International Standard 4869

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Acoustics — Measurement of sound attenuation of hearing protectors — Subjective method

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4869 was developed by Technical Committee ISO/TC 43, *Acoustics*, and was circulated to the member bodies in May 1977.

It has been approved by the member bodies of the following countries :

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Acoustics — Measurement of sound attenuation of hearing protectors — Subjective method

0 Introduction

Hearing protectors are commonly used to reduce to acceptable levels the noise to which the ear is exposed. Hearing protectors are manufactured as ear-plugs, ear-muffs or helmets. Standardized methods of measurement of sound attenuation allow the comparison of performance data obtained in different locations under similar conditions, the rank ordering and selection of various models and the evaluation of design and construction features that may significantly affect performance.

NOTE — Methods other than the one described in this International Standard do not necessarily yield values which are equal to those obtained according to the present International Standard.

1 Scope and field of application

This International Standard specifies a subjective method for the measurement of sound attenuation of hearing protectors determined at the threshold of audibility.

2 References

ISO 266, *Acoustics — Preferred frequencies for measurements.*

ISO 389, *Acoustics — Standard reference zero for the calibration of pure-tone audiometers.*

IEC Publication 225, *Octave, half-octave and third-octave band filters for the analysis of sounds and vibrations.*

IEC Publication 263, *Scales and sizes for plotting frequency characteristics.*

IEC Publication 645, *Audiometers.*

3 Definitions

3.1 hearing protector : A device worn by a person to prevent unwanted auditory effects from acoustic stimuli.

NOTE — Hearing protectors may also include electronic devices for communication or devices designed to play an active role in the reduction of the noise level between the hearing protector and the ear-drum.

3.2 ear-muff : A hearing protector consisting of an ear-cup to be pressed against each pinna or of a circumaural ear-cup to be pressed against the head around the pinna. The ear-cups can be pressed against the head with a special headband or neckband or by means of a device attached to a safety helmet or other equipment.

3.3 ear-plug : A hearing protector worn within the external ear canal (aural) or in the concha against the entrance to the external ear canal (semi-aural).

3.4 helmet : A device which may or may not include hearing protection and which covers a substantial part of the head.

3.5 hearing threshold level : For a given ear and for a specified signal, the number of decibels by which the threshold of hearing for that ear differs from the normal threshold of hearing as given in ISO 389.

3.6 threshold of audibility : For a given listener, the minimum sound pressure level of a specified sound that is capable of evoking an auditory sensation in a specified fraction of trials.

NOTE — For the purpose of this International Standard, the threshold of audibility is measured without and with the hearing protector.

3.7 sound attenuation : At a given test signal, the mean value of the differences, in decibels, between the thresholds of audibility with and without the hearing protector in place for all test subjects.

3.8 pink noise : Noise whose sound pressure spectral density is inversely proportional to frequency.

4 Measurement of the sound attenuation of hearing protectors

4.1 Test signals

The test signals shall consist of a signal from pink noise filtered through one-third octave bands with centre frequencies in

accordance with IEC Publication 225. Tests shall be performed at the following centre frequencies :

63 Hz (optional)
125 Hz
250 Hz
500 Hz
1 000 Hz
2 000 Hz
3 150 Hz (optional)
4 000 Hz
6 300 Hz (optional)
8 000 Hz

NOTE — In cases where it is thought that the sound attenuation of the hearing protector under test varies greatly as a function of frequency, measurements shall be taken at relevant additional one-third octave band centre frequencies selected from ISO 266.

4.2 Test site

4.2.1 The ideal test site is a random-incidence field which reflects the use under live conditions. This sound field is approximately achieved when the field meets the following requirements :

The reference point is defined as the midpoint of a line connecting the listener's ear canal openings. With the subject absent, the sound pressure level shall be measured with an omnidirectional microphone at six positions. These positions shall be 15 cm from the reference point on the front-back, right-left and up-down axes. The sound pressure level tolerance shall be ± 2,5 dB maximum relative to the reference point. Further, the difference between the right-left positions shall not exceed 3 dB.

At test bands with a centre frequency of 500 Hz and above, the sound pressure level at the reference point shall be within 5 dB for any two directions of measurement of the incident sound energy.

With some available directional microphones, the measured field variations may be smaller. The relationship between the front-to-random sensitivity index of the microphone and the measured field variations is given in table 1.

The desired sound field may require the use of more than one (multiple) loudspeaker(s) in the test room. If more than one loudspeaker is used to produce the desired sound field, the loudspeaker may require to be fed with non-coherent electrical signals to eliminate standing waves and other wave interference effects.

If a reverberant chamber is used as the test room, then it must be ascertained that the natural acoustic time-constant does not prevent compliance with the test signal rise and fall times specified in IEC Publication 645.

Table 1

Front-to-random sensitivity index	Measured field variation
dB	dB
5	5
4	4
3,5	3,0
3	2,5
< 3	Microphone unsuitable

4.2.2 The background noise at the test site in the test room shall not exceed the values given in table 2 with the listener absent.

Table 2

Centre frequency	One-third octave band pressure (re 20 µPa)
Hz	dB
31,5*	57
63	25
125	14
250	6
500	2
1 000	1
2 000	2
3 150	−1
4 000	−4
6 300	3
8 000	10

* For a minimum test band centre frequency of 125 Hz, the background noise requirement shall be met down to and including 63 Hz. For a minimum test band centre frequency of 63 Hz, the background noise requirement shall be met down to and including 31,5 Hz.

Compliance with the values given in table 2 may be ascertained by two methods :

Method A

The background noise shall be determined by direct measurement of the sound pressure level.

Method B

The threshold of audibility for at least three listeners with thresholds of hearing known to be better than normal shall be measured under conditions in which the sound attenuation tests are to be conducted. If the average threshold of hearing at each test frequency is no greater than the values listed in table 2 for the centre frequencies given in 4.1, the test space shall be considered adequate with respect to background noise.

4.3 Test equipment

4.3.1 The test equipment shall be capable of producing a test signal at the test site from 112 Hz, the lower limiting frequency of the 125 Hz one-third octave band, (or 56 Hz if the 63 Hz test band centre frequency shall be used) to 9 000 Hz, the upper limiting frequency of the 8 000 Hz one-third octave band.

The equipment, including the loudspeaker system, shall be able to produce the minimum and maximum test signal sound pressure levels at the listener's position given in table 3.

Table 3

Centre frequency	Minimum and maximum test signal sound pressure levels (re 20 µPa)
Hz	dB
63	10 to 70
125	− 5 to 70
250	− 10 to 70
500	− 15 to 70
1 000	− 20 to 80
⩾ 2 000	− 20 to 100

The distortion factor of the equipment, including the loudspeaker system, shall secure the reproduction of test signals without any audible crackle and rattle at each test band and each level as given in table 3. This requirement is considered to be fulfilled for a certain test signal if the maximum one-third octave band pressure levels of any of the one-third octave bands, except for the test frequency band and the two adjacent bands immediately above and below, remain at least 40 dB below the average overall sound pressure level. The time weighting characteristic "F" of the sound level meter is to be used.

4.3.2 Attenuator steps shall be 2,5 dB or smaller.

4.3.3 The error in the difference between the indications at any two positions over the total range of the attenuator when the complete test equipment including the loudspeaker is calibrated shall not exceed 2 dB. This calibration shall be performed acoustically. Outside the range where this calibration can be performed acoustically, the test equipment shall be checked by electrical measurement of the signal voltage at the terminals of the loudspeaker(s).

If it is not possible to achieve the desired accuracy in the attenuation system, the test equipment shall be calibrated and the corrections thus obtained shall be applied to the measurements.

4.3.4 Any transients from switching of the signal shall conform with the requirements of IEC Publication 645.

4.4 Test subjects

4.4.1 Subjects to be used in the tests shall have a hearing threshold level in either ear of no more than 15 dB for frequencies of 2 000 Hz and below, and of no more than 25 dB for frequencies above 2 000 Hz, provided that the hearing in the two ears is substantially similar. All hearing threshold levels are given relative to the reference equivalent threshold sound pressure levels as given in ISO 389.

If the background noise in the test room is at the maximum levels listed in table 2, subjects with hearing threshold levels better than − 10 dB shall be rejected.

4.4.2 Subjects shall be selected without respect to sizes and shapes of heads and ears except that those with obvious abnormalities affecting the fitting of hearing protectors shall be excluded.

4.4.3 Each subject shall be given a practice session before carrying out the definitive test procedure. This practice session shall provide at least two complete audiograms for the test signals given in 4.1 in which the difference between the thresholds of audibility at corresponding centre frequencies shall not exceed 6 dB over the frequency range 250 to 4 000 Hz.

4.4.4 At least ten subjects complying with the requirements of 4.4.1, 4.4.2 and 4.4.3 shall be used for each test.

4.5 Test procedure

4.5.1 More than one test may be made with each subject. The number of tests with each subject shall be the same, and the number of replications shall be reported.

4.5.2 The subjects shall be informed in detail of the test situation and the test procedure.

The experimenter shall instruct each subject on the fitting of the hearing protector according to the manufacturer's instructions. The experimenter shall advise each subject in the selection of the proper size of hearing protector if different sizes are available. Hearing protectors shall be put on by the subject after receiving appropriate instructions.

NOTE — Hearing protectors should be used in a normal position for the test. For the purpose of this International Standard, the wearing of eye-glasses or ear-rings or other conditions likely to diminish the effect of the sealing of the device should be avoided.

The hearing protector shall be adjusted in the presence of a broad-band noise the level (re 20 µPa) of which is between 60 and 80 dB, and the test subjects shall be instructed to adjust the hearing protector for the best attenuation consistent with reasonable comfort. The subject shall make several up-down and right-left movements of the head while opening and closing the lower jaw after the final hearing protector fitting and prior to definitive testing.

Any manipulation of the hearing protector during the test is prohibited.

4.5.3 In the case of ear-muffs, the application force shall be measured on a suitable measuring device. For this measurement the opposing faces of the ear-cushions shall be separated by 145 mm. The headband shall be adjusted to produce a dimension of 129 mm[1)] measured between the centre of the headband (inner surface) to the centre of a line between the centres of the ear-cups. The headband shall remain free during the measurement. The measured force shall be expressed in newtons.

1) For some types of products, for example behind the neck, or under the chin headbands, other dimensions may be more appropriate. The actual dimension shall be reported with the force data.

4.5.4 In the definitive test, the threshold of audibility with open ears and with the hearing protector in place shall be measured in accordance with a recognized audiometric technique.

Anomalies (which may be introduced by learning and fatigue) shall be minimized by appropriate design of the definitive test (see 4.5.1).

4.6 Reporting of the data

The following shall be reported :

— The type of hearing protector; replaceable parts of the hearing protector shall be described.

— The number of subjects used in the definitive tests and the number of test replications.

— The statistical data derived from sound attenuation measured with each subject on each occasion in the definitive test; these shall include the mean value and standard deviation. Individual results, median value, appropriate centiles and the range limit may also be reported. Data on all subjects shall be incorporated in the calculations.

— The application force, in the case of ear-muffs.

When the attenuation is presented in graphical form, the scales and sizes according to the IEC Publication 263 shall be used, and 50 dB per decade shall be chosen. The attenuation scale on the graph shall be directed downwards.