TECHNICAL REPORT

ISO TR 4869-3

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Acoustics — Hearing protectors —

Part 3:
Simplified method for the measurement of insertion loss of ear-muff type protectors for quality inspection purposes

Acoustique — Protecteurs individuels contre le bruit —

Partie 3: Méthode simplifiée de mesurage de l'affaiblissement acoustique des protecteurs du type serre-tête, destinée aux contrôles de qualité

Reference number
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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.

The main task of ISO technical committees is to prepare International Standards. In exceptional circumstances a technical committee may propose the publication of a technical report of one of the following types :

— type 1, when the necessary support within the technical committee cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development requiring wider exposure;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical reports are accepted for publication directly by ISO Council. Technical reports types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical reports type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 4869-3, which is a technical report of type 2, was prepared by Technical Committee ISO/TC 43, *Acoustics.*

ISO 4869 will consist 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*

— *Part 3: Simplified method for the measurement of insertion loss of ear-muff type protectors for quality inspection purposes* [Technical Report]

Annex A of this Technical Report is for information only.

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

During the preparation of ISO 4869 : 1981, *Acoustics — Measurement of sound attenuation of hearing protectors — Subjective method*, the document contained at a certain time both a subjective and a purely physical measurement method. Based on member body comments it was decided to split up the two methods in separate documents, giving priority to the subjective method which was issued in 1981 as ISO 4869. A first draft proposal for the physical method, document 43/1 N 367, was circulated to ISO/TC 43/SC 1 member bodies for comments in the period 1978-12-15 to 1979-03-15 for presentation at the SC 1 meeting in May 1979 in Stockholm, Sweden, where a second draft proposal, document 43/1 N 390, was approved for DIS-circulation subject to amendments in response to comments made at the meeting. ISO/DIS 6290 was circulated for voting amongst all ISO member bodies in the period 1983-01-06 to 1983-07-06. Upon recommendation from Working Group 17, the plenary SC 1 meeeting in April 1985 in Budapest, Hungary, approved that an amended text be submitted to ISO/TC 43 member bodies for adoption as a technical report. Such a proposal for a technical report was circulated for voting amongst ISO/TC 43 member bodies as document 43 N 749 in the period 1986-12-15 to 1987-01-20 with the following result : 12 approvals, 1 disapproval and 1 abstention.

A subjective method for the measurement of the sound attenuation of hearing protectors is given in ISO 4869-1. In order to describe a simplified method for the measurement of the insertion loss using an objective method for production control and certification applications, an acoustic test fixture as specified in this Technical Report has been developed with the aim of achieving a simple but reproducible method of measurement.

The acoustic test fixture was tested in a round robin test including hearing protectors of the ear-muff type tested at some laboratories (Germany, F.R., Sweden, UK). The results were encouraging.

The new testing method has been used in two independent international round robin tests within the EEC and in the Nordic countries.

The reproducibility of the results from these tests is, however, not satisfactory. The major reasons for the deviations observed cannot be fully explained at present. There is a need for further experiments with the acoustic test fixture in order to clarify the reasons for the deviations in the results.

In order to allow gathering of data and experience with this device to provide a background for resolving the present problems and for issuing an International Standard within a few years, it has been decided to publish a description of the test fixture and of the measurement procedure presented in ISO/DIS 6290 — revised in response to comments submitted during the DIS-voting — in the form of a technical report, under number ISO/TR 4869-3.

The method specified in this Technical Report does not provide results which are the same as those obtained by the subjective method because of the requirements for simplicity and reproducibility of test results and other more basic considerations.

The test fixture specified in this Technical Report is not intended to supplant those dummy heads which include simulation of various anatomical features and which are used, for example, for development testing purposes.

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Acoustics — Hearing protectors —

Part 3:
Simplified method for the measurement of insertion loss of ear-muff type protectors for quality inspection purposes

1 Scope

This Technical Report specifies a method for measuring the insertion loss of ear-muff type hearing protectors for quality inspection purposes. The method may also be used to investigate production spreads of performance as part of type approval or certification procedures and to investigate the change of performance with age.

A measurement of application force is specified because the force affects acoustic performance.

The method specified in this Technical Report is not intended to be used as the basic test for type approval purposes. Performance data obtained by this method are not to be quoted as representing the real-ear sound attenuation of an ear-muff, nor the protection provided by the ear-muff.

NOTES

1 A further application of the method is its use to ensure that ear-muff hearing protector samples submitted for subjective testing of attenuation according to ISO 4869-1 have performance typical of the type.

2 For the testing of certain ear-muffs such as those attached to safety helmets, or those with contoured ear-cups or ear-cushions, the procedure described in this Technical Report may have to be slightly modified.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report 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 48 : 1979, *Vulcanized rubbers — Determination of hardness (Hardness between* 30 *and* 85 IRHD*)*.

ISO 4869-1 : —[1], *Acoustics — Hearing protectors — Part 1: Subjective method for the measurement of sound attenuation.*

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

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

IEC 50(801) : 1984, *International Electrotechnical Vocabulary. Chapter 801: Acoustics and electro-acoustics. Section 1: General terms.*

3 Definitions

For the purposes of this Technical Report, the following definitions apply.

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

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 headstrap: A flexible strap fitted to each cup, or to the headband close to the cup. It may be adjusted to support the ear-muffs, usually behind-the-head types, by resting on the top of the head.

3.4 acoustic test fixture: A device that approximates certain dimensions of an average adult human head and is used, for the purposes of this Technical Report, for measuring the insertion loss of hearing protectors of ear-muff type. For this purpose, it includes a microphone arrangement for measuring sound pressure levels.

3.5 insertion loss: The algebraic difference, in decibels, between the one-third octave band pressure level measured by

1) To be published. (Revision of ISO 4869 : 1981.)

the microphone of the acoustic test fixture in a specified sound field under specified conditions with the hearing protector absent and the sound pressure level with the hearing protector on with other conditions identical.

3.6 pink noise: Noise the power spectral density of which is inversely proportional to frequency, i.e. equal energy in each one-third octave band [see IEC 50 (801)].

3.7 noise floor: The output level of the measurement microphone with the test signal switched off and the acoustic isolation test cup in position (see 5.1).

3.8 reference point: The midpoint of a line connecting the centres of the two end faces of the acoustic test fixture.

4 Principle

The level of a test signal in a defined sound field is measured by a microphone located in a test fixture with and without the microphone being occluded by the ear-muffs under test.

5 Measurement of the insertion loss of ear muffs

5.1 Acoustic test fixture

5.1.1 The acoustic test fixture shall allow an ear-muff to be placed properly for measuring the reduction in level of a test signal, by positioning one ear-cup of the hearing protector over a measuring microphone.

The acoustic test fixture shall be set up in a specified acoustic environment (see 5.3).

The acoustic test fixture shall be made of a non-magnetic metal, for example aluminium alloy or brass. It shall be in the shape of a cylinder with its axis horizontal, (145 ± 1) mm between the centres of the two end faces. The diameter of the cylinder shall be (135 ± 5) mm. The angles of each of the two end faces shall be inclined towards the top at 4,5° ± 0,5° to a vertical plane.

The measurement microphone shall be of nominal diameter 24 mm. It shall be of the pressure-operated condenser type.

It shall be placed with its centre axis coinciding with the centre axis of the cylinder and with the centre of its diaphragm in the plane of one of the end faces on the centre line of the cylinder. Provided that these requirements are met, it may have its protective grid in position.

NOTE 1 — Some microphone preamplifiers within the acoustic test fixture could exceed their specified operating temperature.

It may be necessary to equalize the static pressure under the ear-muff during fitting.

NOTE 2 — This could be achieved by:

a) using a capillary tube that is removed before the measurements. Care should be taken not to permanently deform the cushion;

b) a fixed capillary tube connecting the cavity under the ear-muff to the external air. The tube should be of diameter 0,5 mm, of length 25 mm, parallel with and near to the axis of the microphone of the acoustic test fixture, partly closed by a wire of diameter 0,4 mm and combined with a tube of diameter about 3 mm from the bottom of the cylinder perpendicular to the microphone axis.

5.1.2 A spacer shall project from the centre of the length of the cylinder and at right angles to the centre axis of the cylinder to support the centre of the headband of the ear-muff under test. The spacer shall be of length (123 ± 1) mm from the centre axis of the cylinder. The free end of the spacer shall have a cylindrical radius of (100 ± 1) mm. A rubber pad (6 ± 1) mm thick and of hardness within the range 30 IRHD to 85 IRHD (see ISO 48) shall be attached to the end of the spacer to provide a slightly resilient seating for the ear-muff headband. The free face of the rubber pad shall be (50 ± 1) mm wide and (77 ± 1) mm long.

An example of a suitable test fixture is shown in figure 1.

5.1.3 The acoustic isolation of the test fixture shall be at least 50 dB for centre frequencies 63 Hz to 250 Hz, at least 65 dB for centre frequencies between 315 Hz and 4 kHz and at least 55 dB for higher test centre frequencies at the actual test site, measured with the test signal described in 5.2 and with the microphone covered by the acoustic isolation test cup shown in figure 1. The isolation test cup shall be sealed to the acoustic test fixture.

NOTE — The acoustic isolation test cup may be attached to the test fixture by turning the centre axis of the fixture in a vertical position or by fixing a rubber band around the test fixture and cup.

If a fixed tube for pressure equalization is used, it shall be closed at the bottom of the cylinder after the isolation test cup has been fixed.

The acoustic test fixture shall be supported in the test sound field with a resilient mounting so as to achieve a sufficiently low noise floor.

The vertical and horizontal diameters shall be marked with suitable ink on the end faces of the acoustic test fixture, along with two or three concentric circles of suitable radius, to help in positioning the ear-muff properly.

5.2 Test signal

The test signal shall consist of a signal derived from pink noise filtered through one-third octave bands with centre frequencies in accordance with IEC 225 and reproduced through the equipment specified in 5.4. The frequency range of the centre frequencies shall be 63 Hz to 8 000 Hz. The particular centre frequencies used shall be reported.

The sound pressure level of the test signal shall be chosen so that the output signal of the microphone with the hearing protector in position is at least 10 dB higher than the noise floor.

5.3 Test site

The test sound field shall consist either of a random incidence field or a plane progressive wave of a quality as specified in 5.3.1 and 5.3.2.

5.3.1 Random incidence field

With the test fixture removed, the sound pressure level shall be measured at six positions with an omnidirectional microphone. The orientation of the microphone shall be kept the same at each position. The six positions shall be 150 mm from the reference point on the front-back, right-left and up-down axes. The sound pressure level tolerance shall be ± 2,5 dB max. relative to the reference point. 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 when measured with a directional microphone with a front-to-random sensitivity index of 5 dB. For other directional microphones, the relationship between the front-random sensitivity index and the allowable field variations is given in table 1.

NOTE — The test has to be done in a sufficient number of directions, depending upon the directional microphone used.

Table 1 — Random incidence field requirements

Front-to-random sensitivity index dB	Allowable field variation dB
⩾ 5	5
4	4
< 4	Microphone not suitable

NOTES

1 The acoustic test fixture itself may be used as a directional microphone to test the sound field in some of the frequency bands required. See annex A for further details.

2 If more than one loudspeaker is used to produce the desired sound field, the loudspeakers may require to be fed with non-coherent electrical signals to eliminate standing waves and other wave interference effects.

5.3.2 Plane progressive wave

The acoustic test fixture shall be oriented in the test site so that the sound field impinges with grazing incidence on the end faces.

With the test fixture removed:

a) the sound pressure levels at the two points representing the positions normally occupied by the centres of the end faces of the acoustic test fixture shall not differ by more than 2 dB at any test signal centre frequency within the specified range (see 5.2) with 0° incidence to the microphone for each location;

b) the plane progressive wave sound field shall be of sufficient quality for the purpose of this Technical Report if, at test signals with centre frequencies of 500 Hz and above, the sound pressure measured with a unidirectional microphone facing the sound source is at least 10 dB greater than the sound pressure measured with the same microphone turned through 180° to face directly away from the sound source. The microphone shall be positioned at the reference point (3.8). The measuring microphone shall have a front-to-rear sensitivity index greater than 15 dB. It may be necessary to use different microphones at different test signal centre frequencies to achieve the required front-to-rear sensitivity index.

NOTE — The required plane progressive wave sound field would normally be achieved in an anechoic room. As an alternative, when such a facility is not available, the required sound field may be achieved as shown in figure 2.

5.3.3 Permissible background noise

The level of the background noise at the test site, measured in one-third octave bands with the measuring microphone placed at the reference point, shall be at least 10 dB lower than the test signal sound pressure level.

5.4 Test equipment

5.4.1 The test equipment shall consist of:

a) pink noise generator(s), one-third octave band filter(s), loud-speaker(s) and any necessary amplification to produce the test signal specified in 5.2 in the vicinity of the test fixture;

b) a microphone amplifier, one-third octave band filter and indicating instrument to measure the sound pressure levels at the microphone in the acoustic test fixture.

All filters used shall comply with IEC 225.

The indicating instrument shall give the RMS-level.

The peak signal handling capacity of the test signal generating system shall be at least 12 dB above the RMS-level of the signal.

NOTE — It is likely that the test signal generating equipment will need to be capable of producing test signals at the position of the test fixture at the following levels (reference: 20 µPa):

75 dB in the frequency range 63 Hz to 250 Hz
90 dB in the frequency range 315 Hz to 4 000 Hz
85 dB in the frequency range 5 000 Hz to 8 000 Hz

Higher levels may be necessary if the noise floor of the equipment is high. Lower levels may be sufficient if the noise floor of the equipment is sufficiently low or if the insertion loss of the hearing protector to be measured is not very high.

5.4.2 The peak signal handling capacity may be checked by removing the noise signal and applying a sine wave signal to the system. This signal shall be 9 dB higher RMS-level than the noise signal, and it shall be ascertained that no visual clipping occurs when this signal is viewed on an oscilloscope connected to the measuring chain prior to the one-third octave band filters.

It shall always be ensured that replacing the hearing protector under test by the acoustic isolation test cup results in a reduction of the output of the indicating instrument of at least 10 dB.

Care shall be taken that the measurement time at each test frequency allows proper averaging of the signal level.

NOTE — Using an integrating instrument, the product of the bandwidth of the test band and the averaging time selected should exceed a value of 300.

During the test, the test signal sound pressure level shall not change by more than ± 1 dB from the level set before the start of the measurement (see 5.5.2).

The frequency response of the system to one-third octave bands of pink noise in the test range shall be such that the difference between any two adjacent bands is not greater than 5 dB. The frequency response as measured with pure tones at the actual test site shall not vary by more than 10 dB within any one-third octave band. If the test site is a reverberant room, the loudspeaker(s) will need to be moved to a free-field environment for this test to be carried out.

5.5 Test procedure

5.5.1 Positioning of the ear-muff

The ear-muff shall be positioned in the following manner.

Place the ear-muffs on the acoustic test fixture, ensuring that the cushions are centrally located on each end face. Tighten the headband symmetrically to only just touch the appropriate headband support. For behind-the-neck models, ensure that the headstrap (if fitted) passes over the top headband support so as to stabilize the ear-muffs on the acoustic test fixture. A neck-band shall be adjusted so that the ear-cups are as parallel as possible to the end faces of the fixture.

5.5.2 Measurement

The sound pressure levels at the microphone shall at first be measured without ear-muffs. The hearing protector shall be placed as specified in 5.5.1. After the hearing protector has remained in position for about 30 s, the sound pressure levels shall be measured again. For each test signal frequency, the difference in sound pressure levels is the insertion loss of the device determined in accordance with this Technical Report.

It may be necessary to close the pressure equalization tube, if any, after positioning the ear-muff.

5.5.3 The procedures given in 5.5.1 and 5.5.2 shall be repeated a sufficient number of times (but not less than three) until the differences between two successive mean values of insertion loss of each cup at all centre frequencies do not exceed 1 dB.

6 Measurement of application force

The force between the ear-cups shall be measured by some suitable means. For this measurement, the opposing faces of the ear-cushions shall be 145 mm apart. The headband shall be adjusted to a distance of 129 mm [1] between the centre of the headband (inner surface) and the centre of a line between the centres of the ear-cups. The headband shall be left free during the measurement. The measured force shall be expressed in newtons.

The force shall be measured 30 s after the final adjustment of the headband.

7 Reporting of data

Data shall be reported in graphical or tabular form, and clearly labelled "Quality inspection method in accordance with ISO/TR 4869-3".

The type of test site shall be reported with the data.

The results of the measurements of insertion loss and application force may depend on usage and any pre-measurement conditioning of the hearing protector. Any such information shall be stated in the report.

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

The application force, determined in accordance with clause 6, shall be reported.

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

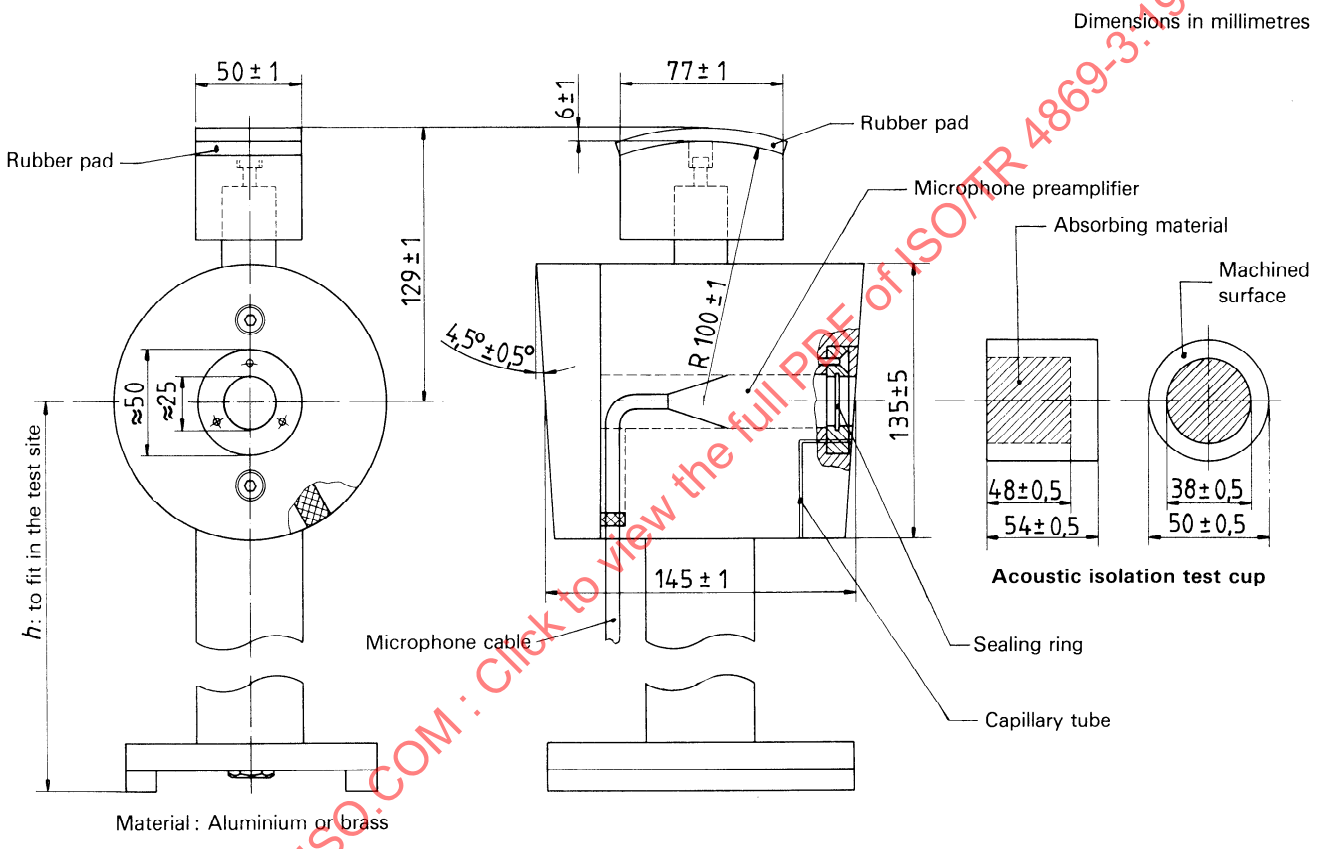

Figure 1 — Example of an acoustic test fixture