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Acoustics — Hearing protectors —

Part 1:
Subjective method for the measurement of sound attenuation

Acoustique — Protecteurs individuels contre le bruit —

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

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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 procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise.*

This second edition cancels and replaces the first edition (ISO 4869-1:1990), which has been technically revised.

The main changes compared to the previous edition are as follows:

The revision includes changes mainly of the sound field requirements, specification of test equipment, test procedures and instructions to the test subjects, and uncertainty of the measurements. The sound field requirements are based on published and unpublished laboratory experience, especially [10] and [11] in the Bibliography.

A list of all parts in the ISO 4869 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Hearing protectors are commonly used to reduce the noise to which the ear is exposed. Hearing protectors are manufactured as earplugs, earmuffs or helmets. A standardized method of sound attenuation measurement allows comparison of performance data obtained in different locations under similar conditions.

Acoustics — Hearing protectors —

Part 1:
Subjective method for the measurement of sound attenuation

1 Scope

This document specifies a subjective method for measuring sound attenuation of hearing protectors at the threshold of hearing. The method is a laboratory method designed to yield reproducible values under controlled measurement conditions. 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.

For a more representative indication of field performance the methods of ISO/TS 4869-5 can be used.

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 document is inapplicable, as it will usually underestimate sound attenuation for these devices.

NOTE Due to masking from physiological noise in the occluded ear tests, sound attenuations below 500 Hz can be overestimated by a few decibels.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 8253-2, *Acoustics — Audiometric test methods — Part 2: Sound field audiometry with pure-tone and narrow-band test signals*

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

IEC 61260-1, *Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
hearing protector
device worn by a person to prevent harmful effects from noise and other loud acoustic stimuli

Note 1 to entry: Hearing protectors can 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 eardrum.

3.2
earmuff
hearing protector consisting of an ear-cup to be pressed against each pinna (supra-aural) or of an ear-cup to be pressed against the head, around the pinna (circumaural)

Note 1 to entry: 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
earplug
hearing protector worn within the external earcanal (aural) or in the concha against the entrance to the external earcanal (semi-aural)

3.4
helmet
device which covers a substantial part of the head

3.5
hearing level (of a pure tone)
difference between the sound pressure level of this pure tone produced by the earphone in a specified ear simulator or acoustic coupler and the appropriate reference equivalent threshold sound pressure level at a specified frequency, for a specified type of earphone and for a specified manner of application

Note 1 to entry: Values of reference equivalent threshold sound pressure levels are specified in ISO 389-1.

3.6
hearing threshold level (of a given ear)
threshold of hearing expressed as hearing level at a specified frequency and for a specified type of earphone

Note 1 to entry: For appropriate test conditions, see, for example, ISO 8253-1.

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

Note 1 to entry: For the purpose of ISO 4869-1, the threshold of hearing is measured with and without the hearing protector. For appropriate test conditions, see ISO 8253-2.

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

Note 1 to entry: The sound attenuation is given in decibels.

3.9
pink noise
random noise signal with a spectral density that decreases by 3 dB per octave, giving constant energy per octave

Note 1 to entry: The definition is often phrased as 'noise whose power spectral density is inversely proportional to frequency'.

[SOURCE: ISO 7240-24:2016, 3.1.11; modified: added Note 1 to entry]

3.10
reference point
fixed spatial position within the test chamber to which all objective measurements of the sound field characteristics are referenced and which coincides with the midpoint of a line connecting the test subject's earcanal openings when the test subject is seated for measurements

3.11
reverberation time
time required for the sound pressure level to decrease by 60 dB after the sound source has stopped

Note 1 to entry: See ISO 354 for information about measurement of reverberation time.

4 Measurement of the sound attenuation of hearing protectors

4.1 Test signals

The test signals shall consist of pink noise filtered through one-third-octave bands with centre frequencies in accordance with IEC 61260-1. Tests shall be performed at the following centre frequencies:

125 Hz, 250 Hz, 500 Hz, 1 000 Hz, 2 000 Hz, 4 000 Hz, 8 000 Hz.

Measurements at an additional centre frequency of 63 Hz are optional.

4.2 Test site

4.2.1 General

The sound field at the test site shall have sound incidence from many directions. Such a sound field is adequately approximated when the requirements of 4.2.2, 4.2.3 and 4.2.4 are met. The measurements of the sound field shall be conducted with the test subject and the subject's chair absent.

4.2.2 Sound pressure level and sound pressure level variation

a) The sound pressure level at all test frequencies 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 ±2,5 dB from the sound pressure level at the reference point. In addition, the difference between the right-left positions shall not exceed 3 dB. The orientation of the microphone shall be kept the same at each position.

b) The directionality of the sound field shall be evaluated at the reference point for test signals with centre frequencies greater than or equal to 500 Hz. The measurements shall be conducted with a directional microphone with a typical free-field polar response at the one-third-octave test signals of at least 10 dB front-to-side rejection for a cosine microphone, or at least 10 dB front-to-back rejection for a cardioid microphone. The microphone shall be rotated at the reference point through 360° in the horizontal plane. The variation of the observed sound pressure levels in each test signal shall remain within the variation allowed in Table 1. The sound pressure levels can also be obtained by measuring at fixed 15 degree increments as the microphone is rotated.

Table 1 — Allowable variation of sound-field sound pressure levels for corresponding directional microphone free-field rejection

Microphone free-field rejection (FFR) dB	Allowable field variation dB
25 ≤ FFR	20
20 ≤ FFR < 25	15
15 ≤ FFR < 20	10
10 ≤ FFR < 15	5
FFR < 10	Microphone not suitable

NOTE The variation in microphone response as the microphone is rotated in a random incidence field is related to the directional characteristics of the microphone and the degree of randomness of the field being measured. Therefore, the allowable sound field response variations are related to the free-field directional response characteristics of the microphone. The microphone characteristics can be obtained from the microphone manufacturer or by measurement in a free field.

4.2.3 Reverberation time

The reverberation time in the test space, with the test subject and the test subject's chair absent, shall not exceed 1,6 s for each of the test signals.

4.2.4 Ambient noise level

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

When the lowest test signal centre frequency is 125 Hz, the ambient noise requirement shall be met down to and including 63 Hz. When the lowest test signal centre frequency is 63 Hz, the ambient noise requirement shall be met down to and including 31,5 Hz.

NOTE The ambient noise level includes the noise present in the room and the possible noise from the test equipment while it is on and running, but in the absence of the test signals.

Table 2 — Maximum permissible ambient sound pressure level

Centre frequency Hz	One-third-octave-band sound pressure level (reference = 20 µPa) dB
31,5	57
40	43
50	31
63	25
80	21
100	18
125	14
160	11
200	9
250	6
315	4
NOTE The levels are set in relation to ISO 8253-1 for the purpose of testing down to −10 dB hearing threshold level.	

Table 2 *(continued)*

Centre frequency Hz	**One-third-octave-band sound pressure level** (reference = 20 μPa) dB
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
NOTE The levels are set in relation to ISO 8253-1 for the purpose of testing down to −10 dB hearing threshold level.	

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 (or 56 Hz if the 63 Hz test signal is used) to 9 000 Hz.

NOTE 1 112 Hz is the lower limiting frequency of the 125 Hz one-third-octave band and 9 000 Hz is the upper limiting frequency of the 8 000 Hz one-third-octave band.

The test equipment shall be able to generate test signal sound pressure levels at the reference point, for any test signal, that vary from at least 10 dB above the subject's occluded threshold of hearing to 10 dB below the subject's open threshold of hearing. An example is given in Annex C. The band levels shall be measured using filters complying with IEC 61260-1. During the test, the sounds shall be reproduced without audible distortion, buzzing, crackle, or rattle.

When the test equipment generates one-third-octave-band test signals at the maximum sound pressure levels (Annex C) the levels of the other one-third-octave bands shall be at least 40 dB down from the maximum level – at octave steps – from one octave below the test signal down to 31,5 Hz, and from one octave above the test signal up to 16 kHz.

NOTE 2 Due to internal noise restrictions in the sound pressure level measurement equipment, low sound pressure levels can be calculated on the basis of electrical measurements.

4.3.2 Attenuators shall have a range of at least 90 dB for each test signal. Attenuator steps shall be 2,5 dB or smaller.

4.3.3 The difference in output between any two attenuator settings, measured with a single one-third-octave-band test signal (see 4.1), shall not differ from the indicated difference by more than 2 dB over the total attenuator range and not more than 1 dB over any 80 dB range. Corrections for departure from linearity shall be applied to the data when this requirement is not met.

Where possible this test shall be performed acoustically with a signal reproduced from all signal channels simultaneously, so that the linearity can be measured under conditions approximating that of the actual test and so as to include all parts of the measurement system that are potentially non-linear. Appropriate time averaging is necessary. When the ratio of the acoustically measured sound pressure level to the ambient noise is less than 20 dB, which can occur for the lowest level test signals, the linearity of the signal voltage shall be measured at the terminals of the loudspeaker(s) using either pure-tone or one-third-octave-band test signals.

4.3.4 To assure that the frequency response of the system remains constant over its dynamic range, the frequency response of the system shall be measured in 10 dB steps from the maximum levels the system can reproduce down to the noise floor set by the ambient noise level. For this test the one-third-octave-band test signals (see 4.1) or a pink noise signal from 40 Hz to 10 kHz shall be used. The family of frequency response curves thus generated shall show no departures from linearity of greater than 2 dB for any of the one-third-octave test bands.

4.3.5 The test room shall be equipped with a viewing window or video system to allow clear observation of the subject at all times during the test.

NOTE A head position reference device, such as a small hanging sphere to the nose or the forehead of the subject, can be used to maintain the subject's head at the reference point. Care needs to be taken that the device does not interfere with the threshold determination e.g. by transmitting vibrations to the head and that it is small enough not to affect the uniformity of the sound field.

4.4 Test subjects

4.4.1 Sixteen test subjects shall be used for each test.

4.4.2 Test subjects to be used in the tests shall have a pure-tone 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 ambient noise in the test room is at the maximum levels listed in Table 2, test subjects with hearing threshold levels lower than −10 dB shall be rejected.

4.4.3 Test 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.

4.4.4 Test subjects used for the test shall have demonstrated the ability to provide three consecutive complete threshold determinations for the test signals given in 4.1, with differences between the thresholds of hearing at corresponding centre frequencies not exceeding 6 dB. Untrained test subjects should first be given practice sessions.

4.5 General test procedure and instruction of the test subject

4.5.1 The attenuation measurement is described in 4.6.

A minimum of four samples of an earmuff hearing protector under test shall be used. The samples shall be evenly distributed among the test subjects. Test subjects shall use the same protector throughout the test. For earmuffs care should be taken to clean the hearing protector between different test subjects.

For earplugs one pair per test subject shall be provided and used throughout the test.

4.5.2 The test subjects shall be fully informed of the test situation and procedures. The tester shall instruct each test 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 tester shall instruct each test subject on how to properly fit the hearing protector. When hearing protectors are supplied in multiple sizes, the tester shall assist the test subject in selecting the appropriate size. Trial sound attenuation measurements shall not be part of the sizing or fitting procedure unless they are included with the product or product delivery process. The wearing of eyeglasses, ear jewellery or any other devices that are 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 that accompany the device, and, as necessary, verbal clarification or physical assistance in adjusting the device in conformance with the written instructions. For standardized measurements on prototypes for development purposes the written instructions can be a draft or interim document. When the tester determines that the test subject can properly fit the device, the hearing protector shall be removed. A period of quiet time for the test subject shall be included before the definitive test is started.

For the definitive test, the test subject shall enter the test chamber, reapply the hearing protector and adjust it for best attenuation consistent with reasonable comfort. The tester shall observe the fitting from outside the test chamber. The test 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(A) to 70 dB(A) at the test subject's head position. The broad-band noise is turned off after the test subject indicates that a best fit has been obtained.

If requested, the occluded threshold measurements shall begin a minimum of two minutes after the hearing protectors have been fitted, to allow hearing protectors to expand or conform to fit the earcanal or circumaural regions. The requester's written instructions can specify that a longer minimum time is required.

When the definitive test begins, any further manipulation of the hearing protector is prohibited.

However, the test subject shall be instructed to inform the tester if, during the test, a change in fit of the device is noticed and, if so, the test shall be stopped. The test subject shall then refit the device and the test shall be restarted from the beginning of the trial. If this occurs a second time, the test shall be completed without refit and the attenuation data shall be used in the computations specified in 4.6.

4.5.4 If an abnormal situation occurs, such as audible noise or signal distortion, or some other unanticipated event, the test shall be terminated and repeated.

4.6 Determination of hearing protector attenuation

4.6.1 The thresholds of hearing shall be measured once with open ears and once with the hearing protector in place for each test subject in accordance with ISO 8253-2. Half of the test subjects shall be tested 'open – occluded' and the other half shall be tested 'occluded – open'.

4.6.2 The individual attenuation for each test subject is calculated for each test signal as the difference between the threshold of hearing measured with the protector in place and the threshold of hearing measured with open ears.

4.6.3 The mean attenuation and standard deviation for each test signal is calculated from the individual attenuations.

5 Application force

5.1 Earmuffs

In the case of earmuffs, the application force shall be measured on a suitable measuring device. For the measurement of earmuffs the opposing faces of the ear-cushions shall be separated by 145 mm ± 1 mm. The headband shall be adjusted to produce a dimension of 130 mm ± 1 mm measured between the centre of the headband (inner surface) and 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 can be more appropriate. The actual dimension shall be reported with the force data.

NOTE An example of a suitable device and procedure is described in EN 13819-1[6].

5.2 Semi-aural earplugs

In the case of semi-aural earplugs, the application force shall be measured on a suitable measuring device.

NOTE An example of a suitable device is described in ANSI S12.6-2016, Annex D[8].

6 Test report

The test report shall include the following:

a) a reference to this document, i.e. ISO 4869-1:2018;

b) the type of hearing protector. Replaceable parts of the hearing protector shall be described;

c) the individual attenuations for each test signal for all test subjects. These data shall be reported for each test configuration of testing (e.g. headband position, band force adjustment);

d) the mean and standard deviation for each test signal of the individual attenuations in c);

e) the expanded measurement uncertainty of the data for a coverage of 95 % of the values, see Annex A;

f) the date(s) on which the tests were conducted;

g) the number of samples of the hearing protector tested;

h) in case of sized hearing protectors, the sizes that were tested and the number of test subjects on which each size was tested;

i) a copy of the manufacturer's fitting instruction given to the test subjects in the test;

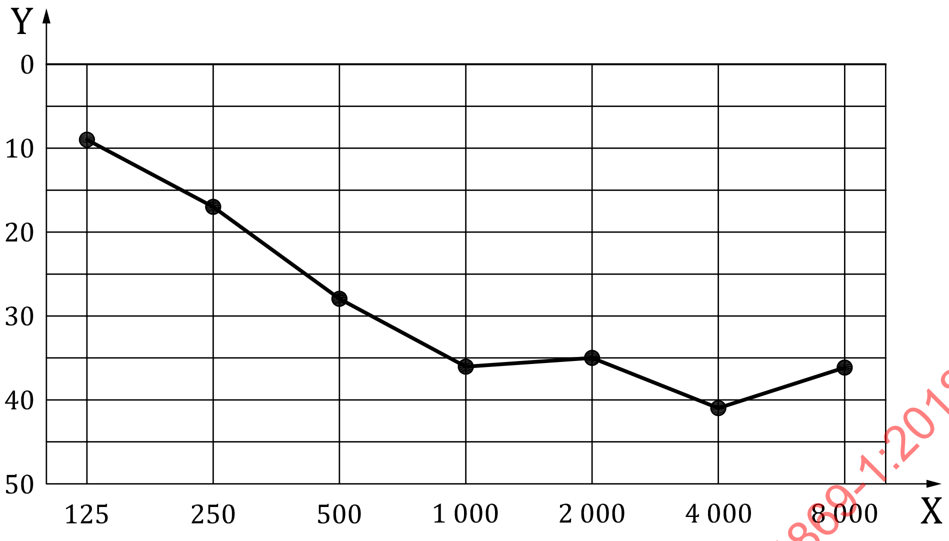
j) the number of re-tests conducted, if any, and the reasons for each re-test;

k) in cases of earmuffs and semi-aural earplugs, the application force for each sample and each test configuration, see c);

l) the mean attenuation presented in graphical form. In accordance with IEC 60263, the length equivalent to 50 dB on the Y axis shall equal the length equivalent to one decade on the X axis. The mean attenuation shall be plotted such that increasing values are directed downwards.

An example of a graphical presentation of the mean attenuation is given in Figure 1.

The test report can include other statistical data that are derived from the individual attenuations, e.g. the median, appropriate centiles and the range. Data on all test subjects shall be incorporated in such calculations.



Key

X test signal centre frequency in Hz

Y attenuation in dB

Figure 1 — Example of the mean attenuation of a hearing protector

Annex A
(normative)

Uncertainty of hearing protector attenuation measurements

A.1 General

Uncertainties in the measurement of the mean attenuation of a hearing protector according to this document arise from various sources such as selection of the test subject group, fitting of the hearing protector on the test subjects, threshold determination by the test subjects, variation in the tester and administration of the test protocol, influence from the sound field, ambient noise and test equipment, etc. The description below follows the outline given in ISO/IEC Guide 98-3.

The model, including uncertainties, for the calculation of the attenuation, A, for the test signals specified in this document is

$$A = A_{\text{REAT}} + \delta_{\text{meth}} + \delta_{\text{eq}} + \delta_{\text{env}} \quad \text{(A.1)}$$

where

A_{REAT} is the outcome of a real-ear attenuation measured according to this document;

δ_{meth} is the input quantity to allow for the variation due to the selection of test subject group, fitting of the hearing protector, the variability of the subject's threshold determination, variation in tester and administration of the protocol, and specimen variability;

δ_{eq} is the input quantity to allow for any deviation in the performance of the test signal generation equipment;

δ_{env} is the input quantity to allow for influence from non-ideal or varying environmental conditions, such as sound field and ambient noise.

A probability density function is associated with each source of uncertainty. The best estimate of each source is the mean value. The mean values of the δ-terms in Formula (A.1) are assumed to be zero, and thus A_{REAT} is the best estimate of A. The standard deviation of each source, i, is an estimate of the standard uncertainty, u_i, associated with that source.

The combined uncertainty, u, depends on the standard uncertainties, u_i, from all sources and their sensitivity coefficients, c_i. The sensitivity coefficient is a measure of how the value of attenuation is affected by the change in its respective input quantity. The combined standard uncertainty is given by the square root of the sum of the squares of the separate standard uncertainties weighted by the sensitivity coefficients [see Formula (A.2)].

$$u = \sqrt{\sum_i \left(c_i u_i\right)^2} \quad \text{(A.2)}$$

where

u is the combined uncertainty;

c_i is the sensitivity coefficient of source i;

u_i is the standard uncertainty of source i.

In the model [Formula (A.1)], all of the probability distributions for the standard uncertainties, u_i, are assumed to be normal and all sensitivity coefficients, c_i, have a value of 1.

NOTE The standard uncertainties are estimated from measurements at Physikalisch-Technische Bundesanstalt, Germany[12], Laboratory of Personal Protection Equipment, Brazil[13][14], Nordic[10][15] and European Round Robin tests[16], National Institute for Occupational Safety and Health, USA[17], National Acoustic Laboratories, Australia[18][19], and supplemented by empirical knowledge.

Table A.1 illustrates the general estimation of the input quantities for δ_{meth}, δ_{eq}, and δ_{env}. The value of the standard uncertainty, u_{meth}, associated with input quantity, δ_{meth}, is frequency dependent. In Table A.2, u_{meth} is specified separately for test signals in three frequency ranges. The uncertainty value, u_{meth}, is greater between laboratories than within laboratories, and generally greater for earplugs than for earmuffs. The values of u_{eq} and u_{env} are assumed to be independent of frequency.

The standard uncertainty values supplied in this annex are considered representative of the measurements and equipment that would normally be used in hearing protector testing.

Table A.1 — General form of an uncertainty budget for hearing protector determinations

Source	Mean estimate dB	Standard uncertainty u_i dB	Probability distribution	Sensitivity coefficient c_i	Uncertainty contribution $u_i \cdot c_i$ dB
δ_{meth}	0	u_{meth}	Normal	1	u_{meth}
δ_{eq}	0	u_{eq}	Normal	1	u_{eq}
δ_{env}	0	u_{env}	Normal	1	u_{env}

The expanded measurement uncertainty, U_{95}, is computed by multiplying the combined standard uncertainty, u, by a coverage factor $k = 2$ (appropriate for normally distributed parameters), such that an interval from $A - U_{95}$ to $A + U_{95}$ covers 95 % of the values of A.

A.2 Uncertainty within a laboratory

The combined uncertainty, u, within a laboratory is the standard deviation of the mean attenuation. This is estimated from a calculation of the standard deviation of the individual attenuations divided by the square root of the number of test subjects, i.e. $\sqrt{16} = 4$.

The investigations referenced in A.1 have been used to find typical uncertainty values. Table A.2 shows the estimated uncertainty contributions within a laboratory for earplugs and earmuffs and for different frequency ranges. It also shows the combined and expanded measurement uncertainties.

Table A.2 — Estimates of the within-laboratory uncertainty for the mean attenuation

Component	Uncertainty contribution dB		
	<250 Hz	250 Hz up to 4 kHz	>4 kHz
u_{meth} – uncertainty of the mean of individual attenuations of 16 test subjects			
— earplug	1,5	1,0	1,5
— earmuff	1,0	0,6	1,0
u_{eq} – uncertainty of test signal generation equipment	0,2	0,2	0,2
u_{env} – uncertainty of deviations from ideal test environment	0,5	0,5	0,5
Combined standard uncertainty u			
— for an earplug	1,6	1,1	1,6
— for an earmuff	1,1	0,8	1,1
Expanded measurement uncertainty U_{95}			
— for an earplug	3,2	2,3	3,2
— for an earmuff	2,3	1,6	2,3
NOTE All calculations are made with full precision before rounding to one decimal.			

For a specific set of measurements at a specific test site, and for a specific hearing protector, the combined uncertainty can be calculated from the individuals' attenuation values. This is shown in the example below.

Table A.3 shows an example of earmuff data from a specific laboratory measured in accordance with this document. The combined standard uncertainty is computed in that table as the experimental standard deviation of the mean, also referred to as the standard error of the mean. Note that this value can be calculated from the attenuation data from a specific laboratory.

Table A.3 — Example of earmuff test data in dB for a given laboratory

Test subject	Frequency Hz						
	125	250	500	1 000	2 000	4 000	8 000
1	9,6	13,5	27,5	32,4	35,2	29,1	28,5
2	14,1	20,2	25,8	32,0	28,9	35,3	35,7
3	21,8	27,8	28,3	46,6	37,4	40,1	38,7
4	18,5	22,2	36,5	44,8	39,1	30,6	33,5
5	15,6	21,9	31,8	42,5	38,9	38,3	37,1
6	18,7	28,6	31,3	39,0	35,6	35,3	29,4
7	23,0	26,5	34,0	41,3	40,8	38,7	35,9
8	17,3	21,7	25,0	30,7	38,6	37,9	40,8
9	19,4	19,6	28,0	36,6	40,7	34,9	39,4
10	11,6	20,4	22,6	38,0	39,2	33,9	30,3
11	20,5	21,8	29,2	40,7	36,2	35,7	38,4
12	18,3	19,6	26,2	34,6	32,7	34,9	26,6

NOTE 1 The data in each row for each subject represent the individual attenuation at each test frequency with that subject.

NOTE 2 All calculations are made with full precision before rounding to one decimal.

Table A.3 *(continued)*

Test subject	Frequency Hz						
	125	250	500	1 000	2 000	4 000	8 000
13	15,1	17,5	30,1	39,0	39,4	38,2	39,5
14	21,7	20,8	28,3	39,5	38,1	40,0	38,4
15	15,9	17,8	26,0	40,6	38,0	40,2	37,2
16	11,8	18,4	29,6	37,2	40,8	36,0	29,9
Mean	17,1	21,1	28,8	38,5	37,5	36,2	35,0
Standard deviation (σ)	3,9	3,9	3,5	4,5	3,2	3,2	4,6
Combined standard uncertainty, u, ($\sigma/\sqrt{N}$)	1,0	1,0	0,9	1,1	0,8	0,8	1,1
Expanded measurement uncertainty, U_{95}	2,0	1,9	1,7	2,2	1,6	1,6	2,3

NOTE 1 The data in each row for each subject represent the individual attenuation at each test frequency with that subject.

NOTE 2 All calculations are made with full precision before rounding to one decimal.

Guidance to evaluation of two hearing protector attenuation measurements is given in Annex B.

Annex B
(informative)

Evaluation of two hearing protector attenuation measurements

B.1 Application of the expanded measurement uncertainty within a laboratory

B.1.1 Using typical uncertainty estimates

As an example of the application of the uncertainty values in Table A.2, consider a comparison of two attenuation measurements. The measurements are made for two different earplugs within a given laboratory on two occasions. The question is: Are the two results significantly different?

The two attenuation values cannot be deemed statistically significantly different if the means differ by less than twice the expanded measurement uncertainty (U_{95}) divided by the square root of two. In order for the difference to be considered significant, the necessary minimum difference is $2 \times U_{95}/\sqrt{2} = \sqrt{2} \times U_{95}$ where U_{95} is the expanded measurement uncertainty.

From Table A.2 the expanded measurement uncertainty for an earplug in the frequency range 250 Hz to 4 kHz is 2,3 dB. The minimum difference is thus $\sqrt{2} \times 2{,}3$ dB = 3,3 dB (rounded to one decimal). Therefore, two test values would have to differ by more than 3,3 dB in this frequency range in order for them to be considered significantly different at a confidence level of 95 %.

For an earmuff the minimum difference will be 2,3 dB in the frequency range 250 Hz to 4 kHz.

B.1.2 Using uncertainty values derived from test data in a specific laboratory

Table B.1 shows an example of data for an earmuff measured for two test conditions (e.g. headband position) in accordance with this document. For each test the mean, *m*, the standard deviation, *sd*, and the expanded measurement uncertainty, U_{95}, are given. The expanded measurement uncertainty is two times the combined standard uncertainty. The combined standard uncertainty is the standard deviation divided by the square root of the number of test subjects. The data for test 1 are the same as those in Table A.3.

A possible significant difference between the mean values can be evaluated by means of the last two rows in Table B.1. One row shows the absolute difference between the means from the two tests. The last row shows the calculation of the square root of the sum of squared expanded measurement uncertainties. The difference between the means is significant at a 5 % level when the difference is greater than the value in the last row.

The example shows that the attenuation values measured at the two test conditions are not significantly different in the frequency range 125 Hz to 4 000 Hz. At 8 000 Hz a significant difference is seen.

