IEC TS 60318-7

Edition 2.0 2017-04

TECHNICAL SPECIFICATION

colour inside

Electroacoustics – Simulators of human head and ear –
Part 7: Head and torso simulator for the measurement of air-conduction hearing aids

IEC TS 60318-7:2017-04(en)

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ELECTROTECHNICAL
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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ELECTROACOUSTICS – SIMULATORS OF HUMAN HEAD AND EAR –

Part 7: Head and torso simulator for the measurement of air-conduction hearing aids

FOREWORD

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 60318-7, which is a Technical Specification, has been prepared by IEC technical committee 29: Electroacoustics.

This publication contains attached files in the form of 3D PDF files. These files are intended to be used as a complement and do not form an integral part of the publication.

This second edition cancels and replaces the first edition published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the document is based on the designs of three different commonly used types of manikins;
b) the cross sections of the head and torso and pinna simulators of the previous edition are replaced by maximum and minimum values of their geometric dimensions;
c) the diffuse field frequency response of the manikin is added;
d) the usable frequency range is extended to 100 Hz to 16 000 Hz;
e) in addition to the cylindrical ear canal extension a tapered ear canal extension is added;
f) design examples of one anatomically shaped manikin and of two different geometrically shaped manikins are given in the annexes;
g) the relationship between tolerance interval, corresponding acceptance interval and the maximum permitted uncertainty of measurement are given in an annex;
h) 3D representations of three different types of pinna simulators are given in an annex.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
29/907/DTS	29/921A/RVDTS

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 60318 series, published under the general title *Electroacoustics – Simulators of human head and ear*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

ELECTROACOUSTICS – SIMULATORS OF HUMAN HEAD AND EAR –

Part 7: Head and torso simulator for the measurement of air-conduction hearing aids

1 Scope

This document, which is a Technical Specification, describes a head and torso simulator, or manikin, intended for the measurement of air-conduction hearing aids in the frequency range from 100 Hz to 16 000 Hz.

The manikin described in this document is intended for airborne acoustic measurements only. It is not suitable for measurements which depend upon vibration transmission paths such as bone conduction, or for measurements requiring the simulation of bone or tissue.

This document specifies the manikin in terms of both its geometrical dimensions and its acoustical properties. Only manikins compliant with both sets of specifications are in conformance with this document.

WARNING – It is acknowledged that devices conforming to this document are used as the basis for applications extending beyond this scope, for example the measurement of sound sources close to the ear or of hearing protection devices. In such cases, it is recommended that any necessary design variations are documented, and that a statistical analysis of the measurement data is carried out to determine the level of repeatability that can be achieved. It will also be necessary to assess the relevance of the measurements made with the head and torso simulator to the application in question.

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.

IEC 60118-8, *Electroacoustics – Hearing aids – Part 8: Methods of measurement of performance characteristics of hearing aids under simulated* in situ *working conditions*

IEC 60318-4, *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 61260-1, *Electroacoustics – Octave-band and fractional-octave-band filters – Part 1: Specifications*

ISO/IEC Guide 98-4, *Uncertainty of measurement – Role of measurement uncertainty in conformity assessment*

ISO 3:1973, *Preferred numbers – Series of preferred numbers*

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:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
manikin
head and torso simulator
simulator of a median adult human head and part of the torso extending in total from the top of the head to the waist and designed to simulate the sound pick-up characteristics and acoustic diffraction

Note 1 to entry The head and torso simulator includes two pinna simulators, and at least one occluded-ear simulator.

3.2
manikin type
designation of the manikin as either anatomical or geometrical in shape

3.3
pinna simulator
device which has the approximate shape and dimensions of a median adult human pinna

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

Note 1 to entry In this document, an ear simulator comprises an ear canal extension and an occluded-ear simulator (see 4.2.4).

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

Note 1 to entry An occluded-ear simulator is standardised in IEC 60318-4.

3.6
ear canal extension
device that provides a connection between the occluded-ear simulator and the aperture of the device simulating the concha

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 ear mould in a human ear canal

3.8
reference point of the manikin
point bisecting the line joining the right and left ear canal entrance points (EEP, see 3.17)

3.9
plane of symmetry of the manikin
plane passing through the reference point of the manikin that divides the left and right portions of the manikin into symmetrical halves, within the allowed tolerances, where left and right is interpreted as for the human torso

Note 1 to entry See Figure 1.

3.10
axis of rotation of the manikin
straight line about which the manikin can be rotated, passing through the reference point of the manikin, lying in the plane of symmetry of the manikin, and having a direction that would be vertical if the manikin were mounted in a position corresponding to that of a standing person

Note 1 to entry See Figure 1.

3.11
reference plane of the manikin
plane perpendicular to the axis of rotation that contains the reference point of the manikin

Note 1 to entry See Figure 1.

3.12
test point
reproducible position in the test space at which the sound pressure level is measured with the manikin absent and at which the reference point of the manikin is to be located for test purposes

Note 1 to entry See Figure 2.

3.13
test axis
line joining the test point and the centre of the sound source

Note 1 to entry See Figure 2.

3.14
test plane
plane perpendicular to the test axis and containing the test point

3.15
azimuth angle of sound incidence
angle between the plane of symmetry of the manikin and the plane defined by the axis of rotation of the manikin and the test axis

Note 1 to entry When the manikin faces the sound source, the azimuth angle of sound incidence is defined as 0°. When the right ear of the manikin faces the sound source, the angle is defined as +90°. When the left ear of the manikin faces the sound source, the angle is defined as +270°.

Note 2 to entry See Figure 2.

3.16
elevation angle of sound incidence
angle between the reference plane of the manikin and the test axis

Note 1 to entry When the vertex points towards the sound source the elevation angle is defined as +90°. When the test axis lies in the reference plane of the manikin, the elevation angle is defined as 0°.

Note 2 to entry See Figure 2.

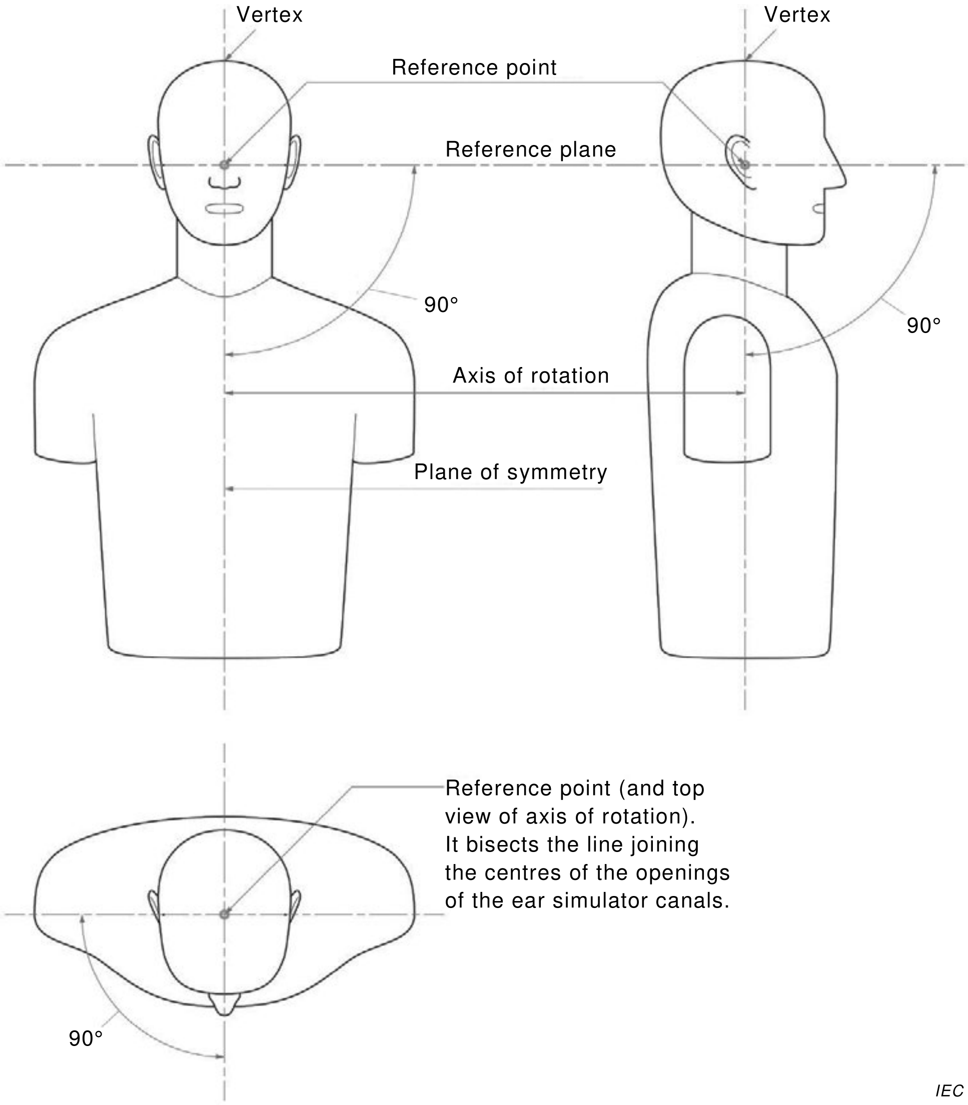
3.17
ear canal entrance point
EEP
point located at the centre of the manikin ear canal at the junction between concha and ear canal extension

3.18
transverse plane of the manikin
plane perpendicular to the plane of symmetry of the manikin and containing the axis of rotation

3.19
reference position of the manikin
position of the manikin in the test space where the reference point of the manikin coincides with the test point, and the azimuth and elevation angles are both equal to zero

3.20
manikin free-field frequency response
difference, as a function of frequency, between the sound pressure level at the ear simulator microphone with the reference point of the manikin at the test point within a free-field measurement environment and the sound pressure level at the test point with the manikin absent

3.21
manikin diffuse-field frequency response
difference, as a function of frequency, between the sound pressure level at the ear simulator microphone with the reference point of the manikin at the test point within a diffuse-field measurement environment and the sound pressure level at the test point with the manikin absent



NOTE The reference point of the manikin is situated within the head.

Figure 1 – Manikin geometrical references

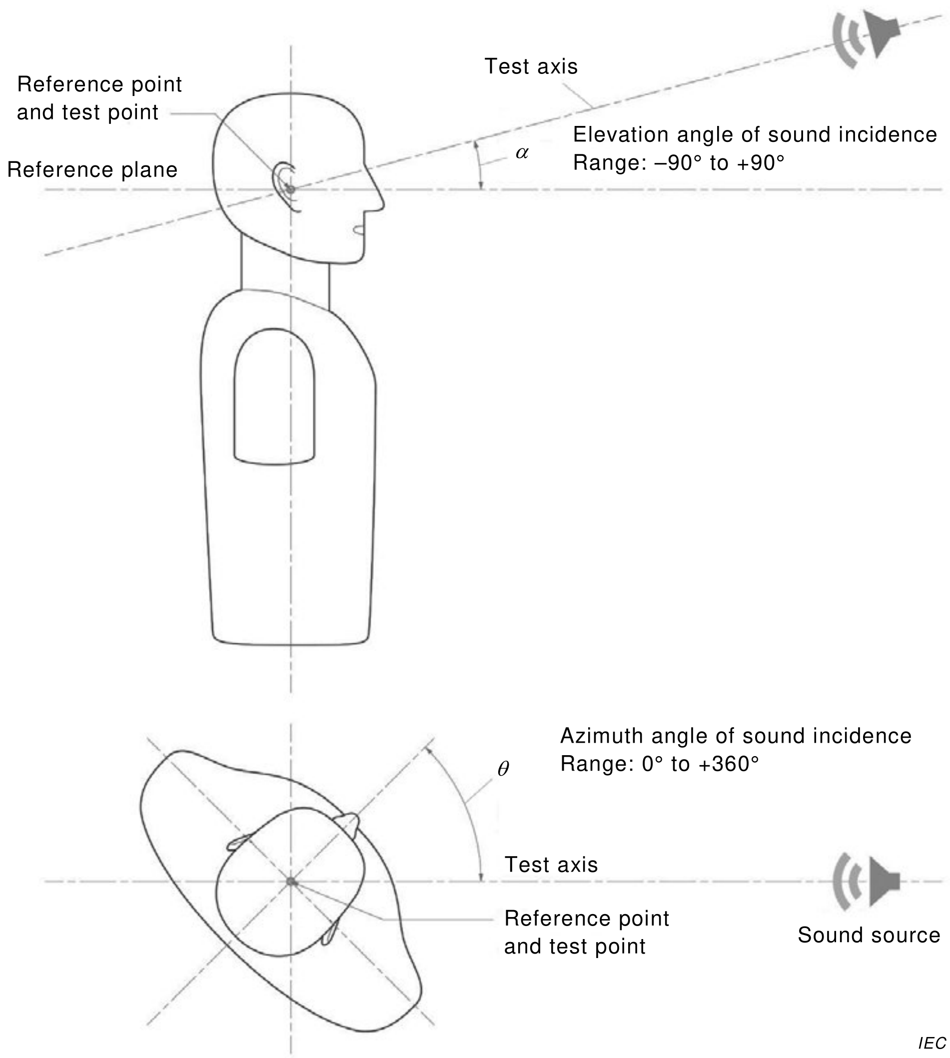


Figure 2 – Coordinate scheme for azimuth and elevation angles

4 Construction

4.1 General

The simulator consists of a head mounted on a torso that extends to the waist. The head is equipped with simulated pinnae and one or two occluded-ear simulators formed of cavities having acoustic impedance terminations corresponding to that of a median human adult, and microphones located at positions corresponding to the eardrums. It has been designed to provide acoustic diffraction similar to that encountered around the median human head and torso. Measurement results obtained with a manikin can differ substantially from similar measurements made on an individual person, due to anatomical variations. Measurement results for a given hearing aid obtained with different models of manikin conforming to this document can also differ, depending on the type and the method of fitting the hearing aid. The same holds for measurement results obtained with the same manikin model but with different models of pinna simulators. Above 10 kHz, an occluded-ear simulator conforming to IEC 60318-4 does not simulate the acoustic impedance of the human ear and can only be used as an acoustic coupler in this frequency range.

The realization of the manikin conforming to this document can be either anatomically shaped (see Annex A) or geometrically shaped (see Annex B) and can have different anatomically shaped pinna simulators. The realization of the ear canal entrance, together with the additional ear canal extension can be either cylindrical or tapered in shape. This enables the measurements of all types of hearing aids, for example behind-the-ear (BTE) and in-the-ear (ITE) designs.

NOTE Nevertheless, some specific ITE hearing aid models might not be compatible.

This document covers both the geometrical dimensions of the manikin's head, torso, pinnae and ear canals and the manikin's acoustical characteristics. As a minimum, the manikin shall be specified with cylindrical ear canal extensions, and comply with the appropriate acoustical characteristics. Optionally, tapered ear canal extensions may also be specified. The model and type of the manikin used (see 3.2) and the model of the pinna simulator used shall be stated when giving results of hearing aid measurements made with the manikin.

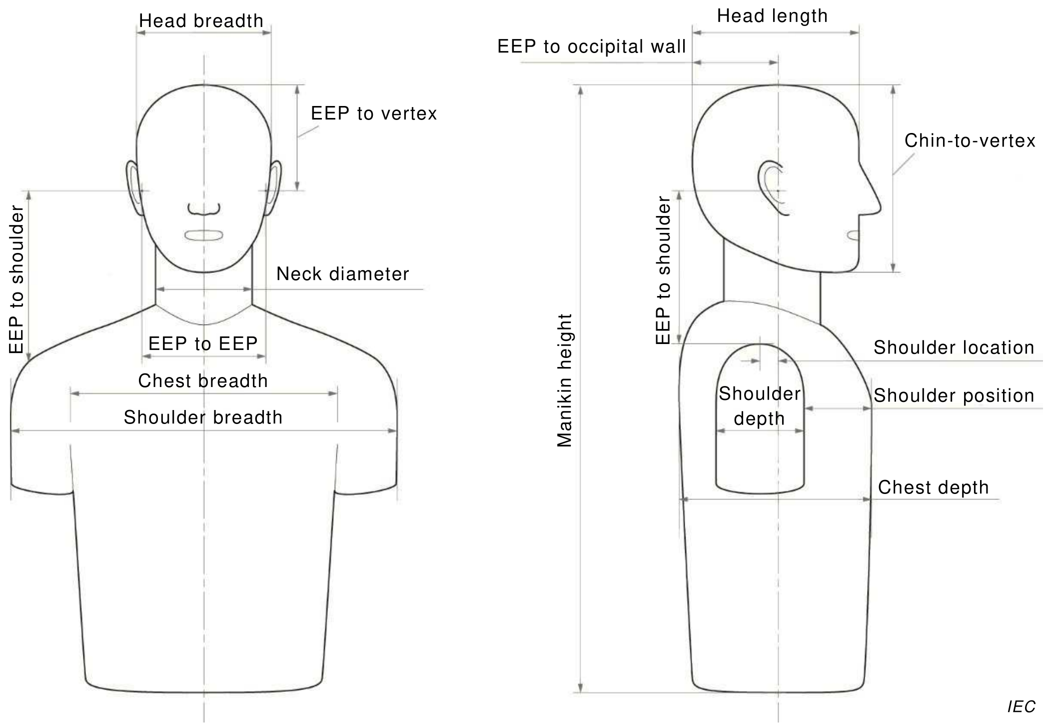
4.2 Geometrical dimensions of the manikin

4.2.1 Head and torso

The geometrical dimensions of the head and the torso are illustrated in Figure 3, and listed in Table 1. The realization of the head (excluding the pinnae) and of the torso can be either anatomically shaped or geometrically shaped. Anatomically shaped manikins are not necessarily completely symmetrical and may be described as "quasi-symmetrical", when staying within the allowable differences from the completely symmetrical manikin. Both anatomically and geometrically shaped manikins shall conform to the specified ranges of geometrical dimensions and acoustical characteristics specified in this document.

The acceptance interval of the quasi-symmetrical left and right portion of the manikin shall be ± 2 mm for the head and ± 3 mm for the torso with respect to the plane of symmetry.

NOTE For measurements that include both head and torso dimensions, for example EEP to shoulder, the acceptance interval sums up to ± 5 mm.



NOTE For position of ear canal entrance point (EEP), see Figure 4.

Figure 3 – Illustration of manikin head and torso dimensions

Table 1 – Manikin head and torso dimensions

Linear dimension of	Nominal mm	Minimum mm	Maximum mm	Average human data [19][1] mm
Head breadth	151	148	153	151
Head length	195	190	204	188
EEP to vertex	130	128	135	130
EEP to EEP distance	132	130	134	132
EEP to occipital wall	95	93	99	95
Chin-to-vertex length	220	217	225	222
EEP to shoulder[c]	175	169	181	176
Neck diameter	113	111	115	112
Shoulder breadth	432	399	456	427
Chest breadth	282	280	284	291
Chest depth	219	180	241	–
Shoulder depth[d]	110	108	161	–
Shoulder location [b, e]	6	–4	20	–
Shoulder position [a, f]	78	76	80	–
Manikin height	–	600	–	

NOTE To be independent of the type of pinna simulator used, this document uses the ear canal entrance point (EEP) rather than the tragion as a reference point. The differences between both sets of values are chosen in conformity with [8] to be 5 mm for EEP to vertex, –11 mm for left EEP to right EEP, –3 mm for EEP to occipital wall and –5 mm for EEP to shoulder.

a For anatomically shaped manikin only.

b For geometrically shaped manikin only.

c Measured from the shoulder surface, 175 mm sideways from the plane of symmetry, to the reference plane of the manikin.

d Measured between front and back shoulder points, 175 mm sideward from the plane of symmetry of the manikin.

e Measured from the point of the shoulder section, 175 mm sideward from the plane of symmetry, to the transverse plane of the manikin (positive behind transverse plane).

f Measured between front shoulder point, 175 mm sideward from the plane of symmetry of the manikin to the front-most point on the torso.

4.2.2 Pinna simulators for hearing aid measurements

The right and left pinna simulators shall be anatomically shaped.

For each type of manikin, only one pair of pinna simulators with cylindrical ear canal extensions and optionally only one pair of pinna simulators with the tapered ear canal extensions shall be specified. Their principal dimensions and orientation are illustrated in Figure 4, and listed in Table 2 and Table 3.

The acceptance intervals of the quasi-symmetrical left and right pinna simulator of the manikin shall be ±2 mm.

NOTE In addition to the pinna simulators described in this document, there are many other models of pinna simulator on the market, for instance a small one used for the measurement of earphones (see IEC 60268-7). However, these pinna simulators are not intended for hearing aid measurements.

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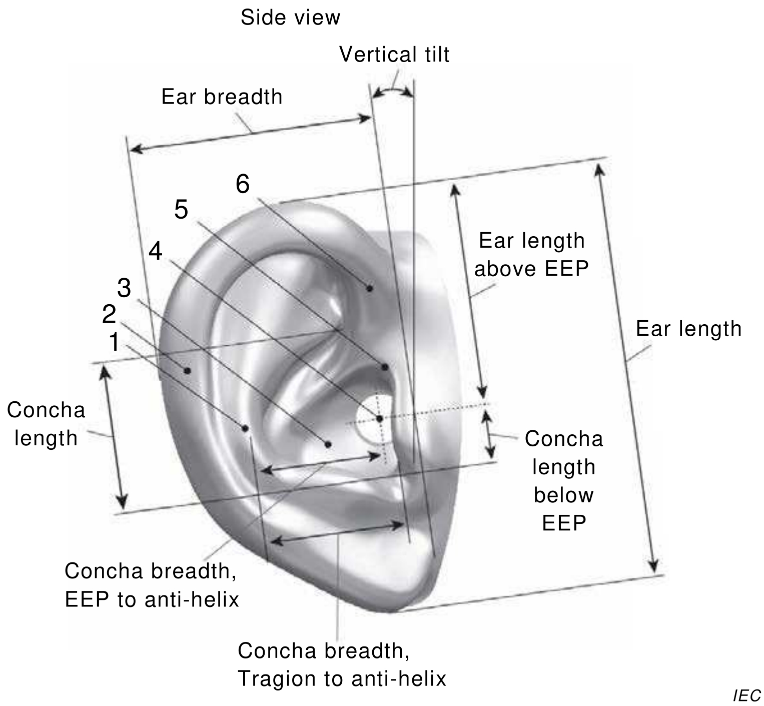
1 Numbers in square brackets refer to the Bibliography.

4.2.3 Ear canal extension

Only one cylindrical, and optionally, one tapered ear canal extension shall be used. The cylindrical ear canal extension shall have a nominal diameter of 7,50 mm. It is mainly intended for the measurement of behind-the-ear and full-concha in-the-ear types of hearing aids. If a tapered ear canal extension is specified, it shall have a nominal diameter of 7,50 mm where it couples to the occluded-ear simulator and a larger diameter where it couples to the bottom of the concha of the pinna simulator (see Table 3). Tapered ear canal extensions are mainly intended for the measurement of in-the-ear and completely-in-the-canal types of hearing aids.



Key

1 anti-helix
2 helix
3 concha
4 EEP
5 tragion
6 crus of helix

Figure 4 a) – Pinna simulator

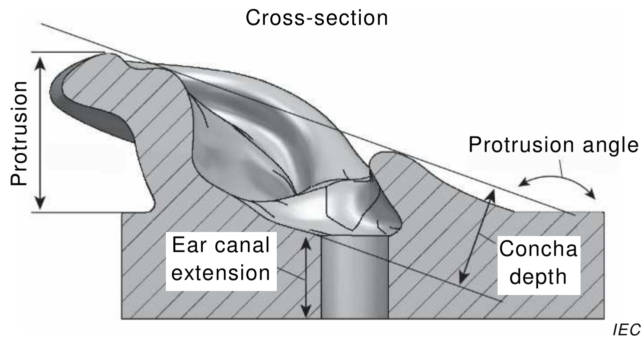


Figure 4 b) – Ear canal extension cylindrical

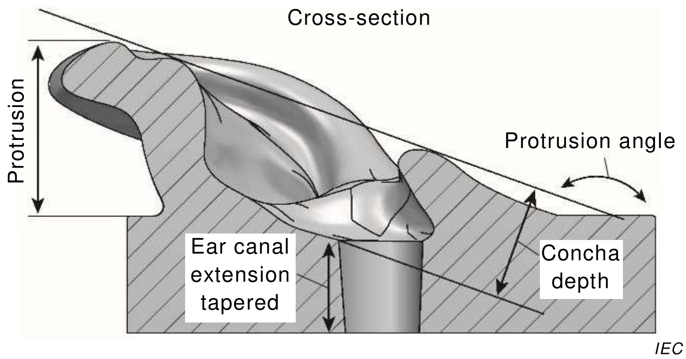


Figure 4 c) – Ear canal extension tapered

Figure 4 – Illustration of manikin pinna simulator dimensions

Table 2 – Dimensions of the pinna simulator and the cylindrical ear canal extension of the manikin

Linear dimension of	Nominal mm or degrees	Minimum mm or degrees	Maximum mm or degrees
Ear length	65	64	67
Ear length above EEP	35	33	38
Ear breadth	37	36	38
Ear protrusion	20	18	24
Ear protrusion angle	160°	159,5°	160,5°
Vertical tilt front view	9°	7,5°	10,5°
Vertical tilt side view	6°	5,5°	6,5°
Concha length	24	23	26
Concha length below EEP	10	8	11
Concha breadth, tragion to anti-helix	23	22	24
Concha breadth, EEP to anti-helix	17	14	20
Concha depth	13	11	16
Diameter of ear canal extension	7,50	7,40	7,60
Length of ear canal extension	10	9	11

Table 3 – Dimensions of the pinna simulator and the tapered ear canal extension of the manikin

Linear dimension of	Nominal mm or degrees	Minimum mm or degrees	Maximum mm or degrees
Ear length	66	65	67
Ear length above EEP	36	35	37
Ear breadth	37	36	38
Ear protrusion	23	19	24
Ear protrusion angle	160°	159,5°	160,5°
Vertical tilt front view	10°	8°	10,5°
Vertical tilt side view	6°	5,5°	6,5°
Concha length	28	24	29
Concha length below EEP	10	9	11
Concha breadth, tragion to anti-helix	23	22	24
Concha breadth, EEP to anti-helix	23	19	24
Concha depth	15	12	16
Diameter of ear canal extension at the reference plane of the occluded-ear simulator	7,50	7,40	7,60
Diameter of ear canal extension at the pinna simulator	10	9,5	10,5
Length of ear canal extension	8,8	7,8	10

4.2.4 Ear simulator

The ear simulator shall comprise an occluded-ear simulator, for example as described in IEC 60318-4, and an ear canal extension (see 3.4).

If occluded-ear simulators differing in detail from that specified in IEC 60318-4 are used, their characteristics should be stated when giving results of measurements of hearing aids made with the manikin.

4.2.5 Materials

The manikin shall have a non-porous surface, with an acoustic impedance which is high compared to that of air, and be of a material which ensures dimensional stability.

The pinna simulators shall be made from a high-quality elastomer. The shore-OO hardness [18] shall be in the range from 30° to 60°. The time interval for which the mechanical characteristics of the pinna simulators are expected to remain compliant with this document shall be indicated by means of an expiration date.

Measurement results on hearing aids obtained with the same manikin fitted with different pinna simulator models can differ by varying degrees depending on the type of hearing aid under test and the way it is fitted. The model, or similar identification, of the pinna simulators together with their shore-OO hardness should be stated when giving results of hearing aid measurements made with the manikin.

4.3 Acoustical characteristics of the manikin

4.3.1 Free-field frequency response

Table 4 and Table 5 give the free-field frequency responses of the manikin (right ear) equipped with cylindrically shaped ear canal extensions. Values are stated for 0° elevation angle and azimuth angles of 0° (frontal incidence), 90°, 180° and 270°. The values also apply for the corresponding symmetrical azimuth angles for the left pinna.

NOTE 1 Difficulties can be experienced when measuring the manikin frequency response at the azimuth angle 270° for 6,3 kHz and higher frequencies. This is due to a combination of reflections from the boundaries of the test enclosure, and the head shadow effect. Hence, these values have been omitted in Table 5.

The nominal free-field frequency responses were obtained from a power average of the measured free-field frequency responses of the three manikins in Annex A and Annex B, extracted from [16]. The free field-frequency response is given in one-twelfth-octave intervals centred at the nominal one-third-octave band centre frequencies.

NOTE 2 The nominal one-third-octave band centre frequencies used as test frequencies in Table 3 and Table 4 correspond to the ISO 3 R 10 preferred number series.

Table 4 – Free-field frequency response of the manikin for an azimuth angle of 0° (right ear)

One-third-octave band centre frequency Hz	Free-field frequency response dB Azimuth angle 0°	Acceptance interval dB	
100	0,0	+1,5	–1,5
125	0,0	+1,5	–1,5
160	0,0	+1,5	–1,5
200	0,0	+1,5	–1,5
250	0,0	+1,5	–1,5
315	1,0	+1,5	–1,5
400	2,0	+1,5	–1,5
500	2,5	+2,0	–1,5
630	3,0	+1,5	–1,5
800	4,0	+1,5	–1,5
1 000	4,0	+2,0	–2,5
1 250	3,0	+2,0	–3,5
1 600	5,0	+1,5	–2,0
2 000	12,0	+2,0	–2,5
2 500	16,5	+3,0	–3,0
3 150	17,5	+2,0	–2,5
4 000	14,0	+2,0	–3,0
5 000	11,5	+2,5	–3,0
6 300	7,0	+2,0	–2,0
8 000	2,0	+3,5	–5,5
10 000	2,0	+4,0	–4,5
12 500	9,0	+4,0	–4,5
16 000	3,0	+4,0	–6,0

NOTE 1 The free field-frequency response is given in one-twelfth-octave intervals centred at the nominal one-third-octave band centre frequencies.

NOTE 2 The values in Table 4 are valid only for pinna simulators for hearing aid measurements by means of cylindrical ear canal extensions according to Table 2.

Table 5 – Free-field frequency responses of the manikin for azimuth angles of 90°, 180° and 270° (right ear)

One-third-octave band centre frequency Hz	Free-field frequency response dB			Acceptance interval dB	
	Azimuth angle				
	90°	180°	270°		
100	0,5	0,0	–0,5	+1,5	–1,5
125	0,5	0,0	–0,5	+1,5	–1,5
160	1,0	–0,5	–1,0	+1,5	–1,5
200	1,5	0,0	–1,0	+1,5	–2,0
250	2,5	0,0	–0,5	+1,5	–1,5
315	3,5	0,0	0,0	+1,5	–1,5
400	4,5	0,5	0,5	+1,5	–1,5
500	5,5	1,0	1,5	+2,0	–1,5
630	7,0	2,0	1,5	+1,5	–2,0
800	8,0	4,0	2,0	+1,5	–2,0
1 000	7,5	4,0	2,5	+1,5	–2,0
1 250	9,5	5,5	3,5	+2,5	–2,5
1 600	9,5	5,5	5,0	+2,0	–2,0
2 000	11,0	9,5	7,0	+2,5	–4,0
2 500	16,5	14,0	10,0	+2,5	–2,5
3 150	17,0	13,5	9,0	+3,0	–2,0
4 000	13,5	10,5	3,5	+5,0	–3,0
5 000	17,0	6,0	–3,5	+7,0	–8,0
6 300	17,0	2,0	–	+2,5	–5,0
8 000	16,5	3,5	–	+5,0	–10,5
10 000	10,5	–1,5	–	+6,0	–10,5
12 500	11,5	–0,5	–	+6,0	–8,5
16 000	3,5	–4,0	–	+6,0	–11,0

NOTE 1 The free field-frequency response is given in one-twelfth-octave intervals centred at the nominal one-third-octave band centre frequencies.

NOTE 2 The values in Table 5 are valid only for pinna simulators for hearing aid measurements by means of cylindrical ear canal extensions according to Table 2.

NOTE 3 Free-field responses for 0° azimuth angle are given in Table 4.

4.3.2 Diffuse-field frequency response

Table 6 gives the diffuse-field frequency response of the manikin (right ear) equipped with cylindrically shaped ear canal extensions.

The nominal diffuse-field frequency responses were obtained from a power average of the diffuse-field frequency responses of the three manikins in Annex A and Annex B, extracted from [16]. The diffuse-field frequency response is given in one-third-octave frequency intervals.

Table 6 – Diffuse-field frequency response of the manikin (right ear)

One-third-octave band centre frequency Hz	Diffuse-field frequency response dB	Acceptance interval dB	
100	-0,5	+1,5	-1,5
125	0,0	+1,5	-1,5
160	0,0	+1,5	-1,5
200	0,5	+1,5	-1,5
250	0,0	+1,5	-1,5
315	0,5	+1,5	-1,5
400	1,5	+1,5	-1,5
500	2,0	+1,5	-1,5
630	3,5	+1,5	-1,5
800	3,5	+1,5	-1,5
1 000	4,0	+1,5	-2,0
1 250	5,0	+1,5	-1,5
1 600	7,0	+1,5	-2,0
2 000	10,5	+2,0	-2,0
2 500	14,0	+2,0	-2,0
3 150	14,5	+2,5	-2,0
4 000	12,5	+2,0	-2,0
5 000	9,5	+2,0	-2,0
6 300	8,0	+2,5	-2,0
8 000	8,0	+2,5	-2,5
10 000	5,0	+3,5	-2,5
12 500	2,5	+4,5	-2,5
16 000	0,0	+6,5	-4,0

NOTE The values in Table 6 are valid only for pinna simulators for hearing aid measurements by means of cylindrical ear canal extensions according to Table 2.

4.3.3 Acceptance intervals

Acceptance intervals on the manikin free-field and diffuse-field frequency responses are stated in Table 4, Table 5 and Table 6. The values include the acceptance interval in the calibration of the occluded-ear simulator, but not the free-field or diffuse-field sensitivity of the microphone. They are rounded to the nearest 0,5 dB increment.

4.3.4 Openings

Any openings for access to the interior of the manikin other than the ears shall not affect the responses of the manikin as specified in 4.3.1 and 4.3.2.

5 Calibration

5.1 Reference environmental conditions

The reference environmental conditions are the following.

Reference ambient pressure: .... 101,325 kPa

Reference temperature: .... 23 °C

Reference relative humidity:.. 50 %

5.2 Calibration method

5.2.1 General

When determining the acoustical characteristics of the manikin, no wig shall be used with the head and no clothing shall be used with the head or torso. If the head can be inclined, the upright position shall be used. If the length of the neck can be adjusted, the nominal value of "EEP to shoulder" from Table 1 shall be used.

5.2.2 Test signal, test space and measurement equipment

5.2.2.1 Free-field testing

The manikin free-field frequency response shall be measured in one-twelfth-octave frequency intervals at centre frequencies as given in the ISO 3 R 10 preferred frequency series.

Any stimulus providing adequate energy at all frequencies of interest can be used as test signal.

NOTE 1 The test signal used in [16] was a 16 seconds long exponential swept sine from 20 Hz to 25,6 kHz. Its advantage is a considerably improved signal-to-noise ratio. The one-twelfth-octave-band frequency response data were in turn calculated from the swept-sine data using the methodology given in [20].

For the manikin free-field frequency response, the test space and sound source shall together provide an approximation to plane progressive waves in free-field conditions in the frequency range 100 Hz to 10 kHz, or optionally up to 16 kHz.

These conditions are deemed to exist if the sound pressure levels measured at distances of 250 mm from the test point do not deviate from the sound pressure level at the test point by more than ±2 dB up to 300 Hz and ±1 dB above 300 Hz. The measurement points for testing compliance shall include two points on the test axis, respectively towards and away from the sound source. Four additional measurement points in the test plane shall be included: two in the reference plane of the manikin, to the left and right as viewed from the sound source, and two on the axis of rotation above and below the test point.

NOTE 2 The permitted deviation of sound pressure level relative to that at the test point takes account of the inverse relationship of pressure with distance and deviations from this, and other deviations due to source directionality.

NOTE 3 For an anechoic room, compliance can be expected provided that the test point is further than 1 m away from the boundaries and the sound source is at least 2 m from the boundaries.

The test sound source shall only contain coaxial elements or a single diaphragm, and the ratio of the maximum frontal sound source dimension to source distance shall be less than 0,25.

NOTE 4 To avoid reflections, the frontal area of the sound source baffle can be covered by a suitable sound absorbing material.

5.2.2.2 Diffuse-field testing

The manikin diffuse-field frequency response shall be measured in one-third-octave frequency intervals as given in IEC 61260-1.

NOTE 1 The test signal used in [16] was broadband pink noise in the frequency range from 20 Hz to 25,6 kHz.

With the manikin absent, the sound pressure level shall be measured by means of a WS3P microphone at six positions at distance of 150 mm above and below, left and right, and in front and behind the reference point of the manikin. The maximum permitted deviation of the sound pressure level measured at these positions from the level measured at the reference point of the manikin is ±2,5 dB. In addition, the difference between the left and right positions shall be ≤ 3 dB.

Further, the sound pressure level at the reference point shall be measured by means of a directional microphone in different directions at frequencies of 500 Hz and above. For a directional microphone with a front to random sensitivity index of 5 dB or more, the maximum difference of sound pressure levels for maximum and minimum readings of the incident sound energy shall be 5 dB or less. For a directional microphone with a front to random sensitivity index of 4,5 dB, the allowable field variation is 4,5 dB and for those with a front to random sensitivity index of 4 dB, the allowable field variation is 4 dB.

NOTE 2 These requirements are also specified in ISO 4869-1 for the checking of the characteristics of the diffuse sound field for hearing protector testing.

5.2.2.3 Positioning of the manikin

The test space shall be equipped with fixtures permitting an accurate and repeatable positioning and calibration of the manikin with respect to the selected test point.

5.2.2.4 Extraneous background noise

The effective sound pressure level of extraneous background noise in the measurement frequency interval shall be at least 15 dB less than the sound pressure level in the frequency interval of the test signal.

5.2.3 Measurement of sound pressure level

The free-field sensitivity level and the diffuse-field sensitivity level of the reference microphones used to measure the unobstructed free-field sound pressure level and diffuse-field sound pressure level shall be known by calibration with an expanded measurement uncertainty (coverage factor k = 2) of no more than 0,5 dB for frequencies up to 5 kHz, of no more than 1,0 dB from 6,3 kHz to 10 kHz and of no more than 1,2 dB from 11 kHz to 16 kHz.

The calibration of the occluded-ear simulator shall conform to the requirements in IEC 60318-4.

The design of the manikin should enable pressure calibration using a sound calibrator or pistonphone to be performed without the removal of the occluded-ear simulator. Any accessories or adaptors necessary for this calibration shall be provided by the manufacturer. The frequency at which the calibration is conducted and any level offset to be applied to the nominal calibration level of the sound calibrator or pistonphone shall be stated.

Harmonic distortion of the measurement system, including the sound source (measured by means of pure-tone signals) shall not exceed 2 % in the frequency range from 100 Hz to 16 000 Hz and at sound pressure levels encountered.

The calibration should be performed under the reference environmental conditions given in 5.1 with the following acceptance intervals.

Ambient pressure:.. ±3,000 kPa

Temperature:.. ±2,5°C

Relative humidity: ....±15,0 %

If it is not possible to comply with these requirements, the actual environmental conditions shall be stated.

The manikin frequency responses shall be determined by one-twelfth-octave analysis for the free field and one-third-octave analysis for the diffuse field.

NOTE For detailed information on a method of determining the frequency response specification, see [16].

5.2.4 Alignment of manikin azimuth and elevation

The azimuth and elevation angle shall be aligned within tolerance limits of ±2,0° around the design goal.

5.2.5 Test for sound leakage

With the ear canal under test effectively sealed from external sound by the device under test at the reference plane of the occluded-ear simulator and the other ear canal blocked, the measurements described in 4.3 shall give results at least 35 dB lower than corresponding results with both ear canals open.

Suitable plugs or equivalent arrangements for checking the conformance of this requirement without disassembling the manikin external ear should be provided by the manufacturer.

6 Marking and instruction manual

6.1 Markings of the manikin

6.1.1 A manikin complying with this document shall be marked with the manufacturer's name or trade mark, the model of the manikin, and the date of manufacture.

6.1.2 The pinna simulators used with a manikin shall be marked with the model or similar identification. This marking should be visible without removal of the pinna simulator from the head.

6.1.3 To facilitate azimuth alignment, the torso shall be equipped with markings indicating the direction of 0° azimuth.

If the head is removable from the torso, both shall be provided with markings to ensure correct alignment.

6.1.4 To assist reproducible placement of hearing aids or other devices under test in and around the pinna simulator, the head surfaces in the immediate vicinity of the pinna simulators may be equipped with coordinate axis markings. The coordinate axes should be parallel to the axis of rotation (y-axis) and the reference plane of the manikin (x-axis) respectively. Values on the x-axis should be positive towards the front of the manikin, and on the y-axis positive towards the vertex.

6.2 Instruction manual

An instruction manual shall be supplied with the manikin and shall include at least the information listed below:

a) the model of manikin for which compliance with this document is claimed, a description of the facilities provided and full operating instruction;
b) the mean head and torso dimensions of the model (see Table 1);
c) the model or similar identification of right and left pinnae with cylindrically formed ear canal extension for which the manikin complies with this document and the mean dimensions of these pinnae (see Table 2) together with acceptance intervals;

d) if provided, the model or similar identification of right and left pinnae with tapered ear canal extension for which the manikin complies with this document and the mean dimensions of these pinnae (see Table 3) together with acceptance intervals;

e) the mean free-field frequency response of the manikin for azimuth angles of 0°, 90°, 180° and 270° for the pinnae with cylindrically formed ear canal extensions;

f) the mean diffuse-field frequency response of the manikin for the pinnae with cylindrically formed ear canal extensions;

g) a description of a suitable device to block the ear canal during the test for sound leakage (see 5.2.5);

h) the compliance time interval for the hardness of the pinna simulators;

i) the mean acoustical characteristics of the manikin as required in IEC 60118-8.

7 Maximum permitted uncertainty of measurements

Table 7 specifies the maximum permitted uncertainty of measurement U_{max} for a confidence probability of approximately 95 % equivalent to a coverage factor of k = 2, associated with the measurements undertaken in this document (see ISO/IEC Guide 98-4). One set of values for U_{max} is given for type approval measurements.

The uncertainties of measurements given in Table 7 are the maximum permitted for demonstration of conformance to the requirements of this document. If the actual uncertainty of a measurement performed by the test laboratory exceeds the maximum permitted value in Table 7, the measurement shall not be used to demonstrate conformance to the requirements of this document.

The relationship between tolerance interval, corresponding acceptance interval and the maximum-permitted uncertainty of measurement is explained in Annex C.

Table 7 – Maximum permitted uncertainty U_{max} for type approval measurements

Requirement	Relevant subclause number	Maximum permitted uncertainty U_{max}
Head and torso dimensions	4.2.1	1,0 mm
Pinna dimensions	4.2.2	1,0 mm
Diameter of ear canal extension	4.2.3	0,5 mm
Length of ear canal extension	4.2.3	0,5 mm
Shore-OO hardness	4.2.5	1,0°
Free-field frequency response of the manikin	4.3.1	
100 Hz to 1 250 Hz		0,5 dB
1 600 Hz to 6 300 Hz		0,7 dB
8 000 Hz to 16 000 Hz		1,0 dB
Diffuse-field frequency response of the manikin	4.3.2	
100 Hz to 1 250 Hz		0,5 dB
1 600 Hz to 12 500 Hz		0,7 dB
16 000 Hz		1,0 dB
Azimuth angle, elevation angle and pinna angle	4.2.2, 4.3.1, 5.2.4	0,5 °
Distortion of measurement system	5.2.3	0,2 %
Microphone free-field and diffuse-field sensitivity levels	5.2.3	
100 Hz to 5 000 Hz		0,5 dB
6 300 Hz to 10 000 Hz		1,0 dB
11 000 to 16 000 Hz		1,2 dB
Ambient pressure	5.2.3	0,1 kPa
Temperature	5.2.3	0,5°C
Relative humidity	5.2.3	5,0 %

Annex A
(informative)

Design example of an anatomically shaped manikin

A commonly used design of an anatomically shaped manikin is shown in Figure A.1.

Figure A.1 – Example of an anatomically shaped manikin

Annex B
(informative)

Design examples of a geometrically shaped manikin

A commonly used design of a geometrically shaped manikin is shown in Figure B.1.

Figure B.1 – Example 1 of a geometrically shaped manikin

A commonly used design of another geometrically shaped manikin is shown in Figure B.2.

NOTE The geometric torso part of this manikin does not affect measurement of sound at the microphone of the occluded-ear simulator (see [16]).

Figure B.2 – Example 2 of a geometrically shaped manikin

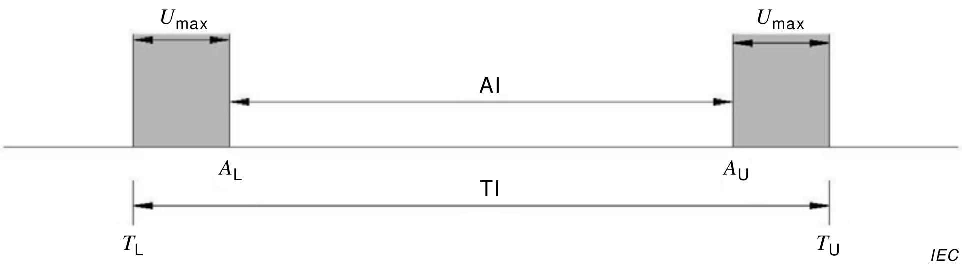
Annex C
(informative)

Relationship between tolerance interval, corresponding acceptance interval and the maximum permitted uncertainty of measurement

This document, in common with others written by IEC/TC 29, uses adaptations of the guidelines from ISO/IEC Guide 98-4 (equivalent to guidance document JCGM 106 from the Joint Committee for Guides in Metrology), as the basis for demonstration of conformance of an instrument to the specifications given in this document.

ISO/IEC Guide 98-4 describes guarded acceptance in terms of tolerance intervals, acceptance intervals and uncertainties of measurement.

To promote clarity for users and testing laboratories, IEC/TC 29 has adopted a policy whereby tolerance limits around design goals are not explicitly stated, but can be determined if required from the specified acceptance limits for allowed deviations from a design goal and the corresponding specified maximum-permitted uncertainty of measurement, by using the illustration in Figure C.1.



Key

AI acceptance interval

TI tolerance interval

U_{max} guard band for the maximum-permitted uncertainty of measurement for a 95 % coverage interval

A_L lower acceptance limit

A_U upper acceptance limit

T_L lower tolerance limit

T_U upper tolerance limit

Figure C.1 – Relationship between tolerance interval, corresponding acceptance interval and the maximum permitted uncertainty of measurement

The limits of an acceptance interval are associated with the acceptance interval and not with the guard band for the maximum-permitted uncertainty of measurement. Hence, a measured deviation equal to a limit of an acceptance interval demonstrates conformance to a specification, providing also that the uncertainty of the measurement from the laboratory performing a test does not exceed the specified maximum-permitted uncertainty.

Annex D
(informative)

3D representation of example pinna simulators

D.1 Background

The purpose of Annex D is to illustrate examples of pinna simulator shapes, to supplement the specification of the basic geometrical details given in 4.2.2 and 4.2.3. The example illustrations have been produced by a 3-dimensional surface scanning technique resulting in a dense set of (x, y, z) co-ordinates that provide a representation of the external surface of the pinna simulator. This scanning process can also be used for the measurement of individual pinna simulators for obtaining detailed information concerning their dimensional and geometrical characteristics.

D.2 Scanning technique

The geometrical form of each pinna simulator example was measured using a scanning laser probe that projects a laser line onto the sample. Reflected light is captured by a camera mounted in the scanner head and a triangulation process is used to determine co-ordinate positions. Collectively, these co-ordinates represent the geometrical form of the sample.

The measurement uncertainty is estimated to be of the order of 0,1 mm. The results from measurements of particular artificial pinna samples showed a dependence on orientation due to the influence of gravity. Variations of approximately 0,5 mm, mainly at the helix, were observed between horizontal and vertical orientations. Consequently, the orientation should be stated when referring to any particular geometrical form. The examples shown relate to the horizontal orientation of the base on which the pinna simulator rests.

A key aspect of the scanning process is the definition of the co-ordinate system origin and orientation with respect to particular pinna simulator features. The recommended convention to be used is based on a rectangular co-ordinate system (x, y, z), with the origin (0, 0, 0) at the EEP. The y-axis is then considered to be parallel to the axis from which the vertical tilt is measured and the x-axis is perpendicular to this. The z-axis is taken as the centre line through the ear canal extension.

Since it is difficult to determine these axes in three dimensions from the two-dimensional representations given in Figure 4, some assumptions need to be made on the form of the pinna simulator. First, the base on which the pinna simulator rests (i.e. the lower surface illustrated in the cross-section views of Figure 4) is assumed to be parallel to the x-y plane, and second that the orientation of the vertical y-axis is clear, or indicated for example by markings on the pinna simulator. The scanning process can identify the plane of the ear canal entrance, which is assumed to be parallel to the pinna simulator base, enabling the height (z-coordinates) of the scanned points to be referred to this plane.

D.3 Examples of pinna simulator shape

Illustrations are provided in Figures D.1 a) to c) (external 3D PDFs) for three example pinna simulator models, intended for use with their respective model of manikin (see Annexes A and B). Further, each type of pinna simulator may have a cylindrical or tapered ear canal extension.

a) Pinna simulator for the anatomically shaped manikin example given in Annex A

b) Pinna simulator for the geometrically shaped manikin example 1 given in Annex B

c) Pinna simulator for the geometrically shaped manikin example 2 given in Annex B

NOTE The 3D images can be manipulated interactively by clicking on the red drawing pin icon found on their static representations. The interactive features include: manipulation of the viewing angle, measurement of dimensions and viewing of cross-sections. For the convenience of the user, these images are also available on a software supplement.

Figure D.1 – (Embedded 3D PDFs) – Examples of a pinna simulator

Pinna simulators may be manufactured in left-hand and right-hand versions. Only left hand versions are illustrated in Annex D.

D.4 Verification of conformance

The measurement process described in Clause D.2 can also be used to verify dimensional characteristics of an individual pinna simulator with the specifications described in 4.2.2 and 4.2.3. Commercial software is available to analyse the data file produced from the scanning. Typically, such software enables linear dimensions between selected points, and angles between defined lines and planes to be determined. This software can therefore be used to verify the specifications given in Table 2 and Table 3. The software typically also enables deviations between two sets of data to be analysed.

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