# INTERNATIONAL STANDARD

# ISO 4869-3

First edition
2007-07-01

## Acoustics — Hearing protectors —

## Part 3:
## Measurement of insertion loss of ear-muff type protectors using an acoustic test fixture

*Acoustique — Protecteurs individuels contre le bruit —*

*Partie 3: Mesurage de l'affaiblissement acoustique des protecteurs du type serre-tête au moyen d'un montage d'essai acoustique*

Reference number
ISO 4869-3:2007(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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 4869-3 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This first edition of ISO 4869-3 cancels and replaces ISO/TR 4869-3:1989, which has been technically revised. The technical changes are as follows:

a) the title has been changed and the standard has been revised;

b) the content of the former subclause on “test signal” has been included in the subclause “Measuring system”;

c) the subclause “Measuring system” no longer contains specific requirements concerning the measuring system;

d) Annex B, dealing with uncertainty, has been added.

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

— *Part 3: Measurement of insertion loss of ear-muff type protectors using an acoustic test fixture*

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

— *Part 5: Method for estimation of noise reduction using fitting by inexperienced test subjects* [Technical Specification]

Part 6, *Measurement of the active noise reduction of hearing protectors*, is under preparation.

# Introduction

A Technical Report describing the use of an acoustic test fixture (ATF) to measure the insertion loss of ear-muff type protectors was published as ISO/TR 4869-3 in 1989. As testing laboratories around the world commonly use the ATF, it was decided that this Technical Report should be revised and changed into an International Standard.

Compared to the original Technical Report, the most important aspect of this part of ISO 4869 is the specification of the ATF. The ATF specified herein 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.

The method specified in this part of ISO 4869 does not provide results which are the same as those obtained by the subjective method, ISO 4869-1.

# Acoustics — Hearing protectors —

## Part 3:
## Measurement of insertion loss of ear-muff type protectors using an acoustic test fixture

## 1 Scope

This part of ISO 4869 specifies a method for measuring the insertion loss of ear-muff type hearing protectors using an acoustic test fixture. The method is applicable to the investigation of production spreads of performance as part of type approval or certification procedures, and to the investigation of the change of performance with age. It is intended to ensure that ear-muff hearing protector samples submitted for subjective testing of attenuation according to ISO 4869-1 have performances typical of the type.

The method specified in this part of ISO 4869 is not applicable as the basic test for type approval. Performance data obtained by this method are not intended to be quoted as representing the real-ear sound attenuation of an ear-muff, nor the protection provided by the ear-muff.

For the testing of certain ear-muffs (such as those attached to safety helmets, or those with contoured ear-cups or ear-cushions, or supra-aural ear-muffs), the procedure described in this part of ISO 4869 might need to be modified.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 48, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

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

ISO/IEC Guide 98:1995, *Guide to the expression of uncertainty in measurement (GUM)*

IEC 60263, *Scales and sizes for plotting frequency characteristics and polar diagrams*

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

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

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

**3.1**
**hearing protector**
device worn by a person to reduce unwanted auditory effects from acoustic stimuli

**3.2**
**ear-muff**
hearing protector consisting of a supra-aural ear-cup to be pressed against each pinna or of a circumaural ear-cup to be pressed against the head around the pinna

NOTE 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**
**head-strap**
flexible strap fitted to each cup, or to the headband close to the cup

NOTE The strap can be adjusted to support the ear-muffs, usually for behind-the-head types, by resting on the top of the head.

**3.4**
**acoustic test fixture**
**ATF**
device that approximates certain dimensions of an average adult human head

NOTE An ATF is used for measuring the insertion loss of hearing protectors of the ear-muff type and includes a microphone for measuring sound pressure levels.

**3.5**
**insertion loss**
algebraic difference, in decibels, between the one-third-octave-band sound pressure level measured by the microphone of the acoustic test fixture with the hearing protector absent and the sound pressure level with the hearing protector present

**3.6**
**pink noise**
noise in which sound power spectral density is inversely proportional to frequency

**3.7**
**acoustic isolation**
algebraic difference, in decibels, between the one-third-octave-band sound pressure level measured by the microphone of the acoustic test fixture with a specially designed sound isolation test cup absent and the sound pressure level with the specially designed sound isolation test cup present

**3.8**
**noise floor**
output level of the measurement system with the test signal switched off and a test cup providing sufficient acoustic isolation in position

**3.9**
**reference point**
midpoint of a line connecting the centres of the two end faces of the acoustic test fixture

## 4 Measurement principle

The level of a test signal in a defined sound field is measured by a microphone located in an acoustic test fixture (ATF). The level is measured without and with the microphone being occluded by the ear-muff under test. The difference between the two measurement results is the insertion loss of the hearing protector.

The ATF shall allow an ear-muff to be placed properly by positioning one ear-cup of the hearing protector over a measuring microphone.

## 5 Measurement of the insertion loss of ear-muffs

### 5.1 Acoustic test fixture (ATF)

#### 5.1.1 General

An example of an ATF is given in Figure 1.

#### 5.1.2 Description

The ATF shall be made of a non-magnetic material, for example aluminium alloy or brass. It shall be in the shape of a cylinder with its axis horizontal and with (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 measuring microphone shall be of type WS1P or WS2P in accordance with IEC 61094-4. It shall be of the pressure-operated condenser type. The microphone shall be placed with its centre axis coinciding with the centre axis of the cylinder. The centre of the microphone diaphragm shall be in the plane of one of the end faces of the cylinder on the centre line. See Figure 2.

To reduce structure-borne sound, the ATF 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 at the end faces of the ATF, along with two or three concentric circles of suitable radius to help in positioning the ear-muff properly. The marking shall not produce any acoustical leakage.

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

a) a capillary tube that is placed between the cushion and the ATF surface during the fitting of the ear-muff to the fixture, and which is removed before the measurements; care shall 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 shall 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 extending from the bottom of the cylinder perpendicular to the microphone axis.

#### 5.1.3 Spacer

A spacer shall project from the cylinder at right angles to the centre axis of the cylinder to support 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 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.

### 5.1.4 Acoustic isolation

The acoustic isolation of the ATF shall be at least 50 dB for test bands with centre frequencies between 63 Hz and 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 5.3 and with the microphone covered by a suitable acoustic isolation test cup (e.g. the one shown in Figure 1). The isolation test cup shall be sealed to the ATF.

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

## 5.2 Test site

### 5.2.1 General

The test sound field shall consist of either a random incidence field or a plane progressive wave of a quality specified in 5.2.2 and 5.2.3.

### 5.2.2 Random incidence field

A random incidence sound field in accordance with the specifications given in ISO 4869-1 shall be used. A specification of the random incidence sound field is given below.

With the ATF removed, the sound pressure level shall be measured at six positions with an omni-directional 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 (see 3.9) on the front-back, right-left and up-down axes. The sound pressure level tolerance shall be ± 2,5 dB max., relative to the level at 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 range of sound pressure levels 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 at least 5 dB. For other directional microphones, the relationship between the front-to-random sensitivity index and the allowable field variations is given in Table 1. The test shall be carried out in a sufficient number of directions, which depends on the type of microphone and the characteristic of the loudspeaker arrangement, and shall include at least the directions where maximum and minimum sound pressure levels will occur.

**Table 1 — Random incidence field requirements**

| Front-to-random sensitivity index<br>dB | Allowable field variation<br>dB |
|---|---|
| $> 5$ | 5 |
| 4 to 5 | 4 |
| $< 4$ | Microphone not suitable |

NOTE 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.

### 5.2.3 Plane progressive wave

With the ATF removed, the sound pressure levels at the two points representing the positions normally occupied by the centres of the end faces of the ATF shall not differ by more than 2 dB at any test signal with 0° incidence to the microphone for both locations.

At test bands with a centre frequency of 500 Hz and above, the sound pressure level measured with a directional microphone facing the sound source shall be at least 10 dB greater than the sound pressure level measured with the same microphone turned 180° to face directly away from the sound source. The microphone shall be positioned at the reference point (see 3.9). 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.

During insertion loss measurements, the ATF shall be oriented so that the sound field impinges with grazing incidence on the end faces.

#### 5.2.4 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 sound pressure level of the test signal.

### 5.3 Measuring system

Various measuring systems may be used for this test. Such systems may be based on broadband pink noise signals, maximum length sequences, impulse response measurements, etc. The analysis shall give the insertion loss in one-third-octave bands. The bands shall be in accordance with IEC 61260. The frequency range of the centre frequencies shall be at least 63 Hz to 8 000 Hz. The indicating instrument shall give the RMS-level.

It is likely that sound pressure levels from 75 dB (low frequencies) to 85 dB (high frequencies) are needed at the test site. Higher levels may be necessary if the noise floor of the equipment is high or if the insertion loss 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.

A signal-to-noise ratio of at least 10 dB shall be guaranteed in all one-third-octave frequency bands. It shall be ensured that replacing the hearing protector under test by a suitable acoustic isolation test cup results in a reduction of the output of the indicating instrument of at least 10 dB. The dynamic range of the measuring system shall be large enough to avoid any clipping of the signals.

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 5.4.2). The one-third-octave frequency response of the system shall be such that the difference between any two adjacent bands is not greater than 5 dB.

### 5.4 Test procedure

#### 5.4.1 Positioning of the ear-muff

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

Place the ear-muffs on the ATF, ensuring that the cushions are centrally located on each end face. Tighten the headband symmetrically so that it just touches the appropriate headband support. For behind-the-neck modes, ensure that the head-strap (if fitted) passes over the top headband support so as to stabilize the ear-muffs on the ATF. A neck-band shall be adjusted so that the ear-cups are as symmetrical as possible to the end faces of the ATF.

#### 5.4.2 Measurement

The sound pressure levels at the microphone shall first be measured without ear-muffs. Then the hearing protector shall be placed as specified in 5.4.1. After the hearing protector has remained in position for about 30 s, measure the sound pressure levels again. The difference in sound pressure levels at each one-third-octave band is the insertion loss of the device determined in accordance with this part of ISO 4869.

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

### 5.4.3 Repetition

The insertion loss depends not only on the hearing protector but also on the fitting of the hearing protector on the ATF. At least three repetitions of the measurements shall be made, unless sufficient experience about the repeatability of the measurement results is available for the device under test.

### 5.4.4 Uncertainty

The uncertainty of results obtained from measurements according to this part of ISO 4869 shall be evaluated in compliance with ISO/IEC Guide 98. The expanded uncertainty, together with the corresponding coverage factor for a stated coverage probability of 95 %, as defined in ISO/IEC Guide 98, shall be given. Guidance on the determination of the expanded uncertainty is given in Annex B.

## 6 Reporting of data

Data shall be reported in graphical or tabular form, and shall be clearly labelled “Method in accordance with ISO 4869-3”. The data are the insertion losses in one-third-octave bands, rounded to the nearest one-tenth of a decibel.

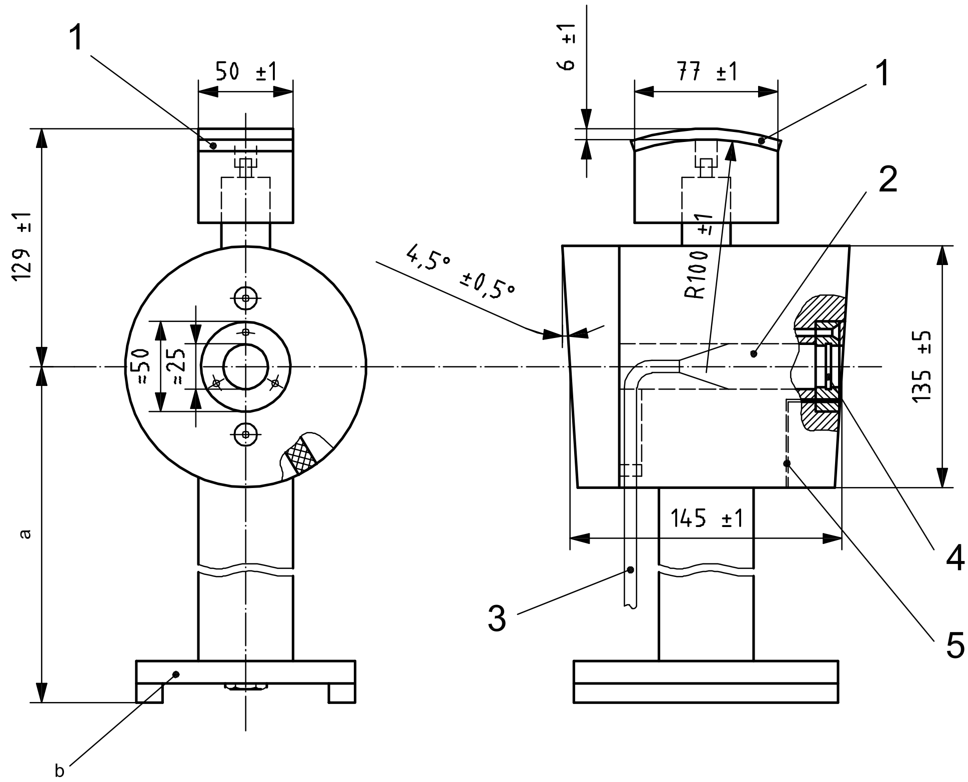
The expanded measurement uncertainty shall be given, together with the selected coverage probability of 95 %.

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

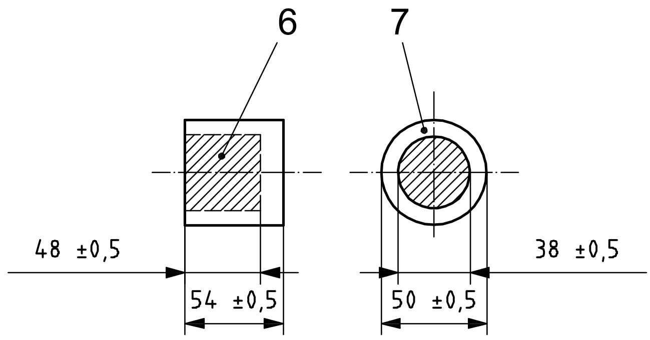
The results of the measurements of insertion loss can depend on usage and any pre-measurement conditioning of the hearing protector. Any such information shall be stated in the report.

When the insertion loss is presented in graphical form, the scales and sizes specified in IEC 60263 shall be used, and the 50 dB per decade scale shall be chosen. The insertion loss shall be plotted such that increasing values are directed downwards.

Dimensions in millimetres




**a) Acoustic test fixture**




**b) Acoustic isolation cup**

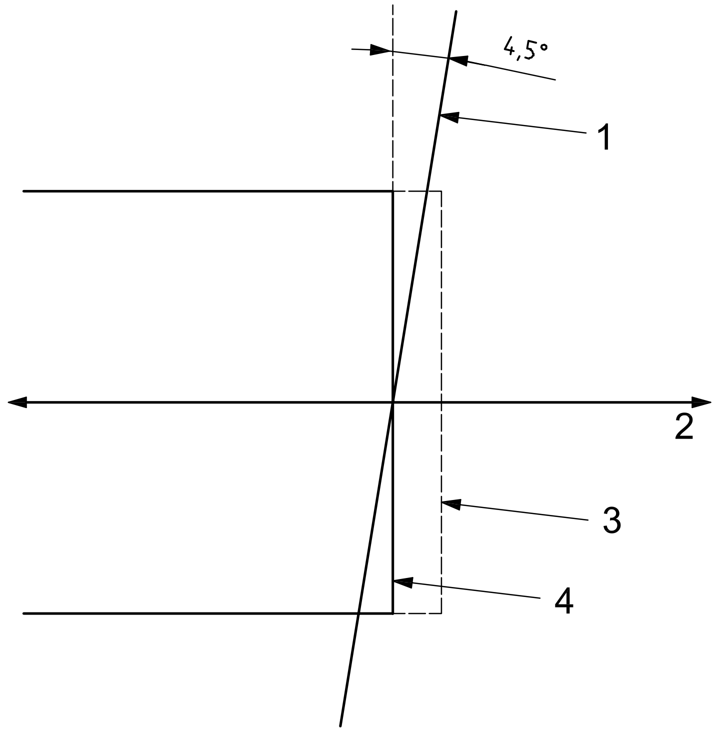
**Key**

1 rubber pad
2 microphone preamplifier
3 microphone cable
4 sealing ring
5 capillary tube
6 absorbing material
7 machined surface

a Height to fit in the test site.

b Material: aluminium or brass.

**Figure 1 — Example of an acoustic test fixture and an acoustic isolation cup**




**Key**

1 acoustic test fixture end face
2 acoustic test fixture axis
3 protective grid
4 microphone diaphragm

**Figure 2 — Details of microphone position**

# Annex A
(informative)

## Use of the acoustic test fixture as a directional microphone

In spite of the complex geometry of the ATF, it behaves almost like a microphone with rotational symmetry, the axis of symmetry being the axis of the cylinder.

The front-to-random sensitivity index for an ATF equipped with a WS1P microphone has been measured and is given in Table A.1 for information.

**Table A.1 — Front-to-random sensitivity index of an ATF equipped with a WS1P microphone**

| **Frequency**<br>Hz | **Front-to-random sensitivity index**<br>dB |
|---|---|
| 500 | 1,7 |
| 630 | 2,2 |
| 800 | 2,8 |
| 1 000 | 3,2 |
| 1 250 | 4,6 |
| 1 600 | 4,6 |
| 2 000 | 6,3 |
| 2 500 | 6,5 |
| 3 150 | 5,9 |
| 4 000 | 2,9 |
| 5 000 | −0,6 |
| 6 300 | 5,1 |
| 8 000 | 5,9 |

# Annex B
(informative)

# Uncertainty of insertion loss measurements

## B.1 General

Uncertainties in the measurement of the insertion loss of a hearing protector in accordance with this part of ISO 4869 can arise from various sources, such as the uncertainty in the measurement of the sound level measurements, the uncertainty in the test signal generators, fitting of the hearing protector on the acoustic test fixture, etc.

## B.2 Model

A general expression for the calculation of the insertion loss, $Y$, is given by the following equation:

$$Y = L_{\text{open}} - L_{\text{occl}} + \sum_{i=1}^{3} \delta_i \tag{B.1}$$

where

$Y$ is the insertion loss;

$L_{\text{open}}$ is the sound pressure level without the hearing protector present;

$L_{\text{occl}}$ is the sound pressure level with the hearing protector present; $L_{\text{occl}}$ is subject to variations from the fitting of the protector on the ATF;

$\delta_1$ is an input quantity due to deviation from nominal specifications of the dimensions and performance of the ATF;

$\delta_2$ is an input quantity due to deviations from an ideal random incidence sound field or from an ideal plane progressive wave;

$\delta_3$ is an input quantity due to uncertainties in the measuring equipment.

A probability function (normal, rectangular, etc.) is associated with each of the input terms on the right-hand side of Equation (B.1). The mean value (equals expectation value) of each of the terms on the right-hand side is the best estimate of that term. The standard deviation of each of the terms is a measure of the dispersion of values, termed uncertainty. The mean value of each of the $\delta$-terms is assumed to be zero. However, in any particular determination of an insertion loss, the uncertainties do not vanish and they contribute to the combined uncertainty associated with insertion loss determinations.

## B.3 Uncertainty budget

The contributions to the combined uncertainty associated with insertion loss determinations depend on each of the input quantities, their respective probability distributions and sensitivity coefficients, $c_i$. The sensitivity coefficients are a measure of how the values of insertion loss are affected by the changes in the values of the respective input quantities. In the model above (Equation B.1), all sensitivity coefficients have a value of 1. The contribution of the respective input quantities to the overall uncertainty is then given by the products of the standard uncertainties and their associated sensitivity coefficients. Thus, the information needed to derive the overall uncertainty is illustrated in Table B.1.

**Table B.1 — Uncertainty budget**

| **Quantity** | **Estimate**<br><br>dB | **Standard uncertainty**<br>$u_i$<br>dB | **Probability distribution** | **Sensitivity coefficient**<br>$c_i$ | **Uncertainty contribution**<br>$u_i \cdot c_i$<br>dB |
|---|---|---|---|---|---|
| $L_{open}$ (sound pressure level without the hearing protector present) | $\overline{L_{open}}$ | 0,5 | Normal | 1 | 0,5 |
| $L_{occl}$ (sound pressure level with the hearing protector present) | $\overline{L_{occl}}$ | 1,0 | Normal | 1 | 1,0 |
| $\delta_1$ (ATF) | 0 | 0,3 | Normal | 1 | 0,3 |
| $\delta_2$ (sound field) | 0 | 0,5 | Normal | 1 | 0,5 |
| $\delta_3$ (equipment) | 0 | 0,2 | Normal | 1 | 0,2 |
| | | | | | Combined: 1,3 |

The standard uncertainty of the occluded and the non-occluded levels (rows 1 and 2 in Table B.1) is the standard deviation of the mean of repeated measurements. The figures given are considered generally valid for mid-range frequencies and for ear-muff type protectors that are not especially sensitive to the positioning on the ATF, but these should be verified in each specific measurement situation. The standard uncertainty of the $\delta$-terms remains to be established by research. The numbers given here are based on experience obtained at various test laboratories around the world.

## B.4 Expanded uncertainty

The combined standard uncertainty of the determination of the insertion loss is given by the equation:

$$u = \sqrt{\sum_i (c_i u_i)^2} \qquad \text{(B.2)}$$

Thus, for the values in Table B.1, the combined standard uncertainty, $u$, is calculated to be 1,3 dB.

ISO/IEC Guide 98 requires an *expanded* uncertainty, $U$, to be specified, such that the interval $[Y - U, Y + U]$ covers, for example, 95 % of the values of $Y$ that might reasonably be attributed to the insertion loss. For this purpose, a coverage factor, $k$, is used, such that $U = k \cdot u$. For a confidence level of approximately 95 % and for normal probability distributions, the coverage factor $k$ has a value of 2. Thus $U$ will be two times $u$, which in this case is 2,6 dB.

The expanded uncertainty of insertion loss measurements according to this part of ISO 4869 is thus calculated to be 2,6 dB.

NOTE Some standard uncertainties can be obtained as statistical estimated standard deviations by the statistical analysis of a series of observations (referred to as type A evaluation of standard uncertainty in ISO/IEC Guide 98). Such estimations might be included in this part of ISO 4869 at a later stage.

**ICS 13.340.20**

Price based on 11 pages