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Acoustics — Normal equal-loudness-level contours

Acoustique — Lignes isosoniques normales

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Contents

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*.

This third edition cancels and replaces the second edition (ISO 226:2003), which has been technically revised.

The main changes are as follows:

— clarification of the scope in the introduction;

— updated bibliography;

— alignment with ISO 389-7 regarding the 0 phon data;

— correction of systematic errors that lead to minor changes in the entire data up to 0,6 dB.

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

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Introduction

Curves defining combinations of pure tones in terms of frequency and sound pressure level, which are perceived as equally loud, express a fundamental property of the human auditory system and are of basic importance in the field of psychoacoustics. Such equal-loudness-level contours were specified in the previous editions of this document.

NOTE 1 In this International Standard, only the equal-loudness-level contours for pure tones are specified because of insufficient equal-loudness-level data for other sounds. Nevertheless, this International Standard could be applicable to one-third-octave or narrower bands of noise. It may be less valid for broader bands of noises or noises with prominent tones.

NOTE 2 For the calculation of loudness of arbitrary signals or the calculation of the tonal loudness other standards must be applied (e.g., for loudness of arbitrary stationary and non-stationary (time-varying) sounds: ISO 532-1,[1][2] for loudness of arbitrary stationary sounds: ISO 532-2,[2][3] for tonal loudness and tonality: ECMA-418–2[3][4]). The tonal loudness is the loudness of the tonal components of a complex sound as the basis for the tonality calculation in[3] Reference [4].

During the technical revision of this document, it was decided to maintain separate documents for the specification of the threshold and supra-threshold data. The threshold values are specified in ISO 389-7,[4][1] as a part of the series of International Standards concerning reference zero values for the calibration of audiometric equipment. The equal-loudness-level contours are presented in this document.

NOTE 3 The equal-loudness-level values given by this document differ from those of the previous edition of ISO 226:2003, although the differences are small, i.e., up to 0,6 dB for the entire range of data. This change was caused by the application of an improved model for the perception of loudness as described in Reference [5]. The normal equal-loudness-level contours for pure tones in this document are essentially identical to those described in Reference [5] since both are based on the same equal-loudness-level data. The only difference is the low equal-loudness levels at 20 Hz caused by the revision of ISO 389-7 in 2019, which introduced a 0,4 dB change in the normative hearing threshold at that frequency.

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Acoustics — Normal equal-loudness-level contours

1 Scope

This document specifies combinations of sound pressure levels and frequencies of pure continuous tones which are perceived as equally loud by human listeners. The specifications are based on the following conditions:

a) the sound field in the absence of the listener consists of a free progressive plane wave;

b) the source of sound is directly in front of the listener;

c) the sound signals are pure tones;

d) the sound pressure level is measured at the position where the centre of the listener's head would be, but in the absence of the listener;

e) listening is binaural;

f) the listeners are otologically normal persons in the age range from 18 years to 25 years inclusive.

The data are given in graphical form in Annex A and in numerical form in Annex B for the preferred frequencies in the one-third-octave series from 20 Hz to 12 500 Hz, inclusive, in accordance with ISO 266.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~ISO 266, *Acoustics — Preferred frequencies*~~

ISO 266, *Acoustics — Preferred frequencies*

3 Terms and definitions

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

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

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

— IEC Electropedia: available at ~~https://www.electropedia.org/~~https://www.electropedia.org/

3.1
otologically normal person

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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 canals, and who has no history of undue exposure to noise, exposure to potentially ototoxic drugs or familial hearing loss

3.2
free field
sound field where the boundaries of the room exert a negligible effect on the sound waves

3.3
loudness level
value in phons that has the same numerical value as the sound pressure level in decibels of a reference sound, consisting of a frontally incident, free sinusoidal plane wave ~~(3.2)~~ at a frequency of 1 000 Hz, which is judged as loud as the given sound

3.4
equal-loudness relationship
curve or function expressing, for a pure tone of a given frequency, the relationship between its *loudness level* (3.3) and its sound pressure level

3.5
equal-loudness-level contour
curve in the sound pressure level/frequency plane connecting points whose coordinates represent pure tones judged to be equally loud

3.6
normal equal-loudness-level contour
equal-loudness-level contour (3.5) that represents the average judgment of *otologically normal persons* (3.1) within the age limits from 18 years to 25 years inclusive

Note 1 to entry: The method for deriving the normal equal-loudness-level contours is described in Annex C.

3.7
threshold of hearing
level of a sound at which, under specified conditions, a person gives 50 % of correct detection responses on repeated trials

4 Formula for derivation of normal equal-loudness-level contours

4.1 Deriving sound pressure level from loudness level

The sound pressure level L_f in dB of a pure tone of frequency, f, which has a loudness level, L_N, in phon, is given by Formula (1) [see also Formula (C.3)]:

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$$L_f = \frac{10}{\alpha_f}\cdot\lg\left(\left(\left(\frac{p_o}{p_a}\right)^2\right)^{(\alpha_r-\alpha_f)}\cdot\left(10^{\left(\alpha_r\frac{L_N}{10\,\text{phon}}\right)}-10^{\left(\alpha_r\frac{T_r}{10\,\text{dB}}\right)}\right)+10^{\left(\alpha_f\frac{T_f+L_U}{10\,\text{dB}}\right)}\right)\text{dB}-L_U$$

$$=\frac{10}{\alpha_f}\cdot\lg\left(\left(4\cdot10^{-10}\right)^{(0{,}3-\alpha_f)}\cdot\left(10^{\left(0{,}03\frac{L_N}{10\,\text{phon}}\right)}-10^{0{,}072}\right)+10^{\left(\alpha_f\frac{T_f+L_U}{10\,\text{dB}}\right)}\right)\text{dB}-L_U$$

$$L_f = \frac{10}{\alpha_f}\cdot\lg\left\{\left[\left(\frac{p_o}{p_a}\right)^2\right]^{(\alpha_r-\alpha_f)}\cdot\left[10^{\left(\alpha_r\frac{L_N}{10\,\text{phon}}\right)}-10^{\left(\alpha_r\frac{T_r}{10\,\text{dB}}\right)}\right]+10^{\left(\alpha_f\frac{T_f+L_U}{10\,\text{dB}}\right)}\right\}\text{dB}-L_U$$

$$=\frac{10}{\alpha_f}\cdot\lg\left\{\left(4\cdot10^{-10}\right)^{(0{,}3-\alpha_f)}\cdot\left[10^{\left(0{,}03\frac{L_N}{10\,\text{phon}}\right)}-10^{0{,}072}\right]+10^{\left(\alpha_f\frac{T_f+L_U}{10\,\text{dB}}\right)}\right\}\text{dB}-L_U \quad (1)$$

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where

T_f is the threshold of hearing in dB as in Reference [41];

T_r is the threshold of hearing at 1 000 Hz in dB;

α_f is the exponent for loudness perception;

α_r is the exponent for loudness perception at 1 000 Hz;

L_U is a magnitude of the linear transfer function normalized at 1 000 Hz in dB

p_0 is 20 µPa.

These values are all given in Table 1 for the preferred third-octave frequencies defined in ISO 266.

Formula (1) applies, at each frequency, for values from a lower limit of 20 phon to the following upper limits:

20 Hz to 4 000 Hz: 90 phon

5 000 Hz to 12 500 Hz: 80 phon

Formula (1) is only informative for loudness levels below 20 phon because of the lack of experimental data between 20 phon and the hearing thresholds. The same holds for loudness levels above 90 phon up to 100 phon from 20 Hz to 1 000 Hz because data from only one institute are available at 100 phon.

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4.2 Deriving loudness levels from sound pressure levels

The loudness level L_N in phon of a pure tone of frequency f, which has a sound pressure level L_f in dB, is given by Formula (2):

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~~$$L_N = \frac{100}{3} \lg \left[\frac{10^{\left(\alpha_f \frac{L_f + L_U}{10\,\mathrm{dB}}\right)} - 10^{\left(\alpha_f \frac{T_f + L_U}{10\,\mathrm{dB}}\right)}}{\left(4 \cdot 10^{-10}\right)^{(0{,}3 - \alpha_f)}} + 10^{0{,}072} \right] \text{phon}$$~~

$$L_N = \frac{100}{3} \cdot \lg \left[\frac{10^{\left(\alpha_f \frac{L_f + L_U}{10\,\mathrm{dB}}\right)} - 10^{\left(\alpha_f \frac{T_f + L_U}{10\,\mathrm{dB}}\right)}}{\left(4 \cdot 10^{-10}\right)^{(0{,}3 - \alpha_f)}} + 10^{0{,}072} \right] \text{phon} \qquad (2)$$

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where T_f, α_f and L_U are the same as in 4.1.

The same restrictions, which apply to Formula (1), also apply to Formula (2).

Table 1 — Parameters of Formula (1) used to calculate the normal equal-loudness-level contours

Frequency, f Hz	α_f	L_U dB	T_f dB
20	0,635	−31,5	78,1
25	0,602	−27,2	68,7
31,5	0,569	−23,1	59,5
40	0,537	−19,3	51,1
50	0,509	−16,1	44,0
63	0,482	−13,1	37,5
80	0,456	−10,4	31,5
100	0,433	−8,2	26,5
125	0,412	−6,3	22,1
160	0,391	−4,6	17,9
200	0,373	−3,2	14,4
250	0,357	−2,1	11,4
315	0,343	−1,2	8,6
400	0,330	−0,5	6,2
500	0,320	0,0	4,4
630	0,311	0,4	3,0
800	0,303	0,5	2,2

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1 000	0,300	0,0	2,4
1 250	0,295	−2,7	3,5
1 600	0,292	−4,2	1,7
2 000	0,290	−1,2	−1,3
2 500	0,290	1,4	−4,2
3 150	0,289	2,3	−6,0
4 000	0,289	1,0	-5,4
5 000	0,289	−2,3	−1,5
6 300	0,293	−7,2	6,0
8 000	0,303	−11,2	12,6
10 000	0,323	−10,9	13,9
12 500	0,354	−3,5	12,3

The data are given in graphical form in Annex A and in numerical form in Annex B for the preferred frequencies in the one-third-octave series from 20 Hz to 12 500 Hz, inclusive, in accordance with ISO 266.

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Annex A
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Normal equal-loudness-level contours for pure tones under free-field listening conditions

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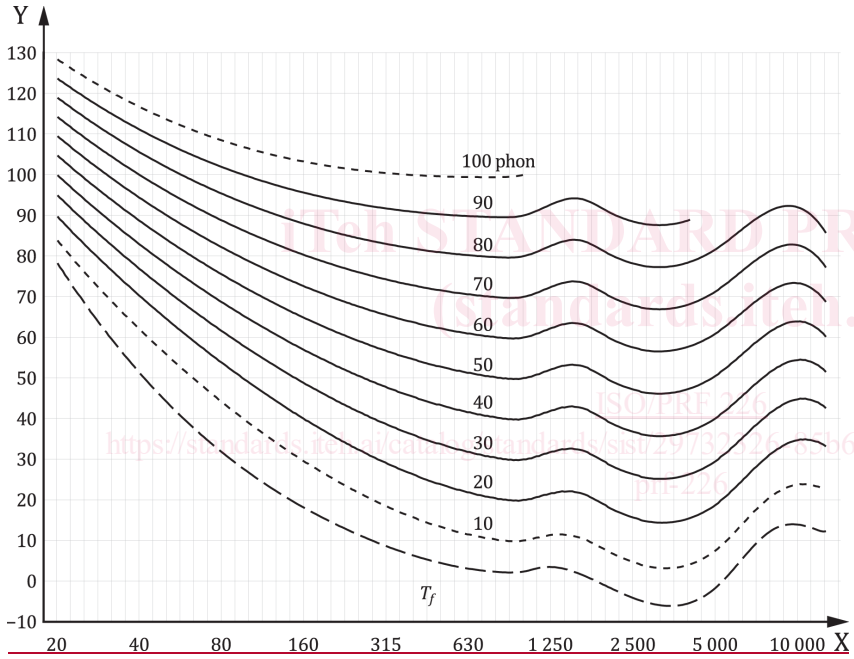

Key

X frequency, expressed in Hz

Y sound pressure level, expressed in dB

T_f hearing threshold

NOTE 1 The hearing threshold under free-field listening condition, T_f, is indicated by a dashed line as defined in ISO 389-7[41].

NOTE 2 The contour at 10 phon is drawn by dotted lines because of the lack of experimental data between 20 phon and the hearing thresholds. Moreover, the 100-phon contour is also described by a dotted line because data from only one institute are available at this loudness level.

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