

INTERNATIONAL STANDARD

ISO
4869-1

First edition
1990-12-15

Acoustics — Hearing protectors —

Part 1:

Subjective method for the measurement of sound
attenuation

Acoustique — Protectors individuels contre le bruit —

*Partie 1: Méthode subjective de mesurage de l'affaiblissement
acoustique*



Reference number
ISO 4869-1:1990(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 4869-1 was prepared by Technical Committee ISO/TC 43, *Acoustics*.

This first edition of ISO 4869-1 cancels and replaces ISO 4869:1981, of which it constitutes a technical revision.

ISO 4869 consists of the following parts, under the general title *Acoustics — Hearing protectors*:

- *Part 1: Subjective method for the measurement of sound attenuation*
- *Part 2: Estimated noise reduction of hearing protectors*
- *Part 3: Simplified method for the measurement of insertion loss of ear-muff type protectors for quality inspection purposes*
[Technical Report]

Annexes A and B of this part of ISO 4869 are for information only.

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International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

Introduction

Hearing protectors are commonly used to reduce the noise to which the ear is exposed. Hearing protectors are manufactured as ear-plugs, ear-muffs or helmets. A standardized method of sound attenuation measurement allows performance data obtained in different locations under similar conditions to be compared. The data may be used for rank ordering and selection of different models and the evaluation of design and construction features that affect performance.

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Acoustics — Hearing protectors —

Part 1:

Subjective method for the measurement of sound attenuation

1 Scope

This International Standard specifies a subjective method for measuring sound attenuation of hearing protectors at the threshold of hearing. The method and procedures are designed to yield values close to the maximum attenuation which are not normally attained under field conditions. This approach has been adopted because the attenuation values can then be consistently reproduced. The values reflect the attenuating characteristics of the hearing protector only to the extent that users wear the device in the same manner as did the test subjects.

This test method yields data which are collected at low sound pressure levels (close to the threshold of hearing) but which are also representative of the attenuation values of hearing protectors at higher sound pressure levels. An exception occurs in the case of amplitude-sensitive hearing protectors for sound pressure levels above the point at which their level-dependent characteristics become effective. At those sound pressure levels the method specified in this International Standard is inapplicable; it will usually underestimate sound attenuation for these devices.

NOTE 1 At low frequencies (below 500 Hz) the sound attenuation may be overestimated by a few decibels as a result of masking the occluded ear thresholds caused by physiological noise during the occluded ear tests.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 4869. At the time of publication, the editions indicated were valid. All standards are

subject to revision, and parties to agreements based on this part of ISO 4869 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 354:1985, *Acoustics — Measurement of sound absorption in a reverberation room*.

ISO 8253-2:—¹⁾, *Acoustics — Audiometric test methods — Part 2: Sound field audiometry with pure tone and narrow-band test signals*.

IEC 225:1966, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations*.

IEC 263:1982, *Scales and sizes for plotting frequency characteristics and polar diagrams*.

IEC 645-1:—²⁾, *Audiometers — Part 1: Pure tone audiometers*.

IEC 651:1979, *Sound level meters*.

IEC 804:1985, *Integrating-averaging sound level meters*.

3 Definitions

For the purposes of this part of ISO 4869, the following definitions apply.

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

1) To be published.

2) To be published. (Revision of IEC 645:1979.)

NOTE 2 Hearing protectors may 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 neck-band 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 covers a substantial part of the head.

3.5 hearing level (of a pure tone): At a specified frequency, for a specified type of earphone and for a specified manner of application, the sound pressure level of this pure tone produced by the earphone in a specified acoustic coupler or artificial ear minus the appropriate reference equivalent threshold sound pressure level.

NOTE 3 Values of reference equivalent threshold sound pressure levels are specified in ISO 389.

3.6 hearing threshold level (of a given ear): At a specified frequency and for a specified type of earphone, the threshold of hearing expressed as hearing level.

NOTE 4 For appropriate test conditions see, for example, ISO 6189 and ISO 8253-1.

3.7 threshold of hearing: The lowest sound pressure level at which, under specified conditions, a person gives a predetermined percentage of correct detection responses on repeated trials.

NOTE 5 For the purpose of this International Standard, the threshold of hearing is measured with and without the hearing protector. For appropriate test conditions, see ISO 8253-2.

3.8 sound attenuation: For a given test signal, the difference, in decibels, between the threshold of hearing with and without the hearing protector in place for a test subject.

3.9 pink noise: Noise the sound pressure spectral density of which is inversely proportional to frequency.

3.10 reference point: The midpoint of a line connecting the test subject's ear canal openings.

3.11 reverberation time: The time required for the sound pressure level to decrease by 60 dB after the sound source has stopped (see ISO 354).

3.12 repeatability: The value below which the absolute difference between two single test results obtained with the same method on identical test material, under the same conditions (same operator, same apparatus, same laboratory, and a short interval of time), may be expected to lie with a specified probability; in the absence of other indications, the probability is 95 %.

3.13 reproducibility: The value below which the absolute difference between two single test results obtained with the same method on identical test material, under different conditions (different operators, different apparatus, different laboratories and/or different time), may be expected to lie with a specified probability; in the absence of other indications, the probability is 95 %.

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 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

4 000 Hz

8 000 Hz

4.2 Test site

4.2.1 Diffuse sound field conditions are required and are adequately approximated when the following requirements are met:

- a) With the test subject and the subject's chair absent, the sound pressure level measured with an omnidirectional microphone at positions 15 cm from the reference point on the front-back, right-left and up-down axes shall deviate by no more than $\pm 2,5$ dB from the sound pressure level at

the reference point for any of the test signals. Further, the difference between the extreme right-left positions shall not exceed 3 dB. The orientation of the microphone shall be kept the same at each position.

- b) At frequencies of 500 Hz and above, the sound pressure level at the reference point shall be within 5 dB for the two directions of measurement that give maximum and minimum readings of the incident sound energy when measured with a directional microphone with a front-to-random sensitivity index of 5 dB. For other directional microphones the relationship between front-to-random sensitivity index and the allowable field variation is given in table 1.

Table 1 — Allowable field variation for different microphones

Front-to-random sensitivity index	Allowable field variation
dB	dB
≥ 5	5
4,5	4,5
4	4
< 4	Microphone not suitable
NOTES	
1 The test should be carried out in a sufficient number of directions, which depend on the type of microphone and the characteristics of the loudspeaker arrangement and include at least the two planes where maximum and minimum sound pressure levels may be expected.	
2 More than one loudspeaker is necessary to produce the desired sound field. The loudspeakers may require to be fed with non-coherent electrical signals to reduce the effects of standing waves.	

4.2.2 The reverberation time in the test space (without subject) shall not exceed 1,6 s for each of the test bands.

4.2.3 The background noise at the test site in the test room shall not exceed the values given in table 2 with the test subject absent. The background noise shall be determined by measuring the sound pressure level.

NOTE 6 Background noise includes the ambient noise present in the room and the noise of the test equipment in the absence of the test signal.

Table 2 — Maximum permissible background sound pressure level

Centre frequency	One-third octave band sound pressure level (reference = 20 μ Pa)
Hz	dB
31,5 ^{*)}	57
40 ^{*)}	43
50 ^{*)}	31
63	25
80	21
100	18
125	14
160	11
200	9
250	6
315	4
400	3
500	2
630	1
800	1
1 000	1
1 250	1
1 600	2
2 000	2
2 500	1
3 150	-1
4 000	-4
5 000	-2
6 300	3
8 000	10
10 000	20

^{*)} 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.

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 is to 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 given in table 3 at the test subject's position.

Table 3 — Minimum and maximum sound pressure levels for test signals

Centre frequency Hz	Minimum and maximum test signal sound pressure levels (reference = 20 µPa) dB
63 *)	10 to 80 **)
125	—5 to 70
250	—10 to 70
500	—15 to 80
1 000	—20 to 80
≥ 2 000	—20 to 90
*) Where appropriate.	
**) Distortion limits given in the text shall be met up to at least a 70 dB sound pressure level.	

The distortion factor of the equipment, including the loudspeaker system, shall secure the reproduction of the test signals without any audible crackle and rattle at each test band and each level as given in table 3. At centre frequencies from one octave above the test band up to 16 kHz and from one octave below the test band down to 31,5 Hz, all one-third octave band sound pressure levels shall remain at least 40 dB below the sound pressure level in the test band all the time under all test conditions. The band levels shall be measured using filters complying with IEC 225. The test band sound pressure levels shall be measured as average values (L_{eq} in IEC 804) and the remaining band levels using time weighting F of IEC 651.

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 of the attenuator with the complete test equipment including the loudspeaker shall not exceed 2 dB over the total range of the attenuator and 1 dB over any 80 dB range. Where possible, this test shall be performed acoustically. At low sound pressure levels it is also permissible to check the test equipment 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 The electrical signals applied to the loudspeakers shall comply with IEC 645-1.

4.4 Test subjects

4.4.1 Subjects to be used in the tests shall have a hearing threshold level by earphone listening 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.

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

4.4.2 Subjects shall be selected without regard 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 Subjects used for the test shall have demonstrated the ability to provide three consecutive complete audiograms for the test signals given in 4.1, with differences between the thresholds of hearing at corresponding centre frequencies not exceeding 6 dB.

NOTE 7 Untrained subjects should first be given practice sessions.

4.4.4 Sixteen 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 A minimum of two samples of the hearing protector under test shall be used. The samples shall be evenly distributed among the subjects. Subjects shall wear the same protector throughout the test.

4.5.2 The subjects shall be fully informed of the test situation and procedures. The experimenter shall instruct each subject that the purpose of the test is to "determine the sound attenuation that is likely to be obtained by an informed and conscientious person wearing the device for normal use."

4.5.3 The experimenter shall instruct each subject on how properly to fit the hearing protector. When hearing protectors are supplied in multiple sizes, the experimenter shall assist the subject in selecting the proper size. Trial sound attenuation measurements shall not be used as a guide or criterion in the size-selection process. The wearing of eyeglasses, earrings or other devices likely to diminish the effect of the sealing of the hearing protector shall be avoided.

Instructions shall consist of a combination of the manufacturer's written instructions, if available, that would normally accompany the device, and, as necessary, verbal clarification or physical assistance in

adjusting the device in conformance with those written instructions, or both. When the experimenter determines that the subject can properly fit the device, the hearing protector shall be removed.

For the definitive test, the subject shall reapply the hearing protector and adjust it for best attenuation consistent with reasonable comfort. The subject shall be instructed that "best attenuation can be obtained by adjusting the hearing protector for minimum perceived sound while listening to a steady noise." The fitting noise shall be a broad-band random noise presented at an overall sound pressure level of 60 dB to 70 dB (reference = 20 μ Pa) at the test subject's head position.

Prior to testing, the subject shall, while still listening to the fitting noise, make several fully extended up-down and right-left rotational movements of the head followed by vigorously saying "ah, ee" several times in order to fully open and close the lower jaw. If the subject notices any loss of attenuation, the device may be readjusted by the subject while still seated in the chamber. The noise is then turned off. The experimenter shall confirm that the subject has properly fitted the hearing protector. When the definitive test begins, any further manipulation of the hearing protector is prohibited.

4.5.4 If an abnormal situation occurs, such as movement of the hearing protector, extraordinary noise, etc., the test shall be terminated and repeated.

4.5.5 The threshold of hearing with open ears and with the hearing protector in place shall be measured once for each subject in accordance with ISO 8253-2.

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

4.6 Application force

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

4.7 Reporting of data

The test report shall include the following:

- reference to this International Standard;
- the type of hearing protector. Replaceable parts of the hearing protector shall be described;
- the number of subjects used;
- the number of hearing protectors used;
- the statistical data derived from sound attenuation measured with each subject 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 16 subjects shall be incorporated in the calculations.

In the case of ear-muffs:

- the application force;
- the mode in which the hearing protector was tested.

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