

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 being 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 derivating 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:

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

where

$$A_f = 4,47 \times 10^{-3} \times (10^{0,025L_N} - 1,14) + \left[0,4 \times 10^{\left(\frac{T_f + L_U}{10} - 9 \right)} \right]^{\alpha_f}$$

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 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:

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

where

$$B_f = \left[0,4 \times 10^{\left(\frac{L_p + L_U}{10} - 9 \right)} \right]^{\alpha_f} - \left[0,4 \times 10^{\left(\frac{T_f + L_U}{10} - 9 \right)} \right]^{\alpha_f} + 0,005\,076$$

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

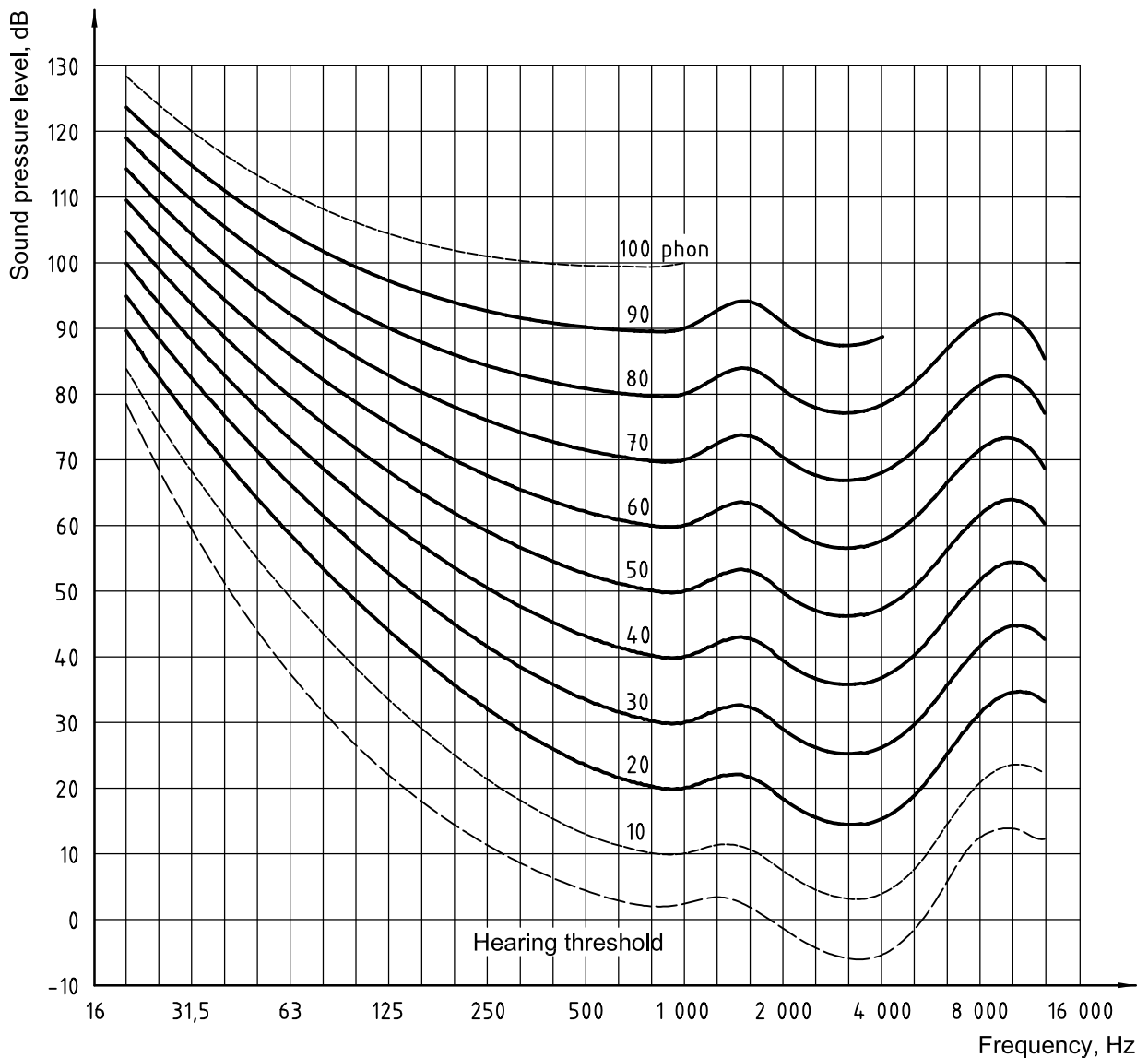
Frequency, f Hz	α_f	L_U dB	T_f dB
20	0,532	-31,6	78,5
25	0,506	-27,2	68,7
31,5	0,480	-23,0	59,5
40	0,455	-19,1	51,1
50	0,432	-15,9	44,0
63	0,409	-13,0	37,5
80	0,387	-10,3	31,5
100	0,367	-8,1	26,5
125	0,349	-6,2	22,1
160	0,330	-4,5	17,9
200	0,315	-3,1	14,4
250	0,301	-2,0	11,4
315	0,288	-1,1	8,6
400	0,276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