BS EN 60318-4:2010

BSI Standards Publication

Electroacoustics — Simulators of human head and ear

Part 4: Occluded-ear simulator for the measurement of earphones coupled to the ear by means of ear inserts

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National foreword

This British Standard is the UK implementation of EN 60318-4:2010. It is identical to IEC 60318-4:2010. It supersedes BS 6310:1982 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/29, Electroacoustics.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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English version

Electroacoustics - Simulators of human head and ear - Part 4: Occluded-ear simulator for the measurement of earphones coupled to the ear by means of ear inserts

(IEC 60318-4:2010)

Electroacoustique -
Simulateurs de tête et d'oreille humaines -
Partie 4: Simulateur d'oreille occluse
pour la mesure des écouteurs couplés
à l'oreille par des embouts
(CEI 60318-4:2010)

Akustik -
Simulatoren des menschlichen Kopfes
und Ohres -
Teil 4: Simulator für den abgeschlossenen
Gehörgang zur Messung an mittels
Ohreinsätzen an das Ohr angekoppelten
Ohrhörern
(IEC 60318-4:2010)

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European Committee for Electrotechnical Standardization
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Foreword

The text of document 29/662/CDV, future edition 1 of IEC 60318-4, prepared by IEC TC 29, Electroacoustics, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60318-4 on 2010-05-01.

This standard supersedes HD 443 S1:1983.

The main changes with respect to the previous edition are listed below:

– extension of the usable frequency range to 100 Hz – 16 000 Hz;
– addition of values of maximum permitted expanded uncertainties to all tolerances.

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

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-02-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2013-05-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60318-4:2010 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

[1]	ISO 389-2	NOTE Harmonized as EN ISO 389-2.
[2]	ISO 389-5	NOTE Harmonized as EN ISO 389-5.
[3]	ISO 389-6	NOTE Harmonized as EN ISO 389-6.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 61094-4	-	Measurement microphones - Part 4: Specifications for working standard microphones	EN 61094-4	-
ISO/IEC Guide 98-3	-	Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)	-	-

CONTENTS

ELECTROACOUSTICS – SIMULATORS OF HUMAN HEAD AND EAR –

Part 4: Occluded-ear simulator for the measurement of earphones coupled to the ear by means of ear inserts

1 Scope

This part of IEC 60318 describes an occluded-ear simulator intended for the measurement of insert earphones in the frequency range from 100 Hz to 10 000 Hz. It is suitable for air conduction hearing aids and earphones, coupled to the ear by means of ear inserts e.g. ear moulds or similar devices. The occluded-ear simulator is also suitable as the basis for an extension intended to simulate the complete ear canal and the outer ear (for instance in head simulators).

The occluded-ear simulator simulates the acoustic transfer impedance for the occluded normal adult human ear. However, it does not simulate the leakage between an earmould and a human ear canal; therefore, the results obtained with the occluded-ear simulator may deviate from the performance of an insert earphone on a real ear, especially at low frequencies. Moreover, large performance variations among individual ears will occur which should be considered when using the ear simulator.

Above 10 kHz the device does not simulate a human ear, but can be used as an acoustic coupler at additional frequencies up to 16 kHz. Below 100 Hz, the device has not been verified to simulate a human ear, but can be used as an acoustic coupler at additional frequencies down to 20 Hz.

NOTE Due to resonances in the acoustic transfer impedance of the occluded-ear simulator above 10 kHz, high measurement uncertainties, e.g. in the order of 10 dB, can occur in earphone responses. Repeatable results mainly are obtained for insert earphones with high acoustic damping (used for instance in the extended high-frequency audiometry, see the earphones listed in ISO 389-6)[3][1] coupled to the occluded-ear simulator by means of a simple, symmetrically designed and air tight coupling device.

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.

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

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

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

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1 Figures in square brackets refer to the Bibliography.

3.1
ear insert
device used to provide the acoustic coupling between an earphone and the ear canal (e.g. an earmould or a similar device with or without a connecting tube)

3.2
insert earphone
small earphone coupled to the ear canal by means of an ear insert or attached to a connecting element which is inserted into the ear canal

NOTE This ear insert may be a part of the insert earphone.

3.3
ear-mould simulator
ear insert simulator
insert which terminates the entrance of the ear simulator and provides for passage of sound into the occluded-ear simulator through an opening on its axis

3.4
ear simulator
device for measuring the acoustic output of sound sources where the sound pressure is measured by a calibrated microphone coupled to the source so that the overall acoustic impedance of the device approximates that of the normal human ear at a given location and in a given frequency band

3.5
occluded-ear simulator
ear simulator which approximates the acoustic transfer impedance of the inner part of the ear canal, from the tip of an ear insert to the eardrum

3.6
acoustic coupler
device for measuring the acoustic output of sound sources where the sound pressure is measured by a calibrated microphone coupled to the source by a cavity of predetermined shape and volume which does not necessarily approximate the acoustical impedance of the normal human ear

3.7
reference plane of the occluded-ear simulator
plane perpendicular to the axis of the cavity of the simulator, chosen to pass through the position normally occupied by the tip of an earmould in a human ear

3.8
acoustic transfer impedance of the occluded-ear simulator
quotient of the sound pressure at the diaphragm of its microphone by the volume velocity through the reference plane

unit: $Pa \cdot s \cdot m^{-3}$

3.9
acoustic transfer impedance level of the occluded-ear simulator
ten times the logarithm to the base of ten of the quotient of the absolute value (modulus) of the squared acoustic transfer impedance of the occluded-ear simulator by the squared reference acoustic transfer impedance of one pascal second per cubic metre ($Pa \cdot s \cdot m^{-3}$)

unit: dB

3.10
effective volume
equivalent volume of air of the acoustic compliance of the ear simulator formed by the cavity and the microphone at a frequency of 500 Hz

unit: mm^3

4 Construction

4.1 General

The occluded-ear simulator shall be constructed of hard, dimensionally stable, non-porous and non-magnetic material. The general construction of the occluded-ear simulator and mounting of the microphone shall aim at minimizing the response of the microphone to vibration (for example from an earphone) or to extraneous sound outside the cavity.

NOTE 1 The external diameter of the occluded-ear simulator should be kept as small as possible in order to minimize diffractional errors which might affect the measurements when the occluded-ear simulator has to be placed in a free sound field.

NOTE 2 In order to avoid a possible sound attenuation caused by the dust protector (see Figure A.1), an earphone calibration should be performed above 10 kHz at least every two years with the occluded-ear simulator equipped with and without its dust protector in place. The two results should not differ by more than 0,2 dB at frequencies up to 16 kHz. If this is not the case at some frequencies, earphone measurements at those frequencies should generally be performed without the dust protector.

The construction of the occluded-ear simulator shall permit the location of a transducer at the reference plane for calibrating the simulator.

Where tolerances are specified in this part of IEC 60318, these shall be reduced by an amount equal to the actual expanded measurement uncertainty of the test laboratory before deciding if a device conforms to the stated requirement.

4.2 Principal cavity dimensions

The diameter of the principal cavity shall be (7,50 ± 0,04) mm.

The length of the principal cavity shall be such as to produce a half-wavelength resonance of the sound pressure at (13,5 ± 1,5) kHz.

4.3 Calibrated pressure-type microphone

A calibrated microphone is located at the base of principal cavity of the occluded-ear simulator. The acoustic impedance of the microphone diaphragm shall be high, so that the equivalent volume is less than 20 mm^3 over the specified range of frequencies. The microphone shall conform to the requirements of IEC 61094-4 for a type WS2P microphone. The microphone shall be coupled to the principal cavity with a seal that prevents acoustic leaks.

In the frequency range 20 Hz to 10 kHz, the overall sound pressure sensitivity level of the microphone and associated measuring system shall be known with an uncertainty not exceeding 0,3 dB for a level of confidence of 95 %. For measurements above 10 kHz, the overall pressure sensitivity level of the microphone and associated measuring system over the specified frequency range shall be known with an uncertainty not exceeding 0,5 dB for a level of confidence of 95 %.

The make and model of the microphone shall be specified by the manufacturer of the occluded-ear simulator.

NOTE The acoustic impedance of the microphone affects the overall acoustic impedance of the occluded-ear simulator.

4.4 Pressure equalization

A vent shall be provided to equalize the static pressure in the cavity of the occluded-ear simulator. The vent shall have an acoustic resistance of (7,0 ± 5,5) GPa·s·m^{-3}.

4.5 Acoustic transfer impedance level

The level of the acoustic transfer impedance modulus of the occluded-ear simulator and the associated tolerances shall be as specified in Table 1.

NOTE 1 At 500 Hz, the specified transfer impedance level corresponds to the magnitude of the acoustic transfer impedance 35,9 MPa·s·m^{-3} and also to the magnitude of the effective volume 1 260 mm^3 of the ear simulator.

NOTE 2 The tolerances have minimum values at the frequency 500 Hz, where the influence of leakage and wave motion is small.

4.6 Example of design

An example of one specific design of occluded-ear simulator is shown in Annex A.

Table 1 – Level of the acoustic transfer impedance modulus and associated tolerances

Nominal frequency Hz	Acoustic transfer impedance level re 1 MPa·s·m^{-3} in dB	
	Level	Tolerances
100	44,8	± 0,7
125	42,9	± 0,7
160	40,8	± 0,7
200	39,0	± 0,6
250	37,0	± 0,6
315	35,0	± 0,6
400	33,0	± 0,6
500	31,1	± 0,3
630	29,2	± 0,6
800	27,2	± 0,6
1 000	26,7	± 0,7
1 250	26,4	± 0,7
1 600	25,5	± 0,7
2 000	24,2	± 0,8
2 500	23,1	± 0,8
3 150	22,0	± 0,9
4 000	21,1	± 1,0
5 000	20,4	± 1,2
6 300	20,5	± 1,2
8 000	20,8	± 1,7
10 000	23,1	± 2,2

NOTE 1 Using the measurement method described in Annex B, it is not easy to measure the acoustical transfer impedance level below 100 Hz, due to the effects of an imperfectly sealed measurement configuration. However, the acoustical transfer impedance between 20 Hz and 100 Hz is governed predominantly by the volumetric elements of the occluded-ear simulator, and their contribution to the overall acoustical transfer impedance can be validated by the measurements at higher frequencies.

NOTE 2 The values in Table 1 are valid for the exact one-third-octave frequencies calculated from $1\,000 \times 10^{n/10}$, where n is a positive or negative integer or zero.

5 Calibration

5.1 Atmospheric reference conditions

Reference ambient pressure: 101,325 kPa

Reference temperature: 23 °C

Reference relative humidity: 50 %

5.2 Calibration method

The manufacturer shall describe the method(s) for determining calibration and overall stability of the complete occluded-ear simulator including the microphone in an instruction manual.

The method shall include the determination of the effective volume at 500 Hz.

The principle of calibration is given in Annex B.

The calibration should be performed for the atmospheric reference conditions given in 5.1 with the following tolerances:

Ambient pressure: ± 3 kPa

Temperature: ± 3 °C

Relative humidity: ± 20 %

If it is not possible to perform the calibration at reference conditions, the calibration shall be referred to the atmospheric reference conditions given in 5.1, see [8], [9].

6 Coupling of earphones and hearing aids to the occluded-ear simulator

6.1 Audiometers with insert earphones

Insert earphones with standardized reference equivalent threshold sound pressure levels shall be connected to the occluded-ear simulator as specified in the relevant ISO standards. For other earphones, the manufacturer of the audiometer shall describe the method of connection.

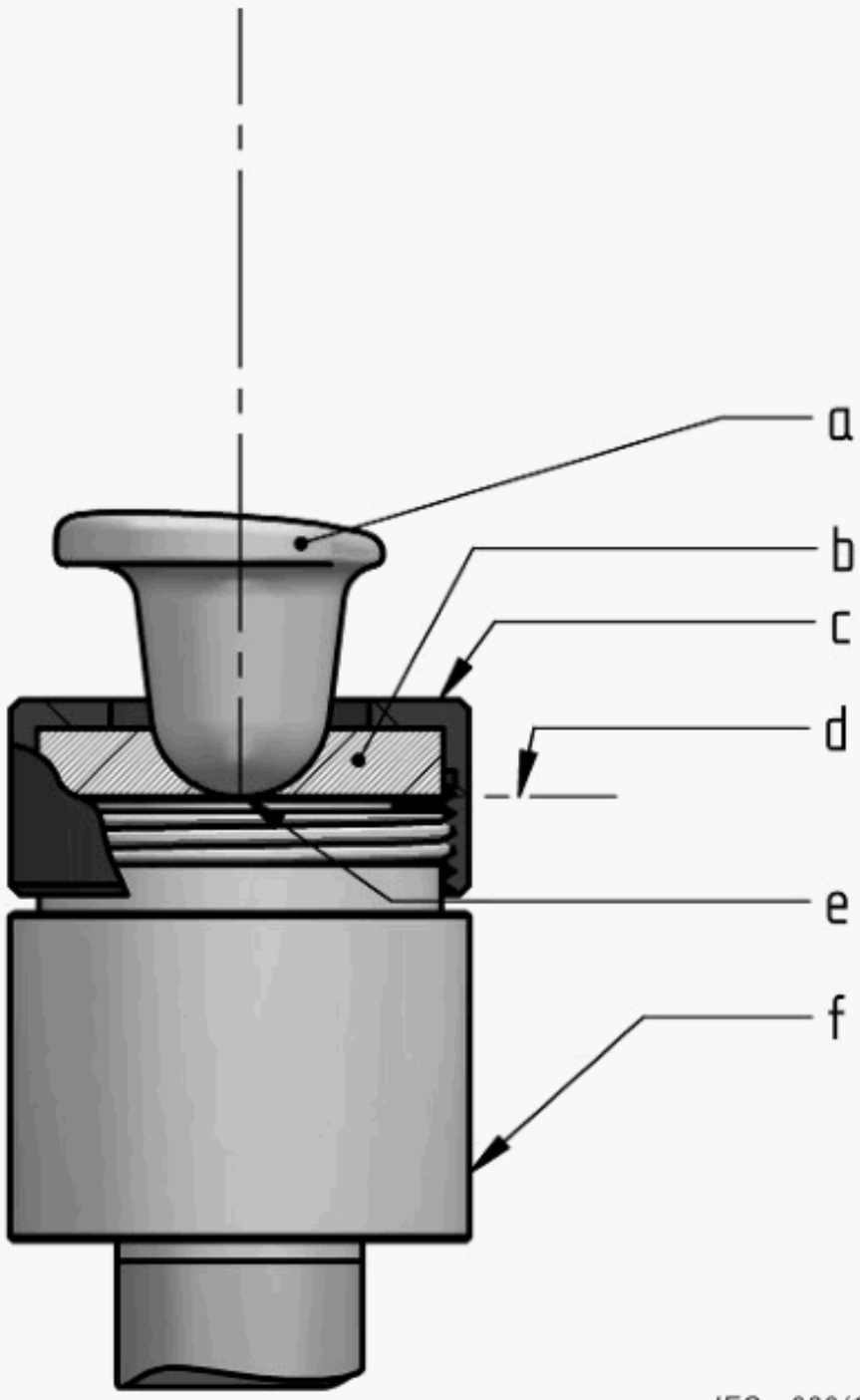
NOTE Reference hearing threshold sound pressure levels of insert earphones for audiometers and its connection to the occluded-ear simulator are standardized in ISO 389-2 [1], ISO 389-5 [2] and ISO 389-6 [3].

6.2 In-the-ear hearing aids (custom made)

The hearing aid shall be connected directly to the cavity of the occluded-ear simulator as indicated in Figure 1. The connection between the hearing aid and the occluded-ear simulator shall be made airtight by using a suitable seal. In doing so, care shall be taken not to introduce additional volume to the cavity which can affect the measured performance of the hearing aid.

In the same way, a hearing aid equipped with a separate ear insert can be measured.

Dimensions in millimetres



IEC 030/10

Key

a hearing aid (custom-made)

b airtight seal and support for hearing aid

c retaining collar

d reference plane

e tip of hearing aid or insert should lie in the reference plane

f occluded-ear simulator

NOTE 1 This diagram is only intended as a schematic representation illustrating the principle of connecting the hearing aid to the occluded-ear simulator. Effective airtight seals should be assured at all connection points.

NOTE 2 In the same manner, a hearing aid equipped with a separate ear insert can be connected to the occluded ear simulator.

Figure 1 – Connection of an in-the-ear hearing aid to the occluded-ear simulator

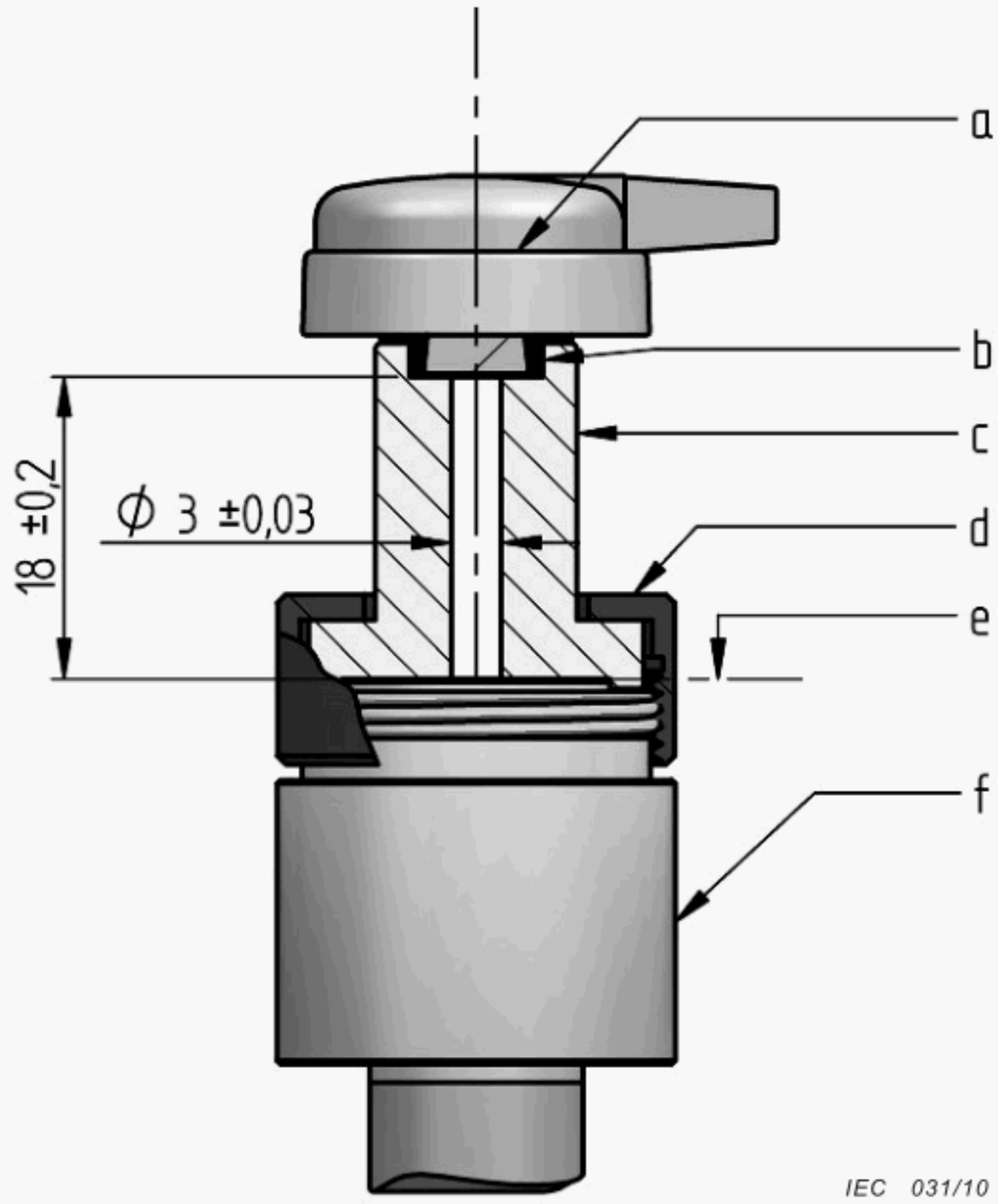
6.3 Hearing aids with insert earphone

Where possible, the ear insert used with the human ear shall be replaced by an ear-mould simulator consisting essentially of a rigid tube, coaxial with the cavity, of length 18,0 mm ± 0,20 mm and internal diameter 3,00 mm ± 0,06 mm, representing the tubular portion of an average ear mould.

The connection between the nub of the earphone and the ear-mould simulator shall be made airtight by using a suitable seal, In doing so, care shall be taken not to introduce additional volume to the cavity which can affect the measured performance of the earphone.

An example of an earphone connected to the occluded-ear simulator with an ear-mould simulator is shown in Figure 2. It illustrates the principal features of the connection method. However, other forms may also be used, provided that they conform to the above specifications.

Dimensions in millimetres



IEC 031/10

Key

a insert earphone

b airtight seal and support for nub of earphone

c ear-mould simulator for insert earphone

d retaining collar

e reference plane

f occluded-ear simulator

NOTE This diagram is only intended as a schematic representation illustrating the principle of connecting the hearing aid to the occluded-ear simulator. Effective airtight seals should be assured at all connection points.

Figure 2 – Connection of an insert earphone to the occluded-ear simulator

If it is inappropriate to disconnect the ear insert used with the human ear from the receiver, the ear insert shall be connected directly to the entrance of the cylindrical cavity and shall be coaxial with it. An airtight seal shall be ensured. In doing so, care shall be taken not to introduce additional volume to the cavity which can affect the measured performance of the earphone.

6.4 Behind-the-ear and spectacle hearing aids

The hearing aid with its acoustic outlet attachment (e.g. hook and flexible connecting tube of behind-the-ear hearing aids or nub and flexible connecting tube of spectacle hearing aids)

shall be connected to the occluded-ear simulator with an ear-mould simulator as described in 6.3. This shall be accomplished by means of a small coupling device of rigid material, having the same internal diameter as the nominal diameter at the end of the acoustic outlet attachment ± 0,06 mm and a length of 5,0 mm ± 0,1 mm.

The connection between the small coupling device and the ear-mould simulator shall be made airtight by using a suitable seal. In doing so, care shall be taken not to introduce additional volume to the cavity which can affect the measured performance of the hearing aid.

The material, length and internal diameter of the connecting tube between the hearing aid and the small coupling device shall conform to the hearing-aid manufacturer's specifications. In particular, the connecting tube can be of flexible or rigid material. This connecting tube between the hearing aid and the small coupling device shall be connected to the nub of a spectacle hearing aid or to the hook, if any, of a behind-the-ear hearing aid. The connecting tube shall not be connected directly to the behind-the-ear type of hearing aid if this aid is intended to be used with a hook.

Unless otherwise specified, the length of the connecting tube measured from the end of the hook or from the end of the nub to the entrance of the 3 mm diameter rigid tube of the ear-mould simulator shall be 25 mm ± 1 mm.

The principal features of the occluded-ear simulator with ear-mould simulator and small coupling device, showing the connection arrangement for a behind-the-ear hearing aid are indicated in Figure 3. As an example, the internal diameter of the small coupling device is chosen to be 2 mm in accordance with the tubing most commonly used. Forms other than the one illustrated may be used, provided that they conform to the above specifications.

NOTE The manufacturer's specifications for the dimensions of the tubing should be in accordance with the average conditions found in practical use of the hearing aid. If, for some unusual reason, it is impossible to simulate the average conditions of practical use with the ear-mould simulator specified above in the occluded-ear simulator, an appropriate different system may be used if fully described.

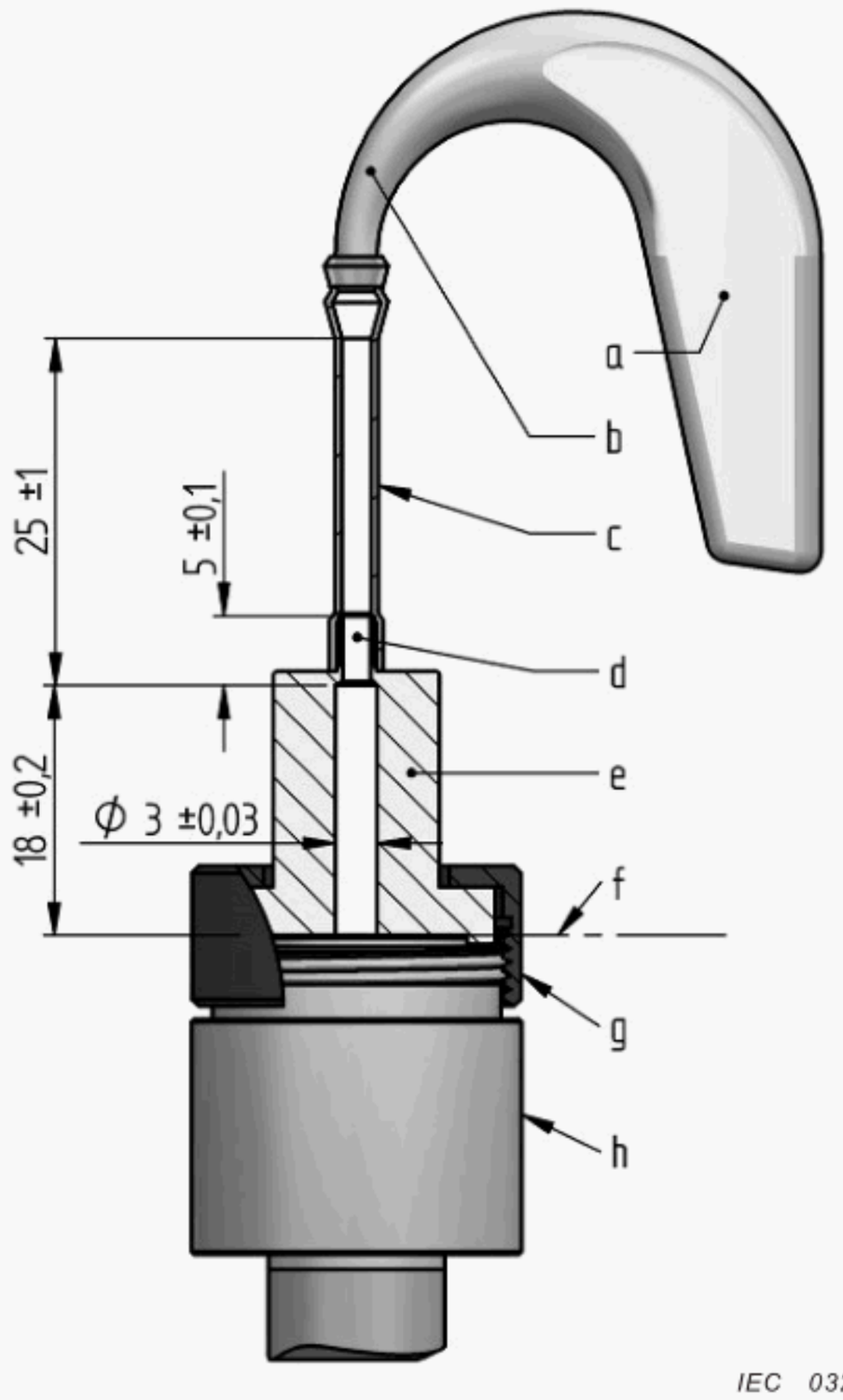
6.5 Modular in-the-ear hearing aids

The modular version of the hearing aid shall be connected directly to the cavity of the occluded-ear simulator as indicated in Figure 4. This shall be accomplished by means of a tube coupling device of rigid material, having the same internal diameter as the nominal diameter at the end of the acoustic outlet attachment ± 0,06 mm and a length of 5,0 mm ± 0,1 mm.

The connection between the tube coupling device and the occluded-ear simulator shall be made airtight by using a suitable seal. In doing so, care shall be taken not to introduce additional volume to the cavity which can affect the measured performance of the hearing aid.

Unless otherwise specified, the length of the connecting tube measured from the outlet of the hearing aid to the entrance of the reference plane of the occluded-ear simulator shall be 8,0 mm ± 0,7 mm.

Dimensions in millimetres



Key

a behind-the-ear type of hearing aid (BTE)

b acoustical outlet of hearing aid (hook)

c flexible connecting tube, typically Ø 2 mm internal

d small tube coupling device having the same internal diameter as the nominal diameter of the acoustical outlet attachment of the hearing aid, typically Ø 2 mm

e ear-mould simulator for hearing aids

f reference plane

g retaining collar

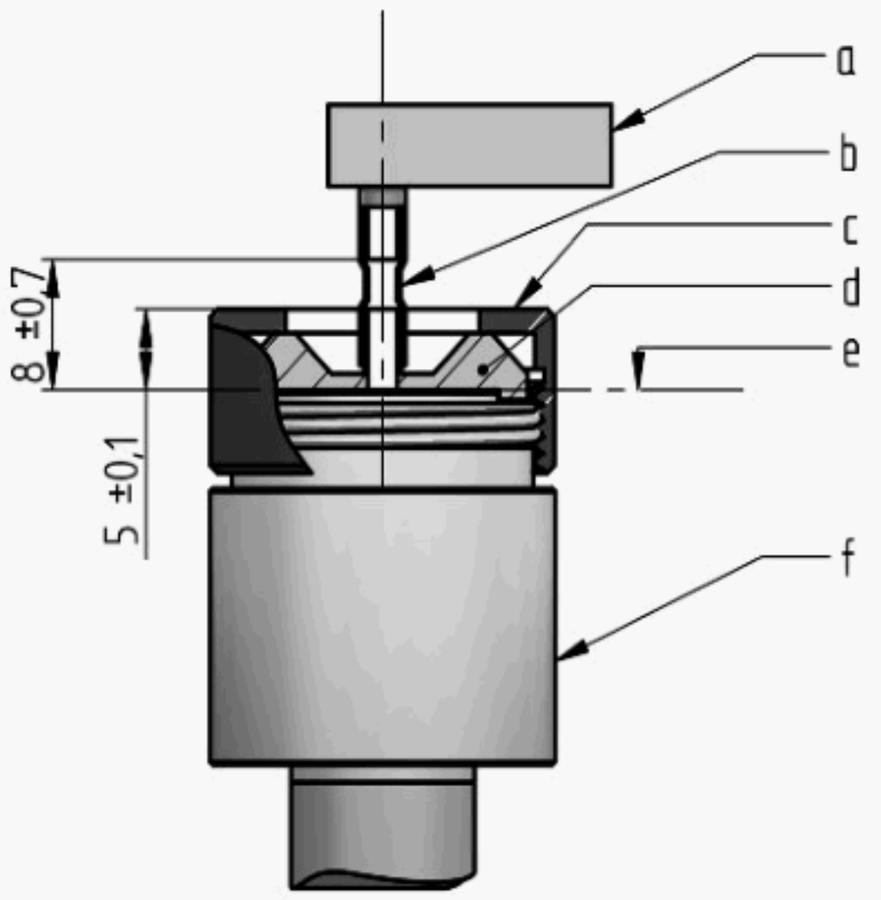
h occluded-ear simulator

NOTE 1 The length of the tubing and the inside diameters of both the tubing and the coupling device (which are to be equal) should be as shown and stated above, unless otherwise specified by the manufacturer, in order to meet the average conditions found in practical use of a particular hearing aid.

NOTE 2 This diagram is only intended as a schematic representation illustrating the principle of connecting the hearing aid to the occluded-ear simulator. Effective airtight seals should be assured at all connection points.

Figure 3 – Connection of a behind-the-ear hearing aid to the occluded-ear simulator

Dimensions in millimetres



Key

a hearing aid (modular type)

b flexible connecting tube, typically Ø 2 mm internal

c retaining collar

d tube coupling device, typically Ø 2 mm internal

e reference plane

f occluded-ear simulator

NOTE 1 The length of the tubing and the inside diameters of both the tubing and the tube coupling device (which are to be equal) should be as shown and stated above, unless otherwise specified by the manufacturer, in order to meet the average conditions found in practical use of a particular hearing aid.

NOTE 2 This diagram is only intended as a schematic representation illustrating the principle of connecting the hearing aid to the occluded-ear simulator. Effective airtight seals should be assured at all connection points.

Figure 4 – Connection of an in-the-ear hearing aid (modular type) to the occluded-ear simulator

7 Maximum permitted expanded uncertainty of measurements

Table 2 specifies the maximum permitted expanded uncertainty U_{max} for a probability of approximately 95 % equivalent to a coverage factor of $k = 2$, associated with the measurements undertaken in this part of IEC 60318 (see ISO/IEC Guide 98-3). One set of values for U_{max} is given for basic type approval measurements.

The expanded uncertainties of measurements given in Table 2 are the maximum permitted for demonstration of conformance to the requirements of this part of IEC 60318. If the actual expanded uncertainty of a measurement performed by the test laboratory exceeds the maximum permitted value in Table 2, the measurement shall not be used to demonstrate conformance to the requirements of this part of IEC 60318.

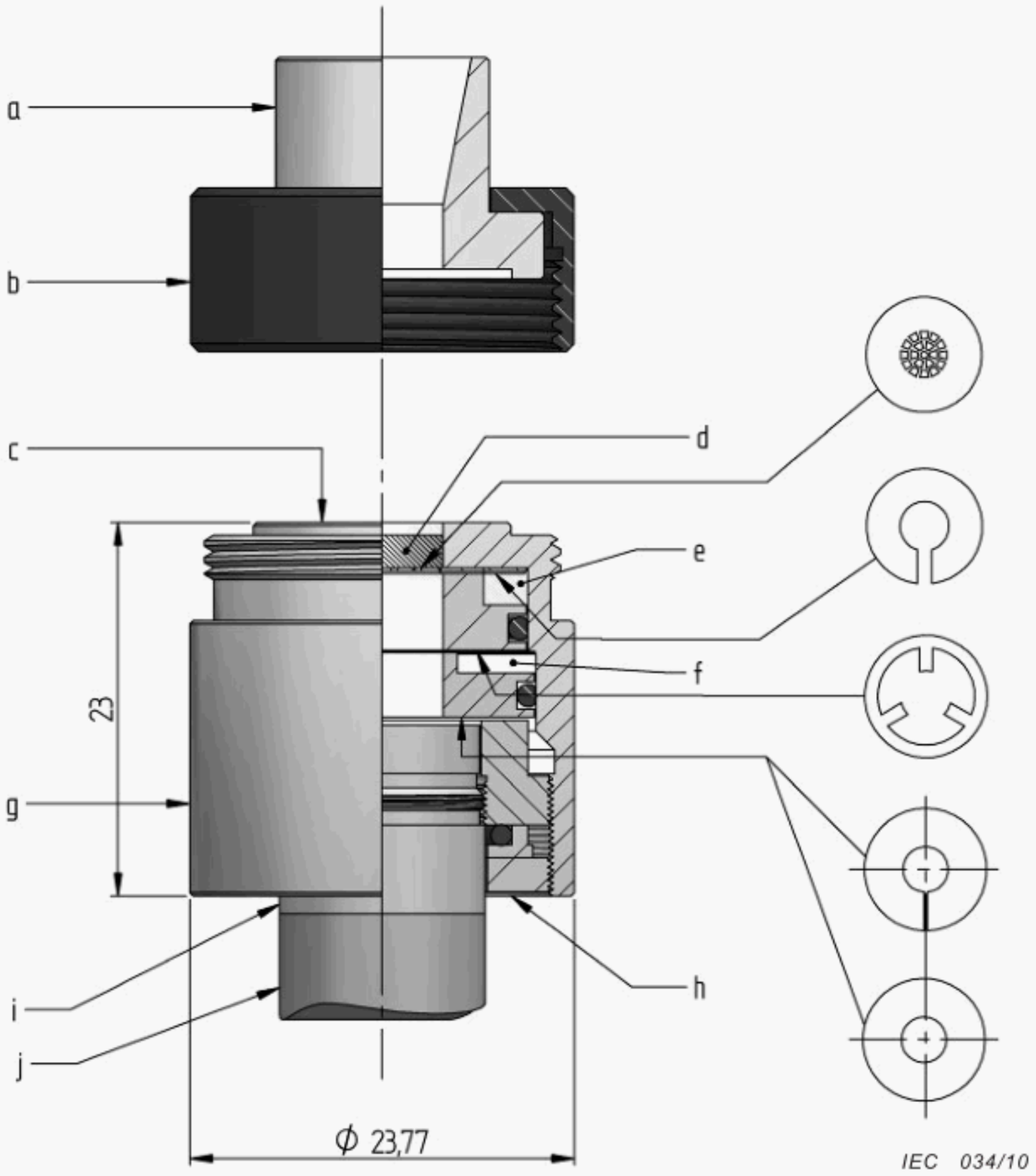
Table 2 – Values of maximum permitted expanded uncertainty U_{max} for basic type approval measurements

Measured quantity	Relevant subclause number	Basic U_{max} ($k = 2$)
Diameter of principal cavity	4.2	0,02 mm
Resonance frequency of the principal cavity	4.2	0,3 kHz
Microphone pressure sensitivity level (≤ 10 kHz)	4.3	0,3 dB
Microphone pressure sensitivity level (> 10 kHz)	4.3	0,5 dB
Microphone equivalent volume	4.3	2 mm^3
Acoustic resistance of vent	4.4	0,5 $GPa \cdot s \cdot m^{-3}$
Acoustic transfer impedance level at 500 Hz	4.5	0,1 dB
Acoustic transfer impedance level (< 500 Hz and > 500 Hz)	4.5	0,3 dB
Ambient pressure	5.2	0,1 kPa
Temperature	5.2	0,5 °C
Relative humidity	5.2	5 %
Effective volume of the occluded-ear simulator at 500 Hz	5.2	15 mm^3
Internal diameter of ear-mould simulator or small coupling device	6.3, 6.4	0,02 mm
Length of ear-mould simulator or small coupling device	6.3, 6.4	0,02 mm

Annex A
(informative)

Example of one specific design of occluded-ear simulator

Dimensions in millimetres



Key

a external-ear simulator
b retaining collar
c reference plane
d dust protector
e annular grove
f annular grove
g main housing
h pressure equalizing holes
i pressure microphone
j microphone preamplifier

NOTE The lower part of the figure shows an example of one specific design of an occluded-ear simulator conforming to this standard.

Figure A.1 – Example of one specific design of occluded-ear simulator

Annex B
(informative)

Principle of calibration for the occluded-ear simulator

The acoustic transfer impedance $Z_t(f)$ of an occluded-ear simulator can be defined as the ratio between the sound pressure $p(f)$ at the membrane of the microphone and the volume velocity at the ear simulator reference plane:

$$Z_t(f) = \frac{p(f)}{\Delta V 2\pi f} \quad \text{(B.1)}$$

where the volume velocity is the volume displacement ΔV times the angular frequency $2\pi f$.

The value of the acoustic transfer impedance $Z_t(f)$ relative to that at the reference frequency 500 Hz can be determined by using as a sound source a transducer producing constant volume displacement at the reference plane.

In this case, at 500 Hz, we have

$$Z_t(500) = \frac{p(500)}{\Delta V 2\pi 500} \quad \text{(B.2)}$$

and – by dividing Equation (B.1) by Equation (B.2) and taking into account that the nominal effective volume of the ear simulator cavity is 1 260 mm^3 corresponding to a magnitude of the acoustic transfer impedance of 35,9 $MPa \cdot s \cdot m^{-3}$ (see 4.5)

$$Z_t(f) = 35{,}9 \frac{500}{f} \frac{p(f)}{p(500)} \quad \text{(B.3)}$$

Thus, the acoustic transfer impedance of the ear simulator at a frequency f can be calculated from the ratio of the sound pressures at that frequency and the frequency 500 Hz.

So, by using logarithmic values, the acoustic transfer impedance level $L_{Zt}(f)$ can be calculated from the measured sound pressure levels at that frequency and the reference frequency 500 Hz:

$$L_{Zt}(f) = 10 \lg Z_t(f)^2 = 20 \lg(35{,}9 \times 500) - 20 \lg f + (L_p(f) - L_p(500)), \quad \text{(B.4)}$$

where $(L_p(f) - L_p(500))$ can be found in Table B.1.

EXAMPLE According to Table B.1, the relative sound pressure level at 100 Hz is –0,3 dB. Using Equation (B.4) we get:

$$L_{Zt}(100) = 85{,}08 - 40 - 0{,}3 = 44{,}78 \text{ dB}$$

For the nominal effective volume of the cavity of 1 260 mm^3 at 500 Hz, the sound pressure level at a frequency f minus the sound pressure level at 500 Hz $(L_p(f) - L_p(500))$ – and the corresponding tolerances – will be as given in Table B.1. If the actual effective volume V in cubic millimetres at 500 Hz deviates from 1 260 mm^3, 10 lg $(V^2/1\,260^2)$ dB shall be added to the magnitudes of the relative sound pressure level given in Table B.1.

NOTE 1 A WS3P microphone driven by a constant voltage may be used as a constant volume displacement sound source.

NOTE 2 The effective volume may be measured using a reference volume of about 1 260 mm^3. For a cylindrical reference volume and frequency of 500 Hz, the diameter should be greater than 0,6 of the length (see [7]).

NOTE 3 The values in Table B.1 are valid for the exact one-third octave frequencies calculated from 1 000 × $10^{n/10}$, where n is a positive or negative integer or zero.

NOTE 4 At high frequencies, the electrically measured frequency response of the occluded-ear simulator has to be corrected for the frequency-response characteristics of the microphone and the sound source.

Table B.1 – Sound pressure level relative to that at the reference frequency 500 Hz ($L_p(f) - L_p(500)$) for the nominal effective volume (1 260 mm^3) of the occluded-ear simulator, and associated tolerances

Nominal frequency Hz	Relative sound pressure level dB	
	Magnitude	Tolerances
100	–0,3	±0,7
125	–0,2	±0,7
160	–0,2	±0,7
200	–0,1	±0,6
250	–0,1	±0,6
315	–0,1	±0,6
400	0	±0,6
630	0,1	±0,6
800	0,2	±0,6
1 000	1,6	±0,7
1 250	3,3	±0,7
1 600	4,5	±0,7
2 000	5,2	±0,7
2 500	6,0	±0,8
3 150	6,9	±0,9
4 000	8,0	±1,0
5 000	9,3	±1,2
6 300	11,4	±1,2
8 000	13,7	±1,7
10 000	18,0	±2,2
NOTE The sound pressure levels in this table are valid for an input with constant volume displacement.		

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