dB (re 20 μPa) at frequencies of 2000Hz or below and of no more than 25dB above. The second is that they shall be selected without regard to the sizes and shapes of heads and ears except that those with obvious abnormalities are excluded. It is also essential that the subjects are practised in the audiogram technique because the third requirement is that they are able to provide three consequitive complete audiograms with differences between the thresholds of hearing at corresponding centre frequencies not exceeding 6dB.

3. TEST FACILITY

The test rig comprises a framework that holds four loudspeakers at the corners of a tetrahedron of side approximately 2m. In practice the fourth loudspeaker is hung from the ceiling and the remainder of the "tetrahedron" aligned to it. The loudspeakers all face a reference point, defined as the mid point of a line connecting the test subjects ear canal openings, which is the approximate centre of the tetrahedron. To ensure that each test subject is in the correct location the subject is seated on an adjustable chair and positioned at the reference point before the test commences. The head is not held rigidly and to allow for normal movement during test the sound field in the volume surrounding the head is carefully controlled. Diffuse sound field conditions are required but the necessity to ensure that the background sound level is sufficiently below the normal threshold of hearing requires that the tests are conducted in an anechoic or hemi-anechoic environment rather than a reverberant one. To create approximate diffuse field conditions the test field around the reference point is checked to ensure that deviations from one point to another meet the requirements defined in the standard and that it is sufficiently omnidirectional.

Further checks are carried out to ensure that the background noise does not exceed defined maxima and that the reverberation time within the test space is lower than 1.6secs in each band.

The test signal consist of one-third octave bandwidth pink noise reproduced at octave band centre frequencies in the range 63Hz to 8kHz. To assist with the field diffusivity the four generators are used so that the signal from each loudspeaker is incoherent. The range of the test signal is sufficient to create a sound pressure level in the sound field from 90db down to –20dB in 2.5dB steps (at 2000Hz and above, slightly less limits for lower frequencies) and the accuracy of the attenuator steps is further controlled.

4. TEST PROCEDURE

Normally, four samples of hearing protector are used, distributed amongst the test subjects. In this instance of course subjects provided their own protection.

The test subjects were fully informed of the requirements before test and were instructed that the test was to determine the sound attenuation that is likely to be obtained by an informed and conscientious person using their own hands in the prescribed way. As a means of introduction, the operator met them, with the words " if I were to give you a warning that a loud noise is about to be turned on what would you do". The reaction, invariable to cup their hands over the ears, was observed and the operator then commented on the best way to hold the hands and arms for each section of the test. The subjects were allowed to try the techniques with the sound field on and to find the most comfortable position. Prior to each test each subject was asked to make several fully extended up-down and left-right rotational movements of the head followed by vigorously saying "ah-ee" several times in order to fully open and close the lower jaw.

Three separate tests were completed:

1) With the fingers inserted in the outer ear canals, elbows held close to the body

2) With the ears cupped by the hands, elbows held close to the body

3) With the tragi depressed into the outer ear canal openings by the index fingers.

This latter test and a similar test to 2) had been completed at an earlier date using a different test panel but using the same test rig, facility and test procedure.

The normal test procedure requires the operator to manually control the output attenuator of the four-channel audiometer by responding to a light which the subject switches on by depressing a "silent" hand-held switch each time the test signal is heard. In this instance, the hand-held silent-switch was replaced by a "silent" foot-switch. Responding to the lights the operator follows a defined procedure [2] of passing through the subjects threshold of hearing in several directions to obtain the threshold itself before noting the attenuator setting. This procedure is repeated for each centre frequency starting and finishing at 1kHz as a consistency check. The threshold of hearing with open ears and with the protection in place was measured once for each subject for each protection method.

The method of instruction and the foot switch were the only changes to the standard procedure that is followed for all ear protector tests.

5. RESULTS

TEST 1 Fingers inserted in outer ear canals

Mean Attenuation	37.6	41.7	34.0	31.1	31.1	33.8	36.4	39.6
Standard Deviation	6.5	7.9	7.7	9.7	6.7	4.9	5.3	7.5
$*APV_{f84}$	31.1	33.7	26.3	21.5	24.3	28.8	31.1	32.2
	$*H_{84}$ 29		$*M_{84}$ 25		$*L_{84}$ 24		SNR_{84} 28	

TEST 2 Hands cupped over ears

Mean Attenuation	34.7	32.6	23.3	19.8	27.0	28.3	40.6	37.3
Standard Deviation	5.0	6.0	6.4	5.2	7.8	6.1	6.4	8.2
APV_{f84}	29.7	26.5	16.9	14.5	19.2	22.2	34.3	29.1
	H_{84} 24		M_{84} 19		L_{84} 17		SNR_{84} 22	

TEST 2 (earlier repeat) Hands cupped over ears

Mean Attenuation	33.1	30.9	20.8	16.3	20.6	26.9	35.0	34.2
Standard Deviation	5.3	7.0	6.1	6.1	6.1	8.9	9.4	10.9
APV_{84}	**27.7**	**23.9**	**14.6**	**10.2**	**14.5**	**18.0**	**25.6**	**23.2**
	H_{84} 19		**M_{84} 14**		**L_{84} 13**		**SNR_{84} 18**	

TEST 3 Fingers holding tragi over ear canal openings

Mean Attenuation	34.3	38.9	31.2	26.1	27.9	33.7	33.8	30.8
Standard Deviation	7.5	9.0	5.5	5.9	4.7	4.3	6.5	10.7
APV_{84}	**26.8**	**29.9**	**25.7**	**20.2**	**23.2**	**29.4**	**27.3**	**20.0**
	H_{84} 25		**M_{84} 23**		**L_{84} 23**		**SNR_{84} 25**	

* for definitions and method of calculation see [3]

6. DISCUSSION

The three methods of self protection are compared in terms of the assumed protection value (APV) as defined in [4] i.e. The mean attenuation minus one standard deviation in figure 1. Included is a second set of data using hands cupped over the ears. This was obtained during an earlier experiment when the observer did not define the procedure to be adopted quite as rigorously and there was no requirement to keep the elbows close to the body. In general the use of fingers in the outer ear canal or pressing the tragi across the opening of each canal provided the best protection value. The use of fingers alone was better than the use of tragi at both low and high frequencies. Cupping the hands over the ears generally produced lower values of APV and the differences of 2-5dB at mid frequencies between the two sets of cupped hands results clearly highlights the problem of holding the hands in place.

Fig 1 Assumed Protection Value

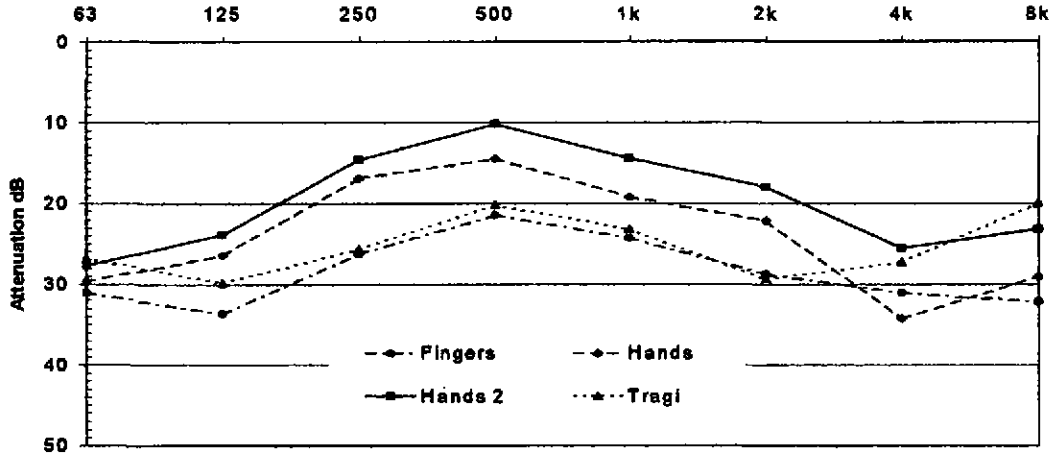
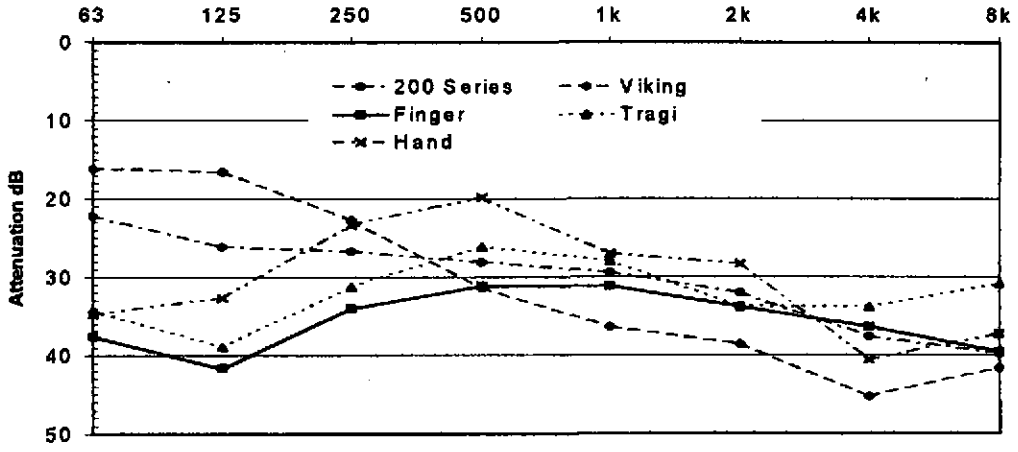


Figure 2 compares the three methods of self protection with the manufacturers defined performance of a readily available ear plug and ear defender. These results are in terms of the

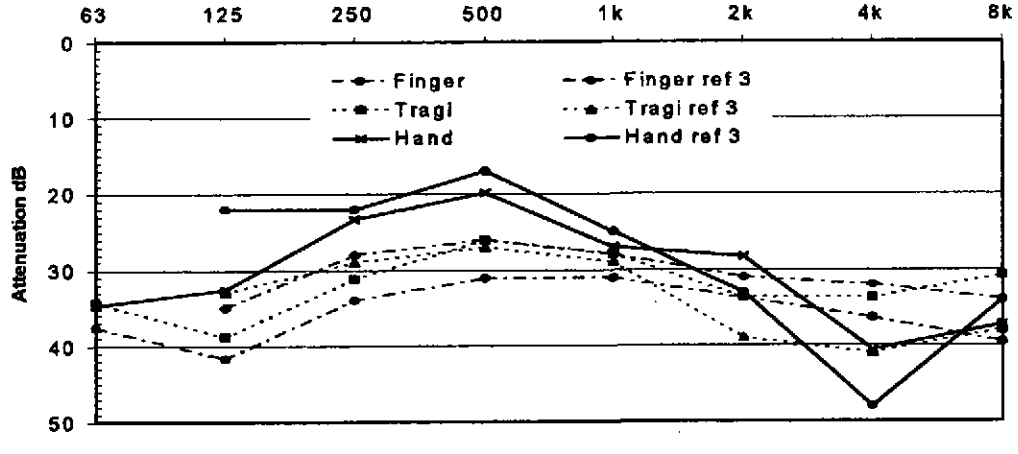
mean sound attenuation. Rather surprisingly the mechanical protectors both perform worse at low frequencies and the finger performs in a similar manner to the plug at mid and high frequencies. This type of ear defender provides the best performance at high frequencies.

Fig 2 Mean Sound Attenuation



The experimental results are compared with another set of data [5] in figure 3. In this case the alternative data were obtained using an earlier American standard procedure which utilised one loudspeaker and a set of test tones. Comparing like with like, each method compares quite favourably although there are some obvious differences which may owe as much to the method as to the measurement procedure.

Fig 3 Mean Sound Attenuation



7. CONCLUSIONS

The use of the hands either in the form of cupped hands over the ears, fingers in the ear canals or tragi depressed into the ear canal openings provide a useful means of hearing protection which is almost always readily available for instant use. Clearly the ability to maintain the measured attenuation values may be limited with time and the fact that the hands cannot be used for anything else means that these methods are no substitute for standard hearing protectors. . It should also be noted that, below 500Hz, self-generated masking sounds have resulted in a slight overestimation of the attenuation. However all three methods performed as well as commercially available devices. The use of a finger in the outer ear canal providing a mean protection value in excess of 20dB.

8. REFERENCES

[1] BS EN 24869-1:1993, Acoustics – Hearing protectors – Subjective method for the measurement of sound attenuation.

[2] ISO 8253-2 Acoustics – Audiometric test methods – Part 2: Sound field audiometry with pure tone and narrow band sound fields.

[5] BS EN ISO 4869–2: 1995, Acoustics – Hearing protectors – Estimation of effective A–weighted sound pressure levels when hearing protectors are worn.

[4] Reducing Noise at Work – Guidance on the Noise at Work Regulations, 1989, HSE L108, HMSO 1998.

[5] Attenuation provided by Fingers, Palms, Tragi and V15R Ear Plugs,
Holland, H. H. Jnr., (1967), J.Acoust.Soc.Am. 41(6), 1545.