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Acoustics — Statistical distribution of hearing thresholds related to age and gender

Acoustique — Distribution statistique des seuils d'audition en fonction de l'âge et du sexe

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Foreword

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on 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.

The committee responsible for this document is ISO/TC 43, *Acoustics*.

This third edition cancels and replaces the second edition (ISO 7029:2000), which has been technically revised with the following changes:

— new data has been adopted, as explained in the introduction;

— estimation accuracy of expected medians and statistical distributions of hearing thresholds were generally improved by modifying the formulae used;

— the age range for which the expected medians and statistical distributions of hearing thresholds are calculable was extended to the age of 80 years at audiometric frequencies of 2 000 Hz and below; it was up to 70 years for all frequencies in the previous editions.

Introduction

The sensitivity of human hearing is well known to decrease with age and the impairment of hearing develops more rapidly for sound at high frequencies than at low frequencies. Moreover, the magnitude of this effect varies considerably among individuals.

When testing the hearing of persons markedly over 18 years of age, part of any observed hearing loss will probably be associated with age. It is important to be aware of this when estimating the amount of hearing loss attributable to other causes under investigation.

It should be noted that a decrease in hearing ability may not necessarily be caused by ageing itself, but by many injurious influences during lifetime, which are not known in detail.

This document is based on a thorough examination of literature data on the differences between groups having different ages for populations of otologically normal persons as defined herein. Distinction is made between males and females since the difference is found to be of significance in the case of older age groups. The data have been derived from investigations using pure tones transmitted to the ear from an earphone, but no evidence is known that disqualifies their use for noise band stimuli.

This document is a revision of the second edition (ISO 7029:2000). The expected medians and statistical distributions of hearing thresholds were re-estimated using audiometric data published after the establishment of the first edition (ISO 7029:1984). All the data on which the second edition had been based were discarded. Thus, this third edition describes the hearing sensitivity profile of people in recent years.

Hearing thresholds presented in this document are generally lower at high frequencies than those in the previous editions of this document. The 4 kHz dip observed in males has become negligibly small. The source data of the previous editions might not have been screened rigorously in terms of hearing abnormalities. Problems related to instrumentation might also have affected measurement data.

The expected median hearing thresholds at the frequencies from 9 000 Hz to 12 500 Hz are presented for information. Audiometry at those frequencies is executable using an extended high-frequency audiometer.

Acoustics — Statistical distribution of hearing thresholds related to age and gender

1 Scope

This document provides descriptive statistics of the hearing threshold deviation for populations of otologically normal persons of various ages under monaural earphone listening conditions. It specifies the following, for populations within the age limits from 18 years to 80 years for the range of audiometric frequencies from 125 Hz to 8 000 Hz:

a) the expected median value of hearing thresholds given relative to the median hearing threshold at the age of 18 years;

b) the expected statistical distribution above and below the median value.

For the frequencies from 3 000 Hz to 8 000 Hz, the median and statistical distribution for populations above 70 years are presented for information only.

This document also provides for information the expected median values at audiometric frequencies from 9 000 Hz to 12 500 Hz within the age limits from 22 years to 80 years.

The data are applicable for estimating the amount of hearing loss caused by a specific agent in a population. Such a comparison is valid if the population under study consists of persons who are otologically normal except for the effect of the specific agent. Noise exposure is an example of a specific agent and for this application, selected data from this document are referred to as “database A” in ISO 1999.

NOTE 1 ISO 1999:2013, Database A is based on a previous edition of ISO 7029.

The data may also be used to assess an individual’s hearing in relation to the distribution of hearing thresholds which is normal for the person’s age group. However, it is not possible to determine for an individual precisely which part of an observed hearing loss is attributable to an accumulation of detrimental effects on the hearing which increase with age, and which part has been caused by other factors such as noise.

The hearing threshold deviation as defined herein and the hearing threshold level as defined in other International Standards (ISO 389-1, ISO 389-2, ISO 389-5, ISO 389-8, ISO 8253-1, ISO 8253-2, IEC 60645-1) express the hearing threshold of an individual or an individual ear, respectively, relative to

— the expected median hearing threshold of 18-year-old age group of the same gender, or

— a reference zero level specified in various parts of ISO 389.

To the extent that the reference zero level represents the median of the 18-year-old population, the values of the two terms will be the same.

NOTE 2 The values of these two are not always the same for some reasons. One reason is that the reference zero level has been determined based on the hearing threshold levels of persons older than 18 years, including those aged up to 25 years or to 30 years, who have slightly worse hearing sensitivity on average.

NOTE 3 ISO 28961 specifies the expected statistical distribution of hearing thresholds, expressed in sound pressure level in decibels, for populations of otologically normal persons of the age from 18 years to 25 years under binaural, free-field listening conditions. It enables the calculation not only at audiometric frequencies, but also for other frequencies at one-third-octave intervals from 20 Hz to 16 000 Hz.

2 Normative references

There are no normative references in this document.

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 https://www.iso.org/obp/

3.1
otologically normal person
person in a normal state of health who is free from all signs or symptoms of ear disease and from obstructing wax in the ear canal and who has no history of undue exposure to noise, exposure to potentially ototoxic substances or familial hearing loss

[SOURCE: ISO 8253-1:2010, 3.7, modified — The term “ototoxic drugs” has been changed to “ototoxic substances”.]

3.2
hearing threshold deviation
ΔH
threshold of hearing of an individual minus the median threshold of hearing of a population of 18-year-old *otologically normal persons* (3.1) of the same gender

Note 1 to entry: The term threshold of hearing is defined in ISO 389-1:1998, 3.4.

4 Specification

4.1 General

The statistical distribution of hearing threshold deviations for otologically normal persons of a specific age Y and a specific gender is given in terms of the median value (see 4.2) and the distribution around the median (see 4.3).

The range of Y is from 18 years to 80 years for audiometric frequencies from 125 Hz to 8 000 Hz. For the frequencies from 3 000 Hz to 8 000 Hz, the Y value above 70 years is given for information purposes only.

NOTE The statistical distribution estimation for the age above 70 years at 3 000 Hz and above is subject to a large uncertainty because the hearing threshold level from many subjects is not obtainable (“scales out”) at those frequencies.

Annex E presents expected median thresholds at audiometric frequencies from 9 000 Hz to 12 500 Hz.

Annex F discusses the derivation of the descriptive statistics of hearing thresholds.

Annex G shows root-mean-square error (RMSE) values and estimating the uncertainty of the statistical values.

4.2 Median

The median value $\Delta H_{md,Y}$, in decibels, at audiometric frequencies from 125 Hz to 8 000 Hz is given by Formula (1):

$$\Delta H_{md,Y} = \alpha_{md} \left(Y - 18\right)^{\beta_{md}} \tag{1}$$

where

α_{md} and β_{md} are dimensionless quantities as given in Table 1;

Y is the age in years.

The age of 18 years is the lower limit of the Y range for which Formula (1) is valid.

Table 1 — Values of α_{md} and β_{md} in Formula (1)

Frequency Hz	α_{md} **Males**	α_{md} **Females**	β_{md} **Males**	β_{md} **Females**
125	$2{,}50 \times 10^{-6}$	$6{,}16 \times 10^{-4}$	3,841	2,451
250	$1{,}39 \times 10^{-4}$	$3{,}98 \times 10^{-4}$	2,832	2,568
500	$4{,}59 \times 10^{-4}$	$2{,}61 \times 10^{-4}$	2,537	2,708
750	$5{,}70 \times 10^{-4}$	$2{,}25 \times 10^{-4}$	2,512	2,775
1 000	$7{,}02 \times 10^{-4}$	$2{,}21 \times 10^{-4}$	2,494	2,805
1 500	$1{,}09 \times 10^{-3}$	$2{,}53 \times 10^{-4}$	2,446	2,813
2 000	$1{,}56 \times 10^{-3}$	$3{,}12 \times 10^{-4}$	2,404	2,792
3 000	$2{,}54 \times 10^{-3}$	$4{,}88 \times 10^{-4}$	2,350	2,728
4 000	$3{,}40 \times 10^{-3}$	$7{,}37 \times 10^{-4}$	2,325	2,660
6 000	$4{,}53 \times 10^{-3}$	$1{,}47 \times 10^{-3}$	2,315	2,539
8 000	$5{,}06 \times 10^{-3}$	$2{,}53 \times 10^{-3}$	2,328	2,439

4.3 Distribution around the median

The distribution around the median shall be approximated by the upper and lower halves, respectively, of two Gaussian distributions, each with their standard deviation s_u and s_l, in decibels, given by Formulae (2) and (3):

$$s_u = \gamma_{0,su} + \gamma_{1,su}\left(Y - 18\right) + \gamma_{2,su}\left(Y - 18\right)^2 + \gamma_{3,su}\left(Y - 18\right)^3 + \gamma_{4,su}\left(Y - 18\right)^4 + \gamma_{5,su}\left(Y - 18\right)^5 \tag{2}$$

$$s_l = \gamma_{0,sl} + \gamma_{1,sl}\left(Y - 18\right) + \gamma_{2,sl}\left(Y - 18\right)^2 + \gamma_{3,sl}\left(Y - 18\right)^3 + \gamma_{4,sl}\left(Y - 18\right)^4 + \gamma_{5,sl}\left(Y - 18\right)^5 \tag{3}$$

The values of coefficients $\gamma_{n,su}$ and $\gamma_{n,sl}$ (n = 0, 1, 2, ..., 5) are given in Tables 2 and 3 for males and in Tables 4 and 5 for females. The age of 18 years is the lower limit of the Y range for which Formulae (2) and (3) are valid.

Table 2 — Values of $\gamma_{n,su}$ (n = 0, 1, 2, ..., 5) in Formula (2) for males

Frequency Hz	$\gamma_{0,su}$	$\gamma_{1,su}$	$\gamma_{2,su}$	$\gamma_{3,su}$	$\gamma_{4,su}$	$\gamma_{5,su}$
125	4,63	0,645	$-8,85 \times 10^{-2}$	$3,69 \times 10^{-3}$	$-5,98 \times 10^{-5}$	$3,39 \times 10^{-7}$
250	5,27	0,710	$-9,13 \times 10^{-2}$	$3,64 \times 10^{-3}$	$-5,74 \times 10^{-5}$	$3,22 \times 10^{-7}$
500	4,98	0,751	$-9,20 \times 10^{-2}$	$3,68 \times 10^{-3}$	$-5,84 \times 10^{-5}$	$3,28 \times 10^{-7}$
750	4,65	0,733	$-8,81 \times 10^{-2}$	$3,59 \times 10^{-3}$	$-5,76 \times 10^{-5}$	$3,24 \times 10^{-7}$
1 000	4,42	0,714	$-8,54 \times 10^{-2}$	$3,57 \times 10^{-3}$	$-5,82 \times 10^{-5}$	$3,29 \times 10^{-7}$
1 500	4,14	0,679	$-8,04 \times 10^{-2}$	$3,52 \times 10^{-3}$	$-5,89 \times 10^{-5}$	$3,35 \times 10^{-7}$
2 000	4,10	0,632	$-7,53 \times 10^{-2}$	$3,46 \times 10^{-3}$	$-5,94 \times 10^{-5}$	$3,40 \times 10^{-7}$
3 000	4,29	0,530	$-6,28 \times 10^{-2}$	$3,09 \times 10^{-3}$	$-5,37 \times 10^{-5}$	$2,95 \times 10^{-7}$
4 000	4,68	0,455	$-5,52 \times 10^{-2}$	$2,95 \times 10^{-3}$	$-5,30 \times 10^{-5}$	$2,92 \times 10^{-7}$
6 000	5,61	0,363	$-4,72 \times 10^{-2}$	$2,92 \times 10^{-3}$	$-5,58 \times 10^{-5}$	$3,12 \times 10^{-7}$
8 000	6,62	0,291	$-4,16 \times 10^{-2}$	$2,92 \times 10^{-3}$	$-5,85 \times 10^{-5}$	$3,33 \times 10^{-7}$

Table 3 — Values of $\gamma_{n,sl}$ (n =0, 1, 2, ..., 5) in Formula (3) for males

Frequency Hz	$\gamma_{0,sl}$	$\gamma_{1,sl}$	$\gamma_{2,sl}$	$\gamma_{3,sl}$	$\gamma_{4,sl}$	$\gamma_{5,sl}$
125	3,34	0,131	$-2,02 \times 10^{-2}$	$1,12 \times 10^{-3}$	$-2,28 \times 10^{-5}$	$1,57 \times 10^{-7}$
250	3,32	0,230	$-2,54 \times 10^{-2}$	$1,20 \times 10^{-3}$	$-2,27 \times 10^{-5}$	$1,46 \times 10^{-7}$
500	3,43	0,362	$-4,11 \times 10^{-2}$	$1,87 \times 10^{-3}$	$-3,44 \times 10^{-5}$	$2,21 \times 10^{-7}$
750	3,60	0,384	$-4,43 \times 10^{-2}$	$1,98 \times 10^{-3}$	$-3,55 \times 10^{-5}$	$2,22 \times 10^{-7}$
1 000	3,77	0,363	$-4,19 \times 10^{-2}$	$1,82 \times 10^{-3}$	$-3,14 \times 10^{-5}$	$1,89 \times 10^{-7}$
1 500	3,93	0,365	$-4,22 \times 10^{-2}$	$1,79 \times 10^{-3}$	$-2,96 \times 10^{-5}$	$1,70 \times 10^{-7}$
2 000	4,01	0,387	$-4,47 \times 10^{-2}$	$1,87 \times 10^{-3}$	$-3,02 \times 10^{-5}$	$1,69 \times 10^{-7}$
3 000	4,11	0,405	$-4,56 \times 10^{-2}$	$1,86 \times 10^{-3}$	$-2,83 \times 10^{-5}$	$1,46 \times 10^{-7}$
4 000	4,09	0,439	$-4,78 \times 10^{-2}$	$1,92 \times 10^{-3}$	$-2,84 \times 10^{-5}$	$1,40 \times 10^{-7}$
6 000	4,01	0,497	$-4,97 \times 10^{-2}$	$1,93 \times 10^{-3}$	$-2,67 \times 10^{-5}$	$1,18 \times 10^{-7}$
8 000	3,90	0,559	$-5,62 \times 10^{-2}$	$2,40 \times 10^{-3}$	$-3,92 \times 10^{-5}$	$2,29 \times 10^{-7}$

Table 4 — Values of $\gamma_{n,\mathrm{su}}$ (n =0, 1, 2, ..., 5) in Formula (2) for females

Frequency Hz	$\gamma_{0,\mathrm{su}}$	$\gamma_{1,\mathrm{su}}$	$\gamma_{2,\mathrm{su}}$	$\gamma_{3,\mathrm{su}}$	$\gamma_{4,\mathrm{su}}$	$\gamma_{5,\mathrm{su}}$
125	5,05	0,400	$-4,60 \times 10^{-2}$	$1,73 \times 10^{-3}$	$-2,75 \times 10^{-5}$	$1,71 \times 10^{-7}$
250	5,01	0,481	$-4,88 \times 10^{-2}$	$1,80 \times 10^{-3}$	$-2,81 \times 10^{-5}$	$1,67 \times 10^{-7}$
500	4,68	0,510	$-5,16 \times 10^{-2}$	$1,95 \times 10^{-3}$	$-3,07 \times 10^{-5}$	$1,77 \times 10^{-7}$
750	4,45	0,511	$-5,25 \times 10^{-2}$	$2,03 \times 10^{-3}$	$-3,18 \times 10^{-5}$	$1,81 \times 10^{-7}$
1 000	4,34	0,492	$-5,15 \times 10^{-2}$	$2,03 \times 10^{-3}$	$-3,18 \times 10^{-5}$	$1,78 \times 10^{-7}$
1 500	4,23	0,479	$-5,12 \times 10^{-2}$	$2,07 \times 10^{-3}$	$-3,26 \times 10^{-5}$	$1,80 \times 10^{-7}$
2 000	4,26	0,456	$-4,91 \times 10^{-2}$	$2,01 \times 10^{-3}$	$-3,16 \times 10^{-5}$	$1,70 \times 10^{-7}$
3 000	4,36	0,476	$-5,15 \times 10^{-2}$	$2,19 \times 10^{-3}$	$-3,51 \times 10^{-5}$	$1,91 \times 10^{-7}$
4 000	4,61	0,477	$-5,07 \times 10^{-2}$	$2,19 \times 10^{-3}$	$-3,51 \times 10^{-5}$	$1,88 \times 10^{-7}$
6 000	5,22	0,483	$-4,83 \times 10^{-2}$	$2,13 \times 10^{-3}$	$-3,39 \times 10^{-5}$	$1,74 \times 10^{-7}$
8 000	5,84	0,516	$-4,89 \times 10^{-2}$	$2,18 \times 10^{-3}$	$-3,49 \times 10^{-5}$	$1,77 \times 10^{-7}$

Table 5 — Values of $\gamma_{\mathrm{n,sl}}$ (n =0, 1, 2, ..., 5) in Formula (3) for females

Frequency Hz	$\gamma_{0,\mathrm{sl}}$	$\gamma_{1,\mathrm{sl}}$	$\gamma_{2,\mathrm{sl}}$	$\gamma_{3,\mathrm{sl}}$	$\gamma_{4,\mathrm{sl}}$	$\gamma_{5,\mathrm{sl}}$
125	3,64	0,047	$2,28 \times 10^{-3}$	$-6,68 \times 10^{-5}$	$-8,72 \times 10^{-7}$	$2,30 \times 10^{-8}$
250	3,11	0,226	$-7,71 \times 10^{-3}$	$9,83 \times 10^{-5}$	$-7,11 \times 10^{-7}$	$9,02 \times 10^{-9}$
500	2,98	0,338	$-1,74 \times 10^{-2}$	$3,53 \times 10^{-4}$	$-2,78 \times 10^{-6}$	$1,01 \times 10^{-8}$
750	3,03	0,378	$-2,24 \times 10^{-2}$	$5,20 \times 10^{-4}$	$-4,60 \times 10^{-6}$	$1,50 \times 10^{-8}$
1 000	3,15	0,382	$-2,39 \times 10^{-2}$	$5,62 \times 10^{-4}$	$-4,60 \times 10^{-6}$	$9,87 \times 10^{-9}$
1 500	3,32	0,387	$-2,64 \times 10^{-2}$	$6,71 \times 10^{-4}$	$-5,76 \times 10^{-6}$	$1,07 \times 10^{-8}$
2 000	3,47	0,392	$-2,84 \times 10^{-2}$	$7,79 \times 10^{-4}$	$-7,35 \times 10^{-6}$	$1,71 \times 10^{-8}$
3 000	3,69	0,392	$-2,96 \times 10^{-2}$	$8,44 \times 10^{-4}$	$-7,55 \times 10^{-6}$	$8,16 \times 10^{-9}$
4 000	3,84	0,402	$-3,17 \times 10^{-2}$	$9,99 \times 10^{-4}$	$-1,08 \times 10^{-5}$	$2,99 \times 10^{-8}$
6 000	4,04	0,403	$-3,15 \times 10^{-2}$	$1,06 \times 10^{-3}$	$-1,21 \times 10^{-5}$	$3,44 \times 10^{-8}$
8 000	4,15	0,413	$-3,01 \times 10^{-2}$	$1,00 \times 10^{-3}$	$-9,97 \times 10^{-6}$	$8,74 \times 10^{-9}$

4.4 Application of data

The hearing threshold deviation $\Delta H_{Q,Y}$ which can be expected to be exceeded by a given fraction Q of an otologically normal population of given age Y and given gender, is given by Formula (4) or (5):

$$\Delta H_{Q,Y} = \Delta H_{\mathrm{md},Y} + k s_{\mathrm{u}} \tag{4}$$

$$\Delta H_{Q,Y} = \Delta H_{\mathrm{md,Y}} + k s_{\mathrm{l}} \tag{5}$$

Formula (4) applies when 0,05 ≤ Q ≤ 0,50, whereas Formula (5) applies when 0,50 ≤ Q ≤ 0,95. Values of the multiplier k correspond to the Gaussian distribution. For information, these values are given in Table A.1.

Due to uncertainties in the experimental data on which this document is based, tails of the statistical distributions are only reliable within the range of 0,05 ≤ Q ≤ 0,95.

The values given in Tables 1 to 5 are the outcome of comprehensive statistical analyses. The resolution provided is for calculation only, and the final results should be rounded to the nearest integer of a decibel.

An example of a calculation is given in Annex B. Calculated values for a range of parameters are given in Figure C.1 and Table D.1.

Annex A
(informative)

Selected values of the Gaussian distribution

Table A.1 — Values of the multiplier *k* corresponding to the Gaussian distribution

Q		*k*	*Q*		*k*
0,05	0,95	1,64	0,26	0,74	0,643
0,06	0,94	1,55	0,27	0,73	0,613
0,07	0,93	1,48	0,28	0,72	0,583
0,08	0,92	1,41	0,29	0,71	0,553
0,09	0,91	1,34	0,30	0,70	0,524
0,10	0,90	1,28	0,31	0,69	0,496
0,11	0,89	1,23	0,32	0,68	0,468
0,12	0,88	1,17	0,33	0,67	0,440
0,13	0,87	1,13	0,34	0,66	0,412
0,14	0,86	1,08	0,35	0,65	0,385
0,15	0,85	1,04	0,36	0,64	0,358
0,16	0,84	0,994	0,37	0,63	0,332
0,17	0,83	0,954	0,38	0,62	0,305
0,18	0,82	0,915	0,39	0,61	0,279
0,19	0,81	0,878	0,40	0,60	0,253
0,20	0,80	0,842	0,41	0,59	0,228
0,21	0,79	0,806	0,42	0,58	0,202
0,22	0,78	0,772	0,43	0,57	0,176
0,23	0,77	0,739	0,44	0,56	0,151
0,24	0,76	0,706	0,45	0,55	0,126
0,25	0,75	0,674	0,46	0,54	0,100
			0,47	0,53	0,075 3
			0,48	0,52	0,050 2
			0,49	0,51	0,025 1
			0,50		0,000

Annex B
(informative)

Numerical example to illustrate the procedure

B.1 Example

Calculate the hearing threshold deviation exceeded by 25 % of an otologically normal male population of age 60 years at the audiometric frequency 4 000 Hz.

B.2 Calculation

Step 1: Table 1, Males, 4 000 Hz, gives $\alpha_{md} = 3{,}40 \times 10^{-3}$ and $\beta_{md} = 2{,}325$.

Step 2: Formula (1), $Y = 60$ years, $\alpha_{md} = 3{,}40 \times 10^{-3}$ and $\beta_{md} = 2{,}325$, gives $\Delta H_{md,60} = 20{,}21$ dB.

Step 3: Table 2, 4 000 Hz, gives $\gamma_{0,su} = 4{,}68$, $\gamma_{1,su} = 0{,}455$, $\gamma_{2,su} = -5{,}52 \times 10^{-2}$, $\gamma_{3,su} = 2{,}95 \times 10^{-3}$, $\gamma_{4,su} = -5{,}30 \times 10^{-5}$ and $\gamma_{5,su} = 2{,}92 \times 10^{-7}$.

NOTE The example concerns 25 % of the population (upper quartile), hence the required parameters are those for the distribution above the median, i.e. $\gamma_{n,su}$ ($n = 0, 1, 2, ..., 5$).

Step 4: Formula (2), $\gamma_{0,su} = 4{,}68$, $\gamma_{1,su} = 0{,}455$, $\gamma_{2,su} = -5{,}52 \times 10^{-2}$, $\gamma_{3,su} = 2{,}95 \times 10^{-3}$, $\gamma_{4,su} = -5{,}30 \times 10^{-5}$ and $\gamma_{5,su} = 2{,}92 \times 10^{-7}$ gives $s_u = 18{,}22$ dB.

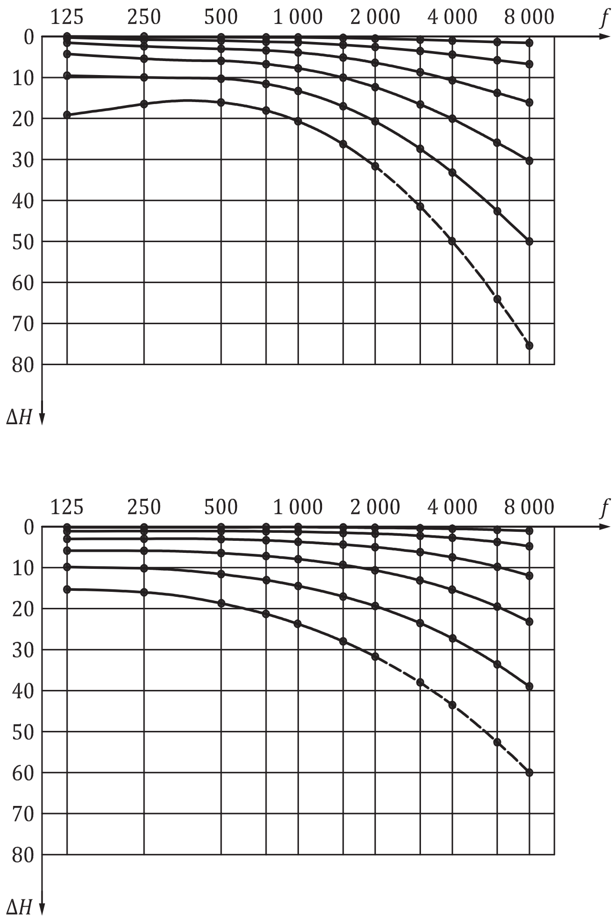
Step 5: Table A.1, $Q = 0{,}25$ (25 %), gives $k = 0{,}674$.

Step 6: Formula (4), $\Delta H_{md,60} = 20{,}21$ dB, $k = 0{,}674$, $s_u = 18{,}22$ dB, gives the required hearing threshold deviation $\Delta H_{25,60} = 32{,}49$ dB.

Step 7: The result should be rounded to the nearest integer, i.e. 32 dB.

Annex C
(informative)

Median values of expected hearing threshold deviations



Key

f frequency, Hz

Δ*H* hearing threshold deviation, dB

From top to bottom, the curves represent $\Delta H_{\mathrm{md},Y}$ values when *Y* is 30 years, 40 years, 50 years, 60 years, 70 years or 80 years.

NOTE 1 The dashed portion of the curve of $\Delta H_{\mathrm{md},Y}$, $Y = 80$, is presented for informative purposes only.

NOTE 2 The $\Delta H_{\mathrm{md},80}$ values at 125 Hz are liable to a large uncertainty of estimation because of the scarcity of source data.

Figure C.1 — Median values of expected hearing threshold deviation for males (upper panel) and females (lower panel)

Annex D
(informative)

Selected values of the statistical distribution of hearing threshold deviations

Table D.1 — Hearing threshold deviation ΔH which can be expected to be exceeded by a given fraction Q of an otologically normal population[a]

Frequency	Age	Males					Females				
		dB					dB				
Hz	years	0,9	0,75	0,5	0,25	0,1	0,9	0,75	0,5	0,25	0,1
125	20	−5	−2	0	4	7	−5	−3	0	4	7
	30	−4	−2	0	3	6	−5	−3	0	4	8
	40	−5	−2	0	2	4	−5	−2	1	4	7
	50	−5	−2	2	4	7	−4	0	3	6	9
	60	−3	0	4	9	14	0	3	6	10	13
	70	2	6	10	16	23	3	6	10	16	22
	80	10	14	19	27	35	6	10	15	26	36
250	20	−5	−2	0	4	8	−4	−2	0	4	7
	30	−5	−3	0	4	8	−6	−3	0	5	8
	40	−5	−2	1	3	6	−6	−2	1	5	8
	50	−4	−1	3	5	8	−4	−1	3	7	10
	60	−2	2	5	10	14	−1	2	6	11	15
	70	3	6	10	16	22	2	6	10	16	22
	80	10	13	17	24	32	5	10	16	25	34
500	20	−5	−3	0	4	8	−5	−2	0	4	7
	30	−5	−3	0	4	8	−6	−3	0	4	8
	40	−5	−2	1	4	6	−5	−2	1	5	8
	50	−4	−1	3	6	10	−3	0	3	7	11
	60	−2	2	6	11	16	0	3	6	12	16
	70	3	6	10	17	23	3	7	12	18	24
	80	8	12	16	24	32	6	12	19	27	35
750	20	−5	−3	0	4	7	−5	−2	0	4	7
	30	−6	−3	0	4	8	−6	−3	0	4	8
	40	−4	−2	1	4	7	−5	−2	1	5	8
	50	−4	0	3	7	11	−3	0	3	8	11
	60	−2	2	7	13	18	0	3	7	13	18
	70	3	7	12	19	26	4	8	13	20	26
	80	9	13	18	27	34	9	15	21	30	37

[a] Values are rounded to the nearest integer.

[b] Values in parenthesis are for information only.

Table D.1 *(continued)*

Frequency	Age	Males					Females				
		dB					dB				
Hz	years	0,9	0,75	0,5	0,25	0,1	0,9	0,75	0,5	0,25	0,1
1 000	20	−6	−3	0	4	7	−5	−3	0	3	7
	30	−6	−3	0	4	8	−6	−3	0	4	8
	40	−4	−1	2	5	8	−5	−2	1	5	8
	50	−3	0	4	9	13	−3	0	4	8	12
	60	−1	3	8	15	21	1	4	8	13	19
	70	4	8	13	22	29	5	9	14	22	28
	80	11	15	21	29	37	11	17	24	32	40
1 500	20	−6	−3	0	4	7	−5	−3	0	3	6
	30	−6	−3	0	4	8	−6	−3	0	4	7
	40	−4	−1	2	6	9	−5	−2	2	5	8
	50	−2	1	5	11	16	−2	1	4	9	13
	60	0	5	10	18	26	1	5	9	16	21
	70	6	11	17	26	34	6	11	17	25	32
	80	14	20	26	35	42	14	21	28	37	45
2 000	20	−6	−3	0	3	7	−5	−3	0	3	6
	30	−6	−3	1	4	8	−6	−3	0	4	7
	40	−3	0	3	7	11	−5	−2	2	5	9
	50	−1	2	6	13	19	−2	1	5	10	14
	60	2	7	12	22	30	2	6	10	17	24
	70	8	14	21	31	39	7	13	19	28	35
	80	18	24	32	40	47	17	24	32	41	49
3 000	20	−6	−3	0	3	7	−6	−3	0	3	7
	30	−6	−3	1	5	8	−7	−3	0	4	8
	40	−3	0	4	9	13	−4	−1	2	6	10
	50	0	4	9	17	24	−1	2	6	12	17
	60	5	10	17	27	37	3	8	13	21	28
	70	12	19	27	38	48	10	16	23	33	41
	80[b]	(25)	(33)	(41)	(47)	(53)	(22)	(30)	(38)	(48)	(57)

[a] Values are rounded to the nearest integer.

[b] Values in parenthesis are for information only.

Table D.1 *(continued)*

Frequency Hz	Age years	Males dB 0,9	Males dB 0,75	Males dB 0,5	Males dB 0,25	Males dB 0,1	Females dB 0,9	Females dB 0,75	Females dB 0,5	Females dB 0,25	Females dB 0,1
4 000	20	−6	−3	0	4	7	−6	−3	0	4	7
	30	−6	−2	1	5	9	−7	−3	1	5	8
	40	−2	1	4	10	15	−4	−1	3	7	11
	50	2	6	11	20	28	−1	3	7	14	19
	60	7	13	20	32	43	4	9	15	24	32
	70	16	24	33	45	55	12	19	27	37	46
	80[b]	(32)	(40)	(50)	(55)	(59)	(27)	(35)	(43)	(53)	(62)
6 000	20	−6	−3	0	4	8	−6	−3	0	4	8
	30	−6	−2	1	6	11	−7	−3	1	6	10
	40	−2	2	6	13	19	−4	−1	4	9	14
	50	3	8	14	25	35	−1	4	10	17	24
	60	10	18	26	40	53	5	12	19	30	39
	70	22	32	43	55	66	15	24	33	45	56
	80[b]	(43)	(53)	(64)	(66)	(69)	(35)	(43)	(52)	(62)	(72)
8 000	20	−6	−3	0	5	9	−6	−3	0	5	9
	30	−6	−2	2	7	12	−7	−3	1	7	11
	40	−2	2	7	15	22	−4	0	5	11	17
	50	4	10	16	29	40	0	6	12	21	29
	60	13	21	30	46	60	6	14	23	35	45
	70	26	37	50	63	74	18	28	39	52	63
	80[b]	(44)	(59)	(75)	(76)	(77)	(40)	(49)	(60)	(70)	(80)

[a] Values are rounded to the nearest integer.

[b] Values in parenthesis are for information only.

Annex E
(informative)

Expected median thresholds at audiometric frequencies from 9 000 Hz to 12 500 Hz

E.1 General

This annex provides expected median thresholds at audiometric frequencies from 9 000 Hz to 12 500 Hz within the age limits from 22 years to 80 years. The values for the age above 70 are less accurate than those for younger ages because of the scarcity of source data. Also, expected medians at 12 500 Hz are liable to a large uncertainty of estimation.

The thresholds are expressed in decibels relative to the reference equivalent threshold sound pressure level (RETSPL) specified in ISO 389-5.

The threshold values are the outcome of statistical analyses of audiometric data which were obtained using an extended high-frequency audiometer as specified in IEC 60645-1 with earphones specified in ISO 389-5 (Sennheiser™[1]) HDA 200), following the procedure specified in ISO 8253-1. Only the threshold data measured employing the apparatus and procedure which conformed to those International Standards can be reasonably compared to the values in this annex.

The expected statistical distribution above and below the median value is not provided in this annex because the source data were not ample enough for estimating the statistical distribution with accuracy.

E.2 Specification

The median value of hearing threshold levels $H_{md,Y}$ at audiometric frequencies from 9 000 Hz to 12 500 Hz is given by Formula (E.1):

$$H_{md,Y} = \alpha_{md} \left(Y - 22\right)^{\beta_{md}} \quad \text{(E.1)}$$

Values of the coefficient α_{md} and the exponent β_{md} for males and females are given in Table E.1. The age of 22 years is the lower limit of the Y range for which Formula (E.1) is valid.

NOTE The hearing threshold level at the age of 22 years, the centre of the age range of 18 years to 25 years, is expected to be zero by the definition of RETSPL in ISO 8253-1.

Table E.1 — Values of α_{md} and β_{md} in Formula (E.1)

Frequency	α_{md}		β_{md}	
Hz	**Males**	**Females**	**Males**	**Females**
9 000	0,037 8	0,042 0	1,88	1,83
10 000	0,193	0,092 4	1,48	1,67
11 200	0,300	0,467	1,39	1,28
12 500	1,41	1,43	1,02	1,01

Calculated values for a range of parameters are given in Table E.2.

1) Sennheiser is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

Table E.2 — Expected median thresholds at audiometric frequencies from 9 000 Hz to 12 500 Hz[a]

Frequency Hz	Age years	Males dB	Females dB
9 000	22	0	0
	30	2	2
	40	9	8
	50	20	19
	60	35	33
	70	54	50
	80[b]	(77)	(71)
10 000	22	0	0
	30	4	3
	40	14	11
	50	27	24
	60	42	40
	70	60	59
	80[b]	(79)	(81)
11 200	22	0	0
	30	5	7
	40	17	19
	50	31	34
	60	48	50
	70	66	67
	80[b]	(86)	(85)
12 500[b]	22	0	0
	30	(12)	(12)
	40	(27)	(27)
	50	(43)	(42)
	60	(58)	(57)
	70	(74)	(72)
	80	(90)	(87)

[a] Values are rounded to the nearest integer.

[b] Values in parenthesis are subject to a large uncertainty because of the scarcity of source data.

Annex F
(informative)

Notes on the derivation of descriptive statistics of hearing thresholds

F.1 General

The descriptive statistics of hearing thresholds in this document have been derived from the results of investigations listed in Tables F.1 and F.2, following the procedure described in F.2 and F.3.

The expected medians and statistical distributions for the audiometric frequencies from 125 Hz to 8 000 Hz have been derived from the data in the references shown in Table F.1. The expected medians for the audiometric frequencies from 9 000 Hz to 12 500 Hz have been derived from the references shown in Table F.2. For both frequency ranges, the calculation was made separately for males and females.

The references in Tables F.1 and F.2 shared the following common features:

— the data were published after the establishment of the first edition (ISO 7029:1984);

— hearing thresholds were measured using a monaural audiometer and a measurement method which conformed to relevant International Standards;

— subjects were rigorously screened for their hearing abnormalities;

— statistics of measurement data were presented in numerical forms;

— hearing thresholds of both ear averages were presented or calculable from the data.

Details of those and other features are shown in Tables F.1 and F.2.

F.2 Medians

F.2.1 Medians for audiometric frequencies from 125 Hz to 8 000 Hz

a) Values of $\Delta h_{\mathrm{md},Y}$, the hearing threshold deviation for individual set of median hearing thresholds, were calculated at each audiometric frequency in References [11] to [17]. Because median thresholds were not shown in Reference [12], the mean thresholds were converted to values corresponding to medians by shifting a constant amount which was estimated using Reference [11] and References [14] to [18].

b) A polynomial surface of fourth degree of logarithmic frequency and third degree of age was fitted to the whole set of $\Delta h_{\mathrm{md},Y}$ values for smoothing. Since the size of data set in Reference [13] was overwhelmingly large, the number of subjects was not taken into account in the fitting process. Audiometric data in each reference was treated with the same weighting.

c) Formula (1) was fitted to the polynomial surface at each audiometric frequency to derive the coefficient α_{md} and the exponent β_{md}.

F.2.2 Medians for audiometric frequencies from 9 000 Hz to 12 500 Hz

Formula (E.1) was fitted to the median values in References [16] and [19] to derive the coefficient α_{md} and the exponent β_{md}. Audiometric data in both references were treated with the same weighting.

F.3 Statistical distribution above and below the median

a) Values of $\Delta h_{Q,Y}$, the hearing threshold deviation which can be expected to be exceeded by a given fraction Q of an otologically normal population of given age Y and given gender for individual set of hearing thresholds, were calculated at each audiometric frequency in Reference [11], References [13] to [17] and References [20] to [21]. The value of Q was varied from 0,5 to 0,95. The standard deviations in Reference [20] were converted to values of $\Delta h_{Q,Y}$, where Q = 0,25 and Q = 0,75.

b) A polynomial surface of third degree of logarithmic frequency and fifth degree of age was fitted to the sets of $\Delta h_{Q,Y}$ values, separately for each Q value, for smoothing. The number of subjects was not taken into account in the fitting process for the same reason as that in F.2.1 b).

c) Two halves of Gaussian distributions were fitted to the polynomial surface at each audiometric frequency and standard deviations of those distributions were obtained.

d) Formulae (2) and (3) were fitted to the standard deviations to derive the values of coefficients in Tables 2 to 5.

Table F.1 — Investigations of hearing thresholds for audiometric frequencies from 125 Hz to 8 000 Hz

Investigation	Reference [11]	Reference [12]	Reference [13]	Reference [14]	Reference [15]
Years of measurement	1980 to 1986	1992 to 2002	1996 to 1998	1998 to 2005	2006
Country	United Kingdom	Japan	Norway	Japan	Japan
Measurement frequencies Hz	250, 500, 1 000, 2 000, 3 000, 4 000, 6 000, 8 000	125, 250, 500, 1 000, 2 000, 4 000, 8 000	250, 500, 1 000, 2 000, 3 000, 4 000, 6 000, 8 000	125, 250, 500, 1 000, 2 000, 4 000, 8 000	125, 250, 500, 750, 1 000, 2 000, 3 000, 4 000, 6 000, 8 000
Calibration method (earphones)	BS 2497 [ISO 389] (TDH 39 and TDH 49)	JIS T 1201 [ISO 389]	ISO 389-1 (TDH 39P with MX-41/AR cushions, calibrated on an IEC 60318 artificial ear)	JIS T 1201-1 [ISO 389] (AD-02B)	ISO 389-8 (HDA 200)
Measurement method	BSI/BAOL, 1981 (similar to ISO 8253-1, shortened ascending method)	Ascending method (essentially identical to ISO 8253-1, shortened ascending method)	ISO 8253-1 (ascending method, automatic computerized procedure)	ISO 8253-1 (ascending method)	ISO 8253-1 (bracketing method)
Number of subjects	Males, 172; Females, 399	Males, 831; Females, 690	Males, 4 435; Females, 14 984	Males, 152; Females, 139	Males, 20; Females, 32
Age range years	18 to 80	15 to 84	20 to 89	15 to 29, 60 to 89	15 to 17
Exclusion criteria	Significant noise emission from occupational, gunfire or social noise exposure, air bone gap; "non-manual" occupation	History of ear disease, exposure to extensive noise, injury to head, ototoxic drugs, familial hearing loss	Otoscopy, ear-related disorders and diseases, history of noise exposure (asymmetric conductive loss based on Weber test, symptoms of hearing loss, known hearing losses)	Otoscopy, tympanometry, extensive exposure to loud sounds in the workplace or in daily life, history of severe ear disease or injury, familial hearing loss, unbalanced threshold between left and right ears	Otoscopy, tympanometry, extensive exposure to loud sounds in the workplace or in daily life, history of severe ear disease or injury, familial hearing loss, unbalanced threshold between left and right ears
Descriptive statistics[a]	Median, mean, 25th and 75th percentiles	Mean	Median, 25th and 75th percentiles	Median, mean; 5th, 10th, 15th, 20th, 25th, 75th, 80th, 85th, 90th, 95th percentiles	Median, mean; 5th, 10th, 15th, 20th, 25th, 75th, 80th, 85th, 90th, 95th percentiles

[a] Statistics adopted for the calculation in this document.

Table F.1 *(continued)*

Investigation	Reference [16]	Reference [17]	Reference [18]	Reference [20]	Reference [21]
Years of measurement	2006 to 2008	2010 to 2012	1993 to 1995	2004 to 2005	2009 to 2011
Country	Japan	Germany	United States	France	Australia
Measurement frequencies Hz	125, 250, 500, 750, 1 000, 2 000, 3 000, 4 000, 6 000, 8 000	250, 500, 1 000, 2 000, 3 000, 4 000, 6 000, 8 000	500, 1 000, 2 000, 3 000, 4 000, 6 000, 8 000	250, 500, 1 000, 2 000, 3 000, 4 000, 6 000, 8 000	500, 1 000, 2 000, 3 000, 4 000, 6 000, 8 000
Calibration method (earphones)	ISO 389-8 (HDA 200)	ISO 389-8 (HDA 200)	ANSI S3.6:1989	ISO 389 (TDH 39P)	(E-A-R tone 3A insert earphones + earmuffs)
Measurement method	ISO 8253-1 (bracketing method)	ISO 8253-1 (shortened ascending method)	Bracketing procedure	ISO 8253-1 (ascending method)	ISO 8253-1
Number of subjects	Males, 210; Females, 280	Males, 295; Females, 524	Males, 86; Females, 269	Males, 85; Females, 210	Males, 262; Females, 364
Age range years	18 to 79	18 to 89	48 to 65	70 to 96	15 to 34
Exclusion criteria	Otoscopy, tympanometry, extensive exposure to loud sounds in the workplace or in daily life, history of severe ear disease or injury, familial hearing loss, unbalanced threshold between left and right ears	Acute ear disease, exposition to considerable noise before the test, sudden hearing loss, ear operations, frequently recurrent otitis media in the past, excessive ear wax, asymmetric thresholds, less than a good to excellent health status and tinnitus, noise exposition during occupation and leisure time	History of otologic disorder, noise exposure, cardiovascular disease, ototoxic drug use or smoking; family history of hearing loss, abnormal middle ear function	Conductive hearing loss, mixed hearing loss, non-age-related sensorineural hearing loss, asymmetric sensorineural hearing loss, unreliable subjects, otologic background, ototoxic exposure, occupational noise exposure, leisure noise exposure	Occluded or abnormal external auditory meatus; abnormal tympanic membrane appearance; middle ear dysfunction; active ear infection; history of middle ear dysfunction, impulse noise exposure, head trauma, significant health problems, occupational noise exposure or passive/non participational exposure to other loud environments; noise exposure prior to test; pre-existing hearing loss; birth trauma; family history; exposure to ototoxic drugs or solvents; cognitive impairment; audiometric air-bone gap; PTA protocols not met
Descriptive statistics[a]	Median, mean; 5th, 10th, 15th, 20th, 25th, 75th, 80th, 85th, 90th, 95th percentiles	Median, mean; 10th, 25th, 75th, 90th percentiles	Median and mean	s_u and s_l according to ISO 7029:2000	Median, 75th and 90th percentiles

[a] Statistics adopted for the calculation in this document.

Table F.2 — Investigations of hearing thresholds for audiometric frequencies from 9 000 Hz to 12 500 Hz

Investigation	Reference [16]	Reference [19]
Years of measurement	2006 to 2008	1998 to 2002
Country	Japan	Norway
Measurement frequencies[a] Hz	9 000, 10 000, 11 200, 12 500	9 000, 10 000, 11 200, 12 500
Earphones and calibration	ISO 389-5 (HDA 200)	ISO 389-5 (HDA 200)
Measurement method	ISO 8253-1 (bracketing method)	ISO 8253-1 (ascending method)
Number of subjects	Males, 210; Females, 280	Males, 17; Females, 43
Age range[b] years	20 to 79	60 to 84
Exclusion criteria	Otoscopy, tympanometry, extensive exposure to loud sounds in the workplace or in daily life, history of severe ear disease or injury, familial hearing loss, unbalanced threshold between left and right ears	State of health, all signs and symptoms of ear disease, obstructing wax in the ear canals, history of undue exposure to noise or ototoxic drugs, any familial hearing loss, scarring of the tympanic membrane
Descriptive statistics[c]	Median	Median

[a] Frequencies adopted for the calculation in this document.

[b] Age range adopted for the calculation in this document.

[c] Statistics adopted for the calculation in this document.

Annex G
(informative)

Dispersion of source data around the expected median of hearing thresholds

G.1 General

Descriptive statistics of hearing thresholds in this document have been derived from audiometric data sets of investigations shown in Tables F.1 and F.2. Since the statistics (i.e. medians and statistical distributions above and below the medians) were derived from comprehensive analyses of the source data, individual data scattered around the statistical values.

This annex provides root-mean-squared errors (RMSE) of the source data about the medians of hearing thresholds for selected frequencies from 125 Hz to 8 000 Hz. The RMSE values serve as a basis for estimating uncertainty of the statistical values.

G.2 Calculation of RMSE values

The RMSE S_{md} of median hearing thresholds of source data around the expected median $\Delta H_{\mathrm{md},Y}$ was calculated for each audiometric frequency from 125 Hz to 8 000 Hz, using Formula (G.1):

$$S_{\mathrm{md}} = \sqrt{\frac{1}{\mathrm{n}} \sum_{Y} \left(\Delta h_{\mathrm{md},Y} - \Delta H_{\mathrm{md},Y} \right)^2} \qquad \text{(G.1)}$$

where

$\Delta h_{\mathrm{md},Y}$ is the deviation of median hearing threshold at the age of Y from the median at the age of 18, in decibels, in individual set of source data;

n is the number of the medians in the data sets used for calculation.

The range of Y in Formula (G.1) was from 18 years to 80 years for frequencies from 125 Hz to 2 000 Hz and from 18 years to 70 years for frequencies from 3 000 Hz to 8 000 Hz. The calculated RMSE values are shown in Table G.1.

Table G.1 — Values of RMSE S_{md} for selected frequencies from 125 Hz to 8 000 Hz

Frequency Hz	**125**	**250**	**500**	**1 000**	**2 000**	**4 000**	**8 000**
S_{md} **for males** dB	2,1	2,0	2,5	3,0	3,2	4,1	4,2
S_{md} **for females** dB	2,1	2,2	2,4	1,7	2,1	1,6	3,7

Bibliography

[1] ISO 389-1:1998, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 1: Reference equivalent threshold sound pressure levels for pure tones and supra-aural earphones*

[2] ISO 389-2, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 2: Reference equivalent threshold sound pressure levels for pure tones and insert earphones*

[3] ISO 389-5, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 5: Reference equivalent threshold sound pressure levels for pure tones in the frequency range 8 kHz to 16 kHz*

[4] ISO 389-8, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 8: Reference equivalent threshold sound pressure levels for pure tones and circumaural earphones*

[5] ISO 1999:2013, *Acoustics — Estimation of noise-induced hearing loss*

[6] ISO 8253-1:2010, *Acoustics — Audiometric test methods — Part 1: Pure-tone air and bone conduction audiometry*

[7] ISO 8253-2, *Acoustics — Audiometric test methods — Part 2: Sound field audiometry with pure-tone and narrow-band test signals*

[8] ISO 28961, *Acoustics — Statistical distribution of hearing thresholds of otologically normal persons in the age range from 18 years to 25 years under free-field listening conditions*

[9] IEC 60645-1, *Electroacoustics — Audiometric equipment — Part 1: Equipment for pure-tone audiometry*

[10] ANSI S 3.6:1989, *Specifications for audiometers*

[11] DAVIS A.C. Hearing in adults. Whurr Publishers Ltd, 1995

[12] TSUIKI T., SASAMORI S., MINAMI Y., ICHINOHE T., MURAI K., MURAI S., KAWASHIMA H. *Age effect on hearing a study on Japanese. Audiol. Jpn.* 2002, 45 pp. 241–250

[13] ENGDAHL B., TAMBS K., BORCHGREVINK H.M., HOFFMAN H.J. *Screened and unscreened hearing threshold levels for the adult population: Results from the Nord-Trøndelag Hearing Loss Study. Int. J. Audiol.* 2005, 44 pp. 213–230

[14] KURAKATA K., MIZUNAMI T., MATSUSHITA K. *Pure-tone audiometric thresholds of young and older adults. Acoust. Sci. Technol.* 2006, 27 pp. 114–116

[15] KURAKATA K., MIZUNAMI T., MATSUSHITA K. *Pure-tone air conduction thresholds of Japanese high-school students. Acoust. Sci. Technol.* 2010, 31 pp. 403–407

[16] KURAKATA K., MIZUNAMI T., MATSUSHITA K., SHIRAISHI K. *Air conduction hearing thresholds of young and older Japanese adults for pure tones from 125 Hz to 16 kHz. Acoust. Sci. Technol.* 2011, 32 pp. 16–22

[17] VON GABLENZ P., HOLUBE I. *Hearing threshold distribution and effect of screening in a population-based German sample. Int. J. Audiol.* 2016, 55 pp. 110–125

[18] WILEY T.L., TORRE P.III, CRUICKSHANKS K.J., NONDAHL D.M., TWEED T.S. *Hearing sensitivity in adults screened for selected risk factors. J. Am. Acad. Audiol.* 2001, 12 pp. 337–347

[19] STENKLEV N.C., LAUKLI E. *Presbyacusis-hearing thresholds and the ISO 7029. Int. J. Audiol.* 2004, 43 pp. 295–306

[20] BLANCHET C., POMMIE C., MONDAIN M., BERR C., HILLAIRE D., PUEL J.L. Pure -tone threshold description of an elderly French screened population. *Otol. Neurotol.* 2008, 29 pp. 432–440

[21] WILLIAMS W., CARTER L., SEETO M. Hearing threshold levels for a population of 11 to 35 year old Australian females and males. *Int. J. Audiol.* 2014, 53 pp. 289–293

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