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Acoustics — Normal equal-loudness-level contours

Acoustique — Lignes isosoniques normales

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Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 226 was prepared by Technical Committee ISO/TC 43, *Acoustics*.

This second edition cancels and replaces the first edition (ISO 226:1987), which has been technically revised.

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. Together with data on the threshold of hearing under free-field and diffuse-field listening conditions, such equal-loudness-level contours were specified in ISO 226:1987.

NOTE 1 Equal-loudness levels can also be determined for bands of noise. However, only the equal-loudness-level contours for pure tones are specified in this International Standard because insufficient data for bands of noise are available. Nevertheless, this International Standard could be applicable to one-third-octave-bands of noise.

During the technical revision of this International Standard, it was decided to separate threshold and supra-threshold data into two separate documents because the available equal-loudness-level data were not sufficient and hearing thresholds were needed. The threshold values were specified in ISO 389-7:1996, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions*, 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 International Standard. They have been revised relative to the data in ISO 226:1987.

NOTE 2 ISO 389-7:1996 is presently under revision in order to align the threshold data with this edition of ISO 226.

Acoustics — Normal equal-loudness-level contours

1 Scope

This International Standard 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 266, *Acoustics — Preferred frequencies*

3 Terms and definitions

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

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

3.2
free sound 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, sinusoidal plane progressive wave 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 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 that represents the average judgment of otologically normal persons within the age limits from 18 years to 25 years inclusive

NOTE 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_p of a pure tone of frequency f, which has a loudness level L_N, is given by:

$$L_p = \left(\frac{10}{\alpha_f} \cdot \lg A_f \right) \text{dB} - L_U + 94 \text{ dB} \qquad (1)$$

where

$$A_f = 4{,}47 \times 10^{-3} \times (10^{0{,}025 L_N} - 1{,}15) + \left[0{,}4 \times 10^{\left(\frac{T_f + L_U}{10} - 9 \right)} \right]^{\alpha_f}$$

T_f is the threshold of hearing;

α_f is the exponent for loudness perception;

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

These values are all given in Table 1.

Equation (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

Equation (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.

4.2 Deriving loudness levels from sound pressure levels

The loudness level L_N of a pure tone of frequency f, which has a sound pressure level L_p, is given by:

$$L_N = \left(40 \cdot \lg B_f\right) \text{phon} + 94 \text{ phon} \tag{2}$$

where

$$B_f = \left[0{,}4 \times 10^{\left(\frac{L_p + L_U}{10} - 9\right)}\right]^{\alpha_f} - \left[0{,}4 \times 10^{\left(\frac{T_f + L_U}{10} - 9\right)}\right]^{\alpha_f} + 0{,}005\,135$$

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

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

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

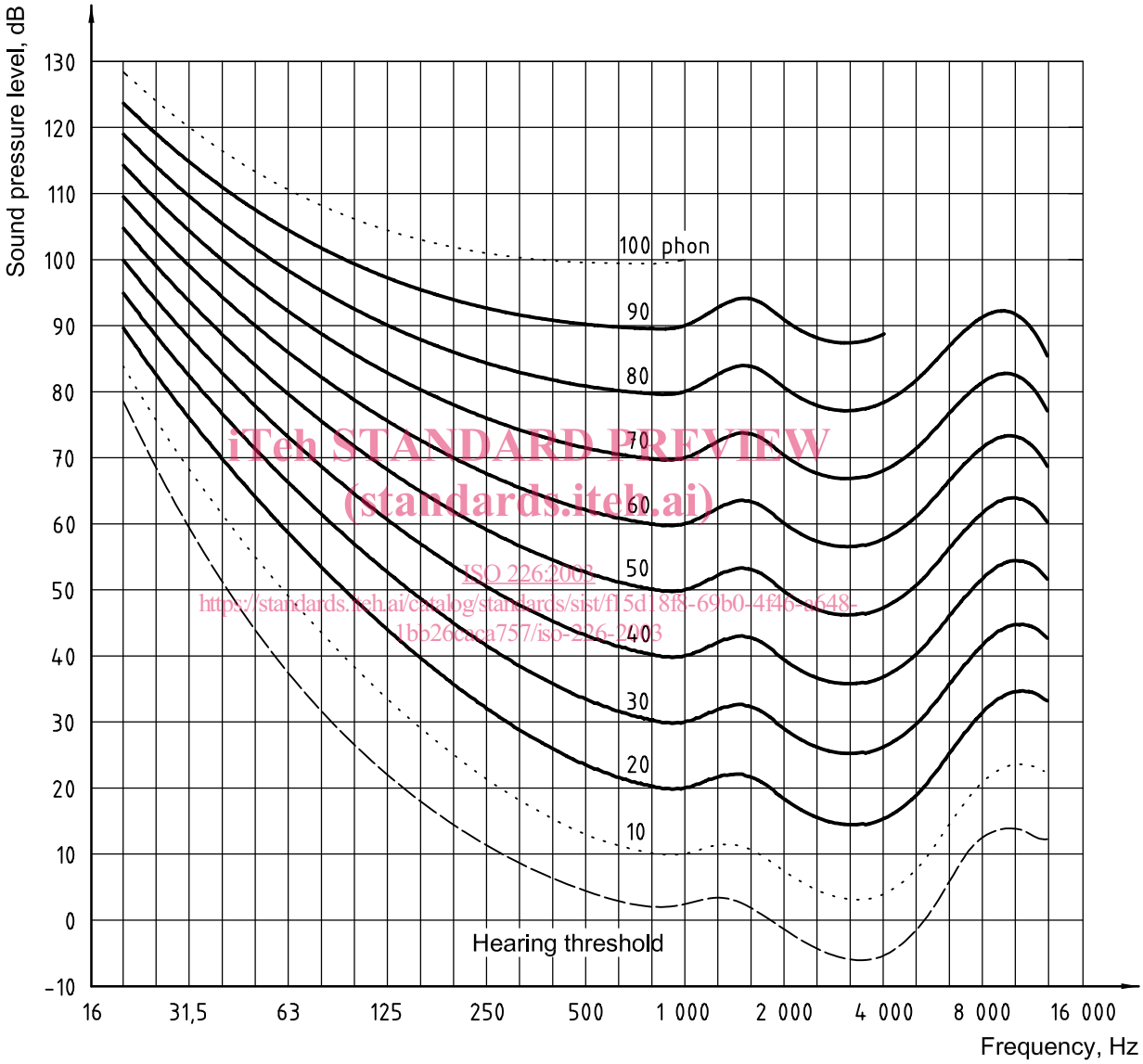
Frequency, f Hz	α_f	L_U dB	T_f dB
20	0,532	−31,6	78,5
25	0,506	−27,2	68,7
31,5	0,480	−23,0	59,5
40	0,455	−19,1	51,1
50	0,432	−15,9	44,0
63	0,409	−13,0	37,5
80	0,387	−10,3	31,5
100	0,367	−8,1	26,5
125	0,349	−6,2	22,1
160	0,330	−4,5	17,9
200	0,315	−3,1	14,4
250	0,301	−2,0	11,4
315	0,288	−1,1	8,6
400	0,276	−0,4	6,2
500	0,267	0,0	4,4
630	0,259	0,3	3,0
800	0,253	0,5	2,2
1 000	0,250	0,0	2,4

Table 1 (*continued*)

Frequency, f Hz	α_f	L_U dB	T_f dB
1 250	0,246	–2,7	3,5
1 600	0,244	–4,1	1,7
2 000	0,243	–1,0	–1,3
2 500	0,243	1,7	–4,2
3 150	0,243	2,5	–6,0
4 000	0,242	1,2	–5,4
5 000	0,242	–2,1	–1,5
6 300	0,245	–7,1	6,0
8 000	0,254	–11,2	12,6
10 000	0,271	–10,7	13,9
12 500	0,301	–3,1	12,3

Annex A
(normative)

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



NOTE 1 The hearing threshold under free-field listening condition, T_f, is indicated by a dashed line.

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.

Figure A.1 — Normal equal-loudness-level contours for pure tones
(binaural free-field listening, frontal incidence)