TECHNICAL REPORT

ISO/TR 4869-4

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Acoustics — Hearing protectors —

Part 4:
Measurement of effective sound pressure levels for level-dependent sound-restoration ear-muffs

Acoustique — Protecteurs individuels contre le bruit —

Partie 4: Mesurage des niveaux effectifs de pression acoustique des serre-tête destinés à la restitution du son

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

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

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— 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 of 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 Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.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 4869-4, which is a Technical Report of type 2, was prepared by Technical Committe ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

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A first CD 4869-4, doc. 43/1 N 924, based on a miniature microphone technique, was circulated for comments in the period 1994-06-30/1994-09-30. The comments, given in doc. 43/1 N 948, showed that such a draft could not be expected to obtain sufficient support. WG 17 then prepared a completely revised draft based on a simplified procedure and using an artificial test fixture (ATF) which was circulated as a second CD, doc. 43/1 N 972, in the period 1995-01-01/1995-03-10.

The comments given in doc. 43/1 N 985, showed that the second CD 4869-4 did not have major support either. WG 17 therefore prepared a revised document, still based on the ATF but with the scope restricted to sound restoration ear-muffs which was circulated as a Draft Technical Report, doc. 43/1 N 986, in the period 1995-10-10/1996-01-10. The votes and comments, given in doc. 43/1 N 1039, showed 16 approvals and 4 disapprovals.

Based on these comments, WG 17 prepared a second draft Technical Report 4869-4, doc. 43/1 N 1069, which was circulated for voting in the period 1997-05-15/1997-08-20 and approved with 15 approvals and 2 disapprovals as given in doc. 43/1 N 1148. The two disapprovals were requesting a technique based on the use of miniature microphones which cannot be incorporated in the present document. Thus, the second TR, with some editorial amendments, is issued as a Technical Report, and the question of the preparation of a possible standard based on a miniature microphone technique must be the subject of a separate discussion and decision in ISO/TC 43/SC 1.

ISO 4869-4 consists of the following parts, under the general title *Acoustics — Hearing protectors*:

— *Part 1: Subjective method for the measurement of sound attenuation*

— *Part 2: Estimation of effective A-weighted sound pressure levels when hearing protectors are worn*

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

— *Part 4: Measurement of effective sound pressure levels for level-dependent sound-restoration ear-muffs*

Annex A of this part of ISO 4869 is for information only.

Introduction

Measurement of sound attenuation according to ISO 4869-1 is intended for conventional, passive hearing protectors where the attenuation is independent of the level of the noise outside the hearing protector. Hearing protectors with level-dependent operation are also available. Such operation is usually obtained by means of electro-acoustic components. The level-dependent characteristics of such protectors cannot be determined using the procedures of ISO 4869-1. The present technical report provides a physical method for the determination of the characteristics of level-dependent sound restoration ear-muffs. The passive sound attenuation characteristics of sound restoration ear-muffs should be measured in accordance with ISO 4869-1.

Acoustics — Hearing protectors —

Part 4:
Measurement of effective sound pressure levels for level-dependent sound-restoration ear-muffs

1 Scope

This Technical Report specifies a physical test method for level-dependent sound-restoration ear-muffs. The physical measurements are made with the acoustic test fixture (ATF) according to ISO/TR 4869-3 or with a suitable head and torso simulator (HATS) with a suitable acoustic isolation (see clause 7). The results of these tests in combination with the results from the ISO 4869-1 tests can be used to estimate the effective A-weighted sound pressure level when sound restoration ear-muffs are worn.

The method described is not suitable for measurement of the effective sound pressure level under ear-muffs in the case of impulsive noise nor for active noise reduction ear-muffs.

2 Normative references

Acoustics — Hearing protectors — Part 1: Subjective method for the measurement of sound attenuation.

ISO 4869-2, *Acoustics — Hearing protectors — Part 2: Estimation of effective A-weighted sound pressure levels when hearing protectors are worn.*

ISO/TR 4869-3:1989, *Acoustics — Hearing protectors — Part 3: Simplified method for the measurement of insertion loss of ear-muff type protectors for quality inspection purposes.*

IEC 60651, *Sound level meters.*

IEC 61094-4, *Measurement microphones — Part 4: Specifications for working standard microphones.*

IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters.*

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 4869. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 4869 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated

3 Terms and definitions

For the purposes of this Technical Report, the terms and definitions given in ISO 4869-1, ISO 4869-2 and ISO/TR 4869-3, and the following apply.

3.1
reference microphone
calibrated microphone meeting the requirements for WS2D microphones given in IEC 61094-4, not located in the acoustic test fixture, which is used to measure sound pressure levels in the test chamber

3.2
reference point
location in the test chamber to which all acoustical measurements are referred, and at which the midpoint of a line connecting the centres of the two end faces of the acoustic test fixture is located

3.3
sound-restoration ear-muff
sound-transmission ear-muff
ear-muff intended to reproduce external sounds within the ear-cup

NOTE A sound-restoration ear-muff exhibits a change in attenuation as a function of sound pressure level (i.e. level dependency).

3.4
pink noise
noise whose power spectral density is inversely proportional to frequency

3.5
effective A-weighted sound pressure level for level-dependent sound-restoration ear-muffs
for a specific noise situation, the A-weighted sound pressure level effective when a given level-dependent sound-restoration hearing protector is worn, calculated from results of measurements on ATF/HATS in active and passive mode and with corrections for bone conduction and leakage

NOTE In this Technical Report, effective sound pressure level is the combined effect of insertion loss and sound transmission.

4 Test conditions

4.1 Test site

Random incidence sound field conditions are required as described in ISO 4869-1:1990, subclause 4.2.1, with the ATF/HATS absent.

4.2 Test signals

The test signal in the absence of the ATF/HATS shall consist of pink noise, whose one-third-octave band levels are uniform within ±2 dB at a frequency range 125 Hz to 8 000 Hz. The pink noise spectrum shall roll off at least 3 dB at 100 Hz and 10 000 Hz, and at least 12 dB per octave below 125 Hz and above 8 000 Hz. The signal shall be presented over a range from 50 dB to at least 110 dB, A-weighted sound pressure level.

NOTE Other additional steady-state broad-band shaped spectra may also be used.

4.3 Measuring equipment

4.3.1 General

An acoustic test fixture in accordance with ISO/TR 4869-3, or a head and torso simulator (HATS), with suitable acoustic isolation shall be used.

At the reference point, the test signals shall be measured with the reference microphone meeting the requirements for WS2D microphones given in IEC 61094-4 and, in the frequency range given in 4.2, with equipment meeting the specifications for Type 1 sound level meters specified in IEC 60651. The one-third-octave filtering shall meet the requirements for class 1 filters given in IEC 61260.

4.3.2 Measurement times

The measurement times at each filter band used in the measurement shall be chosen so that the standard deviation, s, of repeated measurements is less than or equal to 0,2 dB, using the following formula:

$$s = \frac{4{,}34}{\sqrt{B \cdot T}} \text{ dB}$$

where

s is the standard deviation of the r.m.s. level, in decibels;

B is the bandwidth of the one-third-octave-band filter, in hertz;

T is the averaging time in seconds, $T \geqslant 471/B$.

4.4 Signal-to-noise ratio

The signal-to-noise ratio shall be at least 10 dB. This requirement is fulfilled if the recorded one-third-octave-band sound pressure level(s) measured with the ATF/HATS microphone with the settings given in 5.2 decrease(s) by at least 10 dB when the pink noise signal is turned off and all other instrumentation remains on.

5 Test procedure

5.1 Samples of hearing protectors

A minimum of three samples of hearing protectors (i.e. six cups) shall be used.

5.2 Determination of ATF or HATS transfer function

Set the A-weighted sound pressure level of the pink noise to a suitable level at the reference point measured with the reference microphone. Measure and record the one-third-octave-band sound pressure levels. Position the ATF/HATS at the reference point and measure the one-third-octave-band ATF/HATS levels, using the microphone built into the ATF or the HATS.

Calculate the transfer function of the ATF/HATS by subtracting the one-third-octave-band levels measured with the reference microphone from those measured with the ATF/HATS microphone.

Caution: The transfer function will be influenced by the acoustics of the room and the location of the sound source.

NOTE The ATF/HATS levels and the transfer function generally have an arbitrary reference, unless a suitable calibration method for the ATF/HATS is specified.

5.3 Determination of hearing protector performance in active mode

If the hearing protector includes a gain control, it shall be set to maximum gain. Position the ear-muff on the ATF in accordance with ISO/TR 4869-3:1989, subclause 5.5.1, or on the HATS. Measure the one-third-octave-band ATF/HATS levels under the ear-cup for test signals ranging from A-weighted sound pressure levels of 50 dB up to 90 dB in steps of 10 dB or less, and from 90 dB up to at least 110 dB in steps of 5 dB or less. Each cup shall be measured once. The averaging time shall be chosen in accordance with 4.3, e.g. at least 16 s at 125 Hz and 0,3 s at 8 000 Hz.

5.4 Determination of hearing protector performance in passive mode

Switch off the amplifier or disconnect the battery without removing it. Position the ear-muff on the ATF in accordance with ISO/TR 4869-3:1989, subclause 5.5.1, or on the HATS. Measure the one-third-octave-band ATF/HATS levels under the ear-cup for a single A-weighted sound pressure level above 80 dB. Each cup shall be measured once. The averaging time shall be chosen in accordance with 4.3, e.g. at least 16 s at 125 Hz and 0,3 s at 8 000 Hz.

6 Computation of level-dependent A-weighted effective sound pressure levels

6.1 Computation of the A-weighted effective sound pressure levels for each cup

For each test signal level, calculate the effective sound pressure level in each one-third-octave band by subtracting the transfer function determined in accordance with 5.2 from the levels measured in accordance with 5.3. Apply the A-weighting to the one-third-octave-band sound pressure levels and calculate the overall A-weighted effective sound pressure level by summing up all one-third-octave-band levels (on an energy basis, see principle in ISO 4869-2).

6.2 Computation of average A-weighted effective sound pressure levels for the three test samples

Repeat step 6.1 for each of the ear-cups tested. For each test signal level, compute the mean and the standard deviation of the effective A-weighted sound pressure levels of the right ear cups and of the effective A-weighted sound pressure levels of the left ear cups. The larger value shall be taken as the test result.

7 Reporting of data

The test report shall contain the following.

a) A table showing for each cup the effective level-dependent A-weighted sound pressure levels, for each test signal level, calculated according to 6.1, along with the means and standard deviations calculated according to 6.2.

b) A graph showing the relationship between the A-weighted sound pressure levels at the reference point (abscissa) and the effective level-dependent A-weighted sound pressure levels (ordinate), averaged according to 6.2 for the left and right cups (two curves). Both axes shall be labelled in decibels with scales having divisions of identical size. The graph shall also show the result of the measurements of the linear insertion loss in passive mode calculated from 5.4.

c) Attenuation data in accordance with ISO 4869-1 shall be reported for operation in the passive mode. These data may either be obtained from the present samples or alternative samples.

d) If feasible, the type of HATS as well as its ear simulator and its ear canal and pinna simulator and the acoustic isolation shall be reported.

Annex A
(informative)

Combining physical and subjective test results to calculate ear-muff effective levels

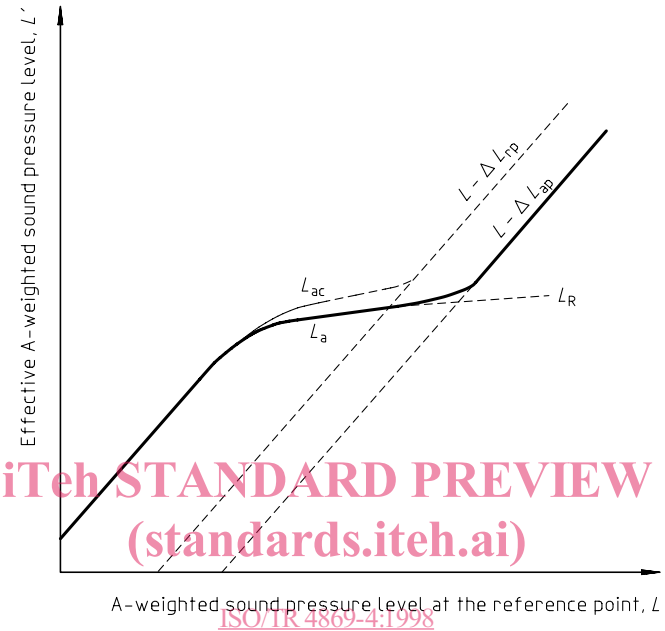

Figure A.1 — The relationship between the A-weighted sound pressure level at the reference point and the effective A-weighted sound pressure level

At a given ambient level L, the sound pressure level L_a measured on the ATF/HATS can be considered as the logarithmic sum of:

— the sound pressure level due to the restored sound (earphone transmitted sound), L_R;

— the sound pressure level due to the sound passing through the cup under ATF/HATS conditions:

$L - \Delta L_{ap}$ (ap indicates: ATF/HATS passive mode), see Figure A.1.

Hence:

$$L_a = 10 \lg (10^{0,1 L_R} + 10^{0,1(L - \Delta L_{ap})}) \text{ dB} \quad \ldots \text{(A.1)}$$

The sound pressure level L_r measured on a real ear would have been the logarithmic sum of:

— the sound pressure level due to the restored sound: L_R, presumed to be the same as on the ATF/HATS;

— the sound pressure level due to the sound passing through the cup under real-ear conditions (taking into account all relevant sound paths, including bone conduction and leakage): $L - \Delta L_{rp}$ (rp means: real ear, passive mode).

Hence:

$$L_r = 10 \lg (10^{0,1 L_R} + 10^{0,1(L - \Delta L_{rp})}) \text{ dB} \quad \ldots \text{(A.2)}$$