

ISO

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO RECOMMENDATION R 226

NORMAL EQUAL-LOUDNESS CONTOURS FOR PURE TONES
AND NORMAL THRESHOLD OF HEARING
UNDER FREE FIELD LISTENING CONDITIONS

1st EDITION

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BRIEF HISTORY

The ISO Recommendation R 226, *Normal Equal-Loudness Contours for Pure Tones and Normal Threshold of Hearing Under Free Field Listening Conditions*, was drawn up by Technical Committee ISO/TC 43, *Acoustics*, the Secretariat of which is held by the British Standards Institution (B.S.I.).

Work on this question by the Technical Committee began in 1957 and led, in 1959, to the adoption of a Draft ISO Recommendation.

In December 1959, this Draft ISO Recommendation (No. 352) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies:

Austria	India	Romania
Belgium	Ireland	Spain
Burma	Italy	Sweden
Chile	Mexico	Switzerland
Colombia	Netherlands	United Kingdom
Czechoslovakia	New Zealand	U.S.A.
Denmark	Norway	U.S.S.R.
France	Poland	Yugoslavia
Hungary	Portugal	

One Member Body opposed the approval of the Draft: Germany.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in December 1961, to accept it as an ISO RECOMMENDATION.

**NORMAL EQUAL-LOUDNESS CONTOURS FOR PURE TONES
AND NORMAL THRESHOLD OF HEARING
UNDER FREE FIELD LISTENING CONDITIONS**

FOREWORD

Curves defining relations between frequencies of sounds and their sound pressure levels for the condition of constant loudness, i.e. "equal-loudness contours", are involved in many aspects of subjective acoustics. They are fundamental to a proper understanding of the function of the human ear in the perception of loudness. They also have important practical applications, for example in the development of methods of computing loudness from the physical properties of sounds.

The following ISO Recommendation specifies the equal-loudness contours and threshold of hearing for continuous sinusoidal tones for subjects of normal hearing under the conditions of binaural listening in free progressive plane waves, with the subject directly facing the source of sound.

It is emphasized that, since the contours here recommended relate only to pure tones presented in a specified manner in free field, they are not directly applicable to other types of sounds (e.g. bands of noise) or to other types of stimulus presentation (e.g. by earphone or with random incidence).

For these other types of sounds and other methods of presentation, contours appropriate to the circumstances will be needed, and may be issued as further data become available.

1. SCOPE

This ISO Recommendation specifies, for the frequency range 20 to 15 000 Hz (c/s) * and for the conditions stated below:

- 1.1 The normal relations existing between sound pressure level and frequency for pure tones of equal loudness.
- 1.2 Values for the normal threshold of hearing (normal binaural minimum audible field or MAF).

Conditions of applicability:

- (a) The source of sound is directly ahead of the listener;
- (b) The sound reaches the listener in the form of a free progressive plane wave;
- (c) The sound pressure level is measured in the absence of the listener;
- (d) The listening is binaural;
- (e) The listeners are otologically normal persons in the age group 18 to 25 years inclusive.

NOTE. Appendix B presents correction formulae to be applied to the above data in respect of otologically normal persons of other ages up to 60 years.

2. EXPLANATION OF TERMS

For the purpose of this ISO Recommendation, the following terms are employed, the pure tone, and the conditions of applicability stated in clause 1.2 being understood where appropriate.

- 2.1 *Equal-loudness relation*. A curve or function expressing, for a pure tone of given frequency, the relation between its loudness level, expressed in phons, and its sound pressure level, expressed in decibels.
- 2.2 *Equal-loudness contour*. A curve in the sound pressure level/frequency plane, connecting points whose co-ordinates represent pure tones judged equally loud.
- 2.3 *Normal equal-loudness relation (contour)*. The equal-loudness relation (contour) corresponding to the judgments of otologically normal subjects within the age limits 18 to 25 years inclusive.
- 2.4 *Threshold of hearing (binaural minimum audible field)*. For a given person at a specified frequency, the minimum value of the sound pressure level which excites the sensation of hearing.
- 2.5 *Normal threshold of hearing (normal binaural minimum audible field or MAF)*. At a specified frequency, the value of the threshold of hearing corresponding to the judgments of otologically normal subjects within the age limits 18 to 25 years inclusive.

NOTE. An "otologically normal subject" is understood to be a person in a normal state of health who is free from all signs or symptoms of ear disease and from wax in the ear canal.

* Hz (Hertz): International use
c/s (cycles per second): Used in United Kingdom and U.S.A.

3. SPECIFICATION

The recommended normal equal-loudness contours and the recommended normal threshold of hearing (normal binaural minimum audible field or MAF) are presented in graphical form in Figure 1.

NOTE. Further information concerning the method of derivation of the recommended equal-loudness contours, and correction formulae for the effects of the age of listeners, are given, for information only, in the Appendices to this ISO Recommendation. Appendix A, Table A-1, also includes a tabular version of the normal threshold contour.

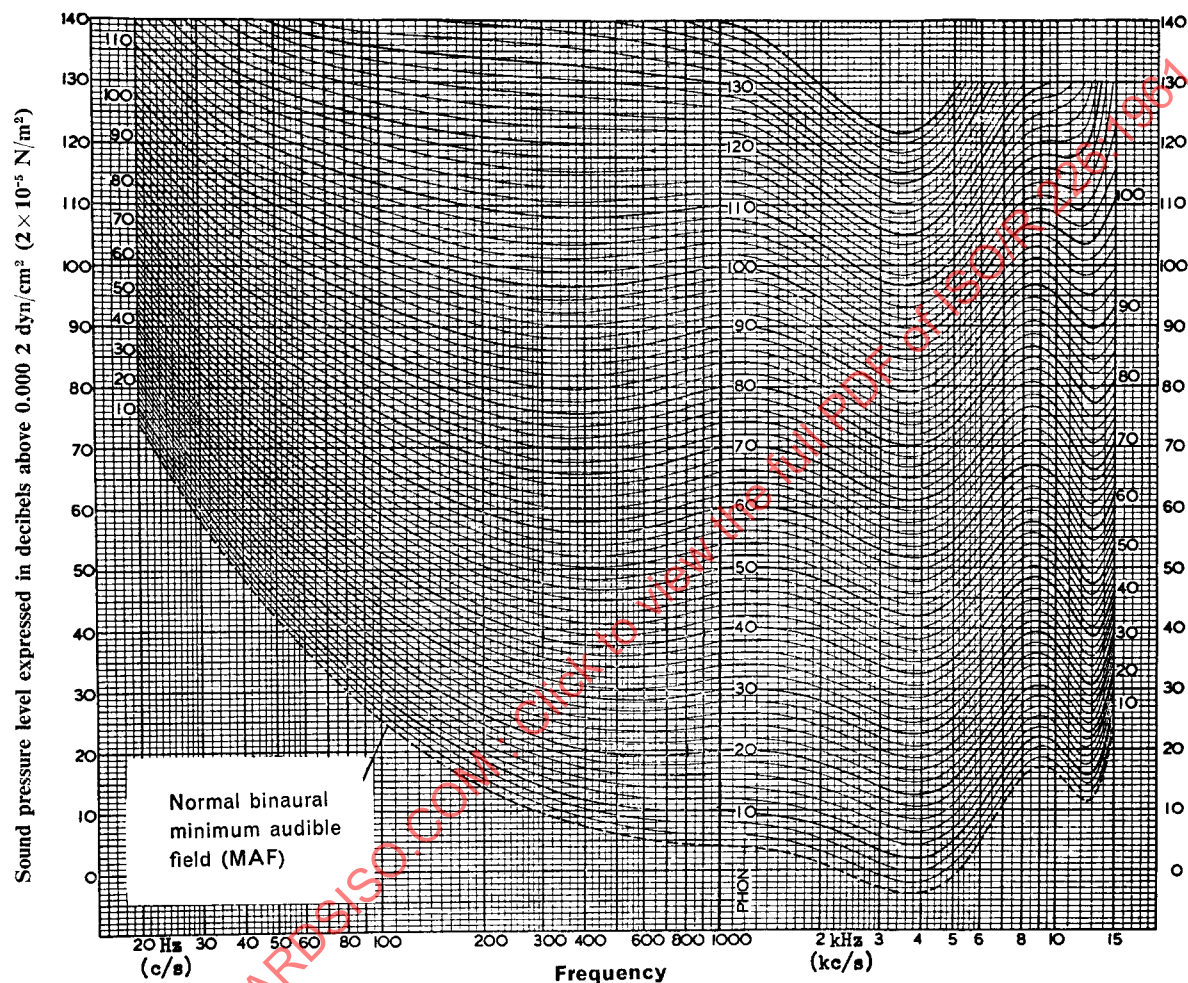


FIG. 1. — Normal equal-loudness contours for pure tones (Binaural free-field listening)

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APPENDIX A
(for information only)

Method of derivation of recommended normal equal-loudness contours

In the derivation of the normal equal-loudness contours presented in section 3 above, the following procedure has been adopted:

(a) The normal equal-loudness relations have been expressed by formulae of the type:

$$y = a + bx + cx^2$$

where x is the sound pressure level of the pure tone of frequency f ,
 y is the loudness level in phons of a pure tone of frequency f and sound pressure level x , and
 a , b and c are functions of the frequency f .

TABLE A-1

Frequency	a	b	c	Normal threshold sound pressure level, t	Frequency
Hz (c/s)				dB	Hz (c/s)
20	-217.2	3.669	-0.009 27	+74.3	20
25	-167.2	3.145	7 82	65.0	25
30	-135.7	2.801	6 77	58.1	30
35	-113.2	2.538	5 89	52.7	35
40	-96.3	2.325	5 15	48.4	40
45	-83.2	2.154	4 54	44.8	45
50	-73.0	2.021	4 07	41.7	50
55	-65.1	1.918	3 70	39.1	55
60	-58.7	1.836	-0.003 41	+36.8	60
60	-58.7	1.836	-0.003 41	+36.8	60
70	-49.1	1.723	3 05	32.9	70
80	-42.5	1.652	2 85	29.8	80
90	-37.4	1.603	2 74	27.2	90
100	-33.5	1.570	-0.002 69	+25.1	100
100	-33.5	1.570	-0.002 69	+25.1	100
120	-27.0	1.512	2 60	21.4	120
140	-22.7	1.473	2 53	18.9	140
160	-19.4	1.444	2 48	16.8	160
180	-16.9	1.422	2 44	15.2	180
200	-14.7	1.404	-0.002 42	+13.8	200
200	-14.7	1.404	-0.002 42	+13.8	200
250	-10.8	1.362	2 31	11.2	250
300	-8.1	1.325	2 18	9.4	300
350	-6.1	1.290	2 02	8.1	350
400	-4.7	1.259	-0.001 85	+ 7.2	400
400	-4.7	1.259	-0.001 85	+ 7.2	400
500	-3.0	1.205	1 51	6.0	500
600	-1.8	1.155	1 17	5.2	600
700	-1.0	1.109	0 84	4.7	700
800	-0.5	1.064	0 50	4.4	800
900	-0.2	1.028	-0.000 22	4.3	900
1 000	0	1	0	+ 4.2	1 000

(continued overleaf)

TABLE A-1 (concluded)

Frequency	<i>a</i>	<i>b</i>	<i>c</i>	Normal threshold sound pressure level, <i>t</i>	Frequency
Hz (c/s)				dB	Hz (c/s)
1 000	0	1	0	+ 4.2	1 000
1 200	+ 0.5	0.972	+0.000 23	3.9	1 200
1 400	+ 1.1	0.953	0 47	3.4	1 400
1 600	+ 1.7	0.937	0 71	2.6	1 600
1 800	+ 2.5	0.927	0 90	1.8	1 800
2 000	+ 3.3	0.924	+0.001 00	+ 1.0	2 000
2 000	+ 3.3	0.924	+0.001 00	+ 1.0	2 000
2 500	+ 5.3	0.928	1 18	- 1.2	2 500
3 000	+ 6.9	0.937	1 20	- 2.9	3 000
3 500	+ 7.9	0.946	1 13	- 3.9	3 500
4 000	+ 7.9	0.954	0 98	- 3.9	4 000
4 500	+ 7.1	0.963	0 80	- 3.0	4 500
5 000	+ 5.3	0.973	+0.000 59	- 1.1	5 000
5 000	+ 5.3	0.973	+0.000 59	- 1.1	5 000
6 000	- 0.5	1.011	+0.000 14	+ 4.6	6 000
7 000	- 7.5	1.075	-0.000 35	10.9	7 000
8 000	- 13.3	1.159	0 89	15.3	8 000
9 000	- 16.5	1.242	1 45	17.0	9 000
10 000	- 16.8	1.314	2 03	16.4	10 000
11 000	- 14.8	1.377	2 69	14.2	11 000
12 000	- 12.7	1.450	3 50	12.0	12 000
13 000	- 13.9	1.566	4 54	12.0	13 000
14 000	- 22.7	1.777	5 91	16.0	14 000
15 000	- 43.0	2.146	-0.007 72	+24.1	15 000

The values of *a*, *b* and *c* are given in columns 2, 3 and 4 of Table A-1. The spacing of frequencies in the table has been so chosen that linear interpolation will give values of *y* to an accuracy better than 1 phon. The values (*t*) of the normal threshold of hearing are given in column 5.

- (b) The normal equal-loudness contours have been obtained by expressing the data contained in columns 2 to 4 of Table A-1 as continuous functions of the frequency and presenting them as curves of constant loudness level in the sound pressure level/frequency plane.

APPENDIX B

(for information only)

Correction formulae for the age of listeners

The following clauses present the corrections to be applied to the normal equal-loudness relations and MAF values in respect of the age of otologically normal subjects outside the age limits 18 to 25 years. The corrections are given as functions of the frequency and the sound pressure level. They are illustrated graphically in Figure B-1 for typical frequencies.

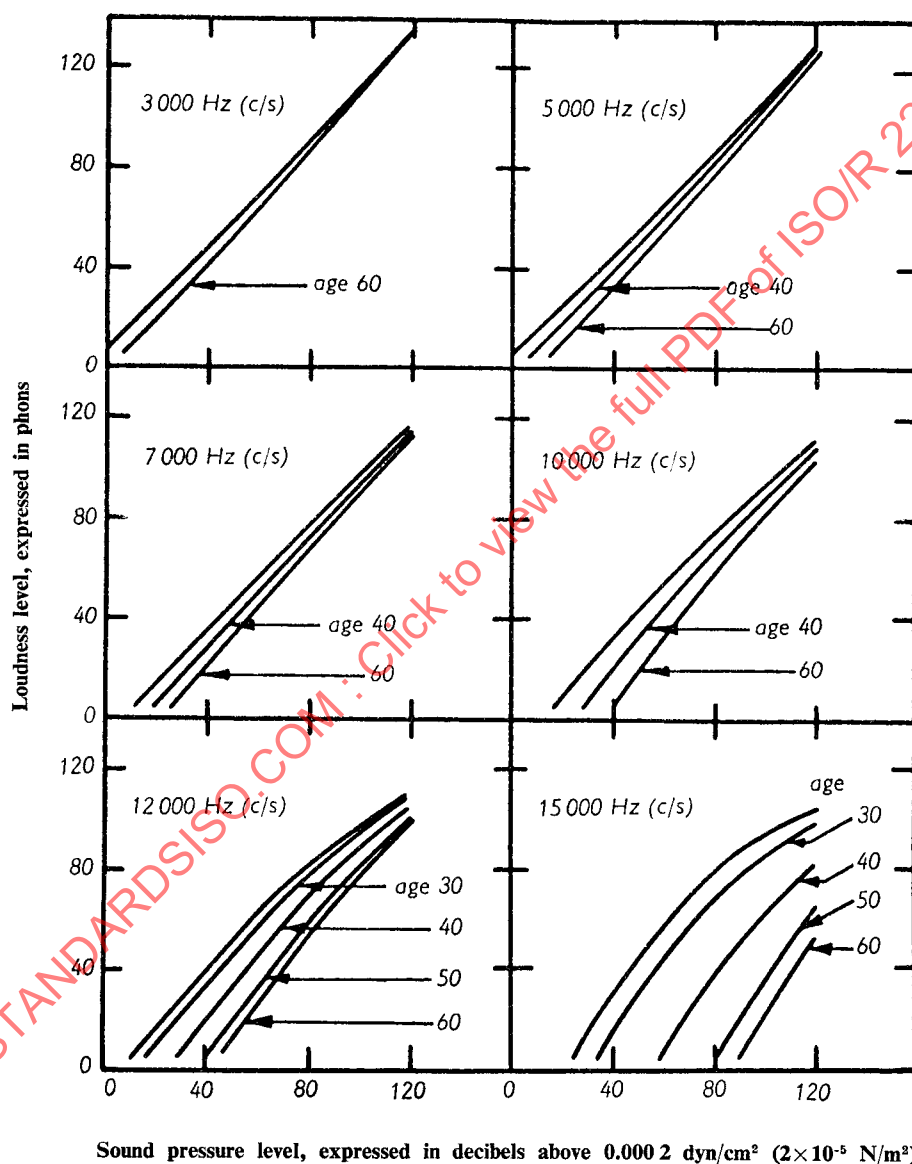


FIG. B-1. — Effect of listeners' age on loudness level of pure tones

The upper curve in each case represents the normal equal-loudness relation (age group 18-25).