INTERNATIONAL STANDARD

ISO 389-3

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Acoustics — Reference zero for the calibration of audiometric equipment —

Part 3:
Reference equivalent threshold force levels for pure tones and bone vibrators

Acoustique — Zéro de référence pour l'étalonnage d'équipements audiométriques —

Partie 3: Niveaux de référence équivalents de force liminaire pour les vibrateurs à sons purs et les ossivibrateurs

Reference number
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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.

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.

International Standard ISO 389-3 was prepared by Technical Committee ISO/TC 43, *Acoustics*.

This first edition of ISO 389-3 cancels and replaces ISO 7566:1987, of which it is a minor revision.

ISO 389 consists of the following parts, under the general title *Acoustics — Reference zero for the calibration of audiometric equipment*:

— *Part 1: Reference equivalent threshold sound pressure levels for pure tones and supra-aural earphones*

— *Part 2: Reference equivalent threshold sound pressure levels for pure tones and insert earphones*

— *Part 3: Reference equivalent threshold force levels for pure tones and bone vibrators*

— *Part 4: Reference levels for narrow-band masking noise*

— *Part 5: Reference equivalent threshold sound pressure levels for pure tones in the frequency range 8 kHz to 16 kHz*

— *Part 6: Reference equivalent threshold sound pressure levels for acoustic test signals of short duration*

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— *Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions*

Part 1 will be a re-issue of ISO 389:1991.

Annexes A, B, C, D and E of this part of ISO 389 are for information only.

Introduction

Each part of ISO 389 specifies a specific reference zero for the calibration of audiometric equipment. ISO 389:1991 (to be re-issued as ISO 389-1) and ISO 389-2 are applicable to audiometric equipment for the transmission of pure tones by air conduction.

For clinical diagnostic and other audiometric purposes, it is often necessary to compare the measured hearing threshold levels of a person for sound transmitted to the inner ear by the air-conduction and bone-conduction pathways, respectively. Bone-conducted sound is provided for this purpose by an electromechanical vibrator applied to the mastoid prominence or to the forehead of the person under test.

The reference zero for the calibration of audiometric equipment for air conduction is defined in ISO 389:1991 and ISO 389-2 in terms of reference equivalent threshold sound pressure levels (RETSPLs), i.e. threshold sound pressure levels produced in a coupler, ear simulator or artificial ear of specified characteristics by supra-aural or insert earphones of various patterns, when excited electrically at a level corresponding to the threshold of hearing of young otologically normal persons. Similarly, this part of ISO 389 provides a reference zero for bone-conduction audiometry in terms of reference equivalent threshold force levels (RETFLs), i.e. the vibratory force levels produced by a bone vibrator on a specified mechanical coupler when the vibrator is excited electrically at a level corresponding to the threshold of hearing of young otologically normal persons. In some countries, the preferred location is the mastoid prominence; in other countries, the forehead location is used in addition to the mastoid prominence. Different RETFL values are valid for each of the two positions (see annex C).

For bone-conduction measurements, it is necessary to specify the static force of application of the vibrator to the skull of the test subject and to the mechanical coupler, as well as certain geometrical features of the vibrator tip. In addition, it is usually necessary to apply masking noise to the ear not under test, since excitation of the skull by the vibrator may be heard by that ear instead of (or in addition to) the ear intended for the test. An appropriate specification of the masking noise is, therefore, required as an adjunct to the reference equivalent threshold force levels, and such a specification is given in this part of ISO 389. Due to the so-called "occlusion effect" whereby the wearing of the transducer needed to provide the (air-conducted) masking noise causes a lowering of the bone-conduction threshold of hearing of the ear receiving the masking signal, it is necessary for the level of masking noise to be raised to cancel out the occlusion effect and provide adequate masking of the ear not under test. The specification of masking noise given in this part of ISO 389 is based on the procedures used in the experimental investigations from which the reference zero of this part of ISO 389 is derived.

Use of this reference zero to calibrate audiometers will ensure that measured bone-conduction hearing threshold levels of persons with un-

impaired hearing or with hearing losses of purely sensorineural type (i.e. having unimpaired outer and middle ear function) will be compatible with the air-conduction hearing threshold levels of the same persons when using the reference zero of ISO 389:1991 or ISO 389-2, respectively. Although exact equivalence of air-conduction and bone-conduction thresholds for any individual in these classes cannot be expected, due to biological variability of sound tansmission through the external and middle ear and through the skull, this part of ISO 389 will ensure that systematic deviations averaged over groups of such persons are reduced to a practical minimum.

This part of ISO 389 is based on an assessment of technical data provided by laboratories in three countries using methods of threshold testing which, in the respects described, were essentially uniform. Examination of the data showed that the experimental results were consistent. It has, therefore, been possible to standardize a reference zero by means of RETFL values which are to be used for all bone vibrators used in audiometry having similar characteristics to those used by the laboratories. The systematic uncertainties introduced by this deliberate simplification will be small in comparison to the usual step size of hearing level controls in clinical audiometers (5 dB).

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Acoustics — Reference zero for the calibration of audiometric equipment —

Part 3:
Reference equivalent threshold force levels for pure tones and bone vibrators

1 Scope

This part of ISO 389 specifies the following data applicable to the calibration of bone vibrators for pure-tone bone-conduction audiometry.

a) Reference equivalent threshold force levels (RETFLs), corresponding to the threshold of hearing of young otologically normal persons by bone-conduction audiometry. RETFL is the vibratory force level transmitted to a mechanical coupler of specified characteristics (see 5.3) by a vibrator when applied to the mechanical coupler under stated conditions of test and when energized at the voltage level corresponding to the normal threshold of hearing for location on the mastoid prominence.

NOTE 1 Interim values for the differences in reference equivalent threshold force levels between location on the forehead and mastoid are included for information in annex C.

b) Essential characteristics of the bone vibrator and of its method of coupling to a person under test and to the mechanical coupler.

c) Essential characteristics and datum level of the masking noise applied to the ear not under test.

Guidance on the practical application of this part of ISO 389 in the calibration of audiometers is given in annex B.

NOTE 2 Recommended procedures for carrying out bone-conduction audiometry are specified in ISO 8253-1.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 389. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 389 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 389:1991, *Acoustics — Standard reference zero for the calibration of pure-tone air conduction audiometers.*[1)]

ISO 389-2:1994, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 2: Reference equivalent threshold sound pressure levels for pure tones and insert earphones.*

IEC 373:1990, *Mechanical coupler for measurements on bone vibrators.*

1) To be re-issued as ISO 389-1.

3 Definitions

For the purposes of this part of ISO 389, the definitions given in ISO 389:1991 and ISO 389-2 and the following definitions apply.

3.1 bone conduction: Transmission of sound to the inner ear primarily by means of mechanical vibration of the cranial bones.

3.2 bone vibrator: Electromechanical transducer intended to produce the sensation of hearing by vibrating the cranial bones.

3.3 alternating force level (force level) (of a vibration)**:** Force level, in decibels, which is 20 times the common logarithm of the ratio of the r.m.s. value of the force transmitting the vibration to the reference value, 1 μN.

3.4 mechanical coupler: Device designed to present a specified mechanical impedance to a bone vibrator applied with a specified static force and equipped with a mechano-electric transducer to determine the alternating force level at the surface of contact between a vibrator and mechanical coupler.

NOTE 3 A mechanical coupler is specified in IEC 373.

3.5 equivalent threshold force level (monaural listening)**:** For a given ear, at a specified frequency, for a specified configuration of bone vibrator and for a stated force of application of the bone vibrator to the human mastoid bone, the alternating force level set up by the bone vibrator on a specified mechanical coupler when the bone vibrator is actuated by that voltage which, with the bone vibrator applied to the mastoid bone concerned, would correspond to the threshold of hearing.

3.6 reference equivalent threshold force level (RETFL): At a specified frequency, the mean value of the equivalent threshold force levels of a sufficiently large number of ears of otologically normal persons, of both sexes, aged between 18 and 30 years inclusive, expressing the threshold of hearing in a specified mechanical coupler for a specified configuration of bone vibrator.

3.7 hearing level (of a pure tone)**:** At a specified frequency, for a specific type of transducer and for a specified manner of application, the alternating force level (or the sound pressure level) of this pure tone, produced by the transducer in a specified mechanical coupler (or acoustic coupler, ear simulator or artificial ear) minus the appropriate reference equivalent threshold force level (or reference equivalent threshold sound pressure level) for bone conduction or air conduction, as applicable.

NOTE 4 By extension, this definition may be applied to a narrow band of noise.

3.8 occlusion effect: Lowering of the hearing threshold level of a given ear, stimulated by bone conduction, when an earphone or earplug is placed over or in the entrance to the ear canal, thereby forming an enclosed air volume in the external ear. The effect is greatest at low frequencies.

3.9 masking:

(1) Process by which the threshold of hearing of a sound is raised by the presence of another (masking) sound.

(2) Amount by which the hearing threshold level is so raised, expressed in decibels.

3.10 datum level of masking noise: Level, expressed as hearing level (see note to 3.7) of a one-third-octave band of noise delivered by air conduction in the presence of which a pure tone at the centre frequency of the noise band and at a hearing level of 35 dB is just audible, on the basis of 50 % detection in repeated trials by an otologically normal person, having zero hearing threshold level by air conduction for that pure tone.

NOTES

5 The value of 35 dB has been adopted arbitrarily as lying within the range used in experimental studies on which this part of ISO 389 is based. It does not imply a recommendation to adopt this level of masking noise in clinical practice.

6 The relationship between the levels of a masking noise and a pure tone just masked by the presence of this noise is specified in ISO 389-4.

3.11 critical bandwidth: Widest frequency band within which the loudness of a band of continuously distributed random noise of constant band sound pressure level is independent of its bandwidth.

3.12 vibrotactile threshold level: Level of an alternating force at which a person gives 50 % of correct detection responses on repeated trials due to the sensation of vibration on the skin.

3.13 white noise: A noise the power spectral density of which is essentially independent of frequency.

4 Reference equivalent threshold force levels (RETFLs)

Reference equivalent threshold force levels for location of the vibrator on the mastoid bone are given in table 1. They are derived from determinations of the threshold of hearing by bone conduction of otologically normal persons as measured on the mastoid bone, under the conditions described in clause 5 (see annex A).

NOTES

7 It is emphasized that the data given in table 1 are derived from results obtained with different types of bone vibrators having different electromechanical properties, applied to the head in the specified manner. The procedures used to compensate for differences in the masking levels used in the three studies may also have contributed to differences among studies.

8 Values for frequencies below 250 Hz are not specified in this part of ISO 389. Results from one laboratory are given for information in annex D.

5 Test conditions and requirements

The reference equivalent threshold force levels apply when the conditions and requirements specified in this clause are met.

5.1 Bone vibrator

The vibrator shall have a plane, circular tip, of nominal area 175 mm^2. Any airborne sound which it radiates when in contact with the head of a test subject having unimpaired external and middle ear function shall be low enough in level to provide a margin of 10 dB or more between the true bone-conduction hearing threshold level and a false air-conduction hearing threshold level evoked by the bone vibrator.

If this condition is not met directly at all frequencies, the unwanted sound radiation is excluded by inserting an earplug into the external canal of the ear under test at the frequencies which are affected. Due to the occlusion effect, use of the earplug is confined to frequencies above 2 000 Hz.

5.2 Fitting of the bone vibrator

A headband shall be used to hold the vibrator on the mastoid bone with a nominal static force of 5,4 N. The vibrator shall be placed on the mastoid prominence, not touching the pinna, and adjusted so as to remain in a stable position.

Table 1 — Reference equivalent threshold force levels (RETFLs) for location of the vibrator on the mastoid bone

Frequency Hz	RETFL[1] (reference: 1 µN) dB
250	67,0
315 [2]	64,0
400 [2]	61,0
500	58,0
630 [2]	52,5
750 [3]	48,5
800 [2]	47,0
1 000	42,5
1 250 [2]	39,0
1 500 [3]	36,5
1 600 [2]	35,5
2 000	31,0
2 500 [2]	29,5
3 000	30,0
3 150 [2]	31,0
4 000	35,5
5 000 [3]	40,0
6 000 [3]	40,0
6 300 [3]	40,0
8 000 [3]	40,0

1) Values rounded to the nearest 0,5 dB.

2) Values for these frequencies are derived by interpolation.

3) Values for these frequencies are derived from the results from one laboratory only.

5.3 Mechanical coupler

The mechanical coupler shall comply with the specification in IEC 373 (see annex B, in particular B.3).

NOTE 9 The mechanical coupler specified in the first edition (1971) of IEC 373 differs in material respects and is not applicable to this part of ISO 389.

5.4 Test signal

The alternating force signal produced by the bone vibrator at the excitation level corresponding to table 1, as measured on the mechanical coupler, shall exhibit total harmonic distortion not exceeding 1 % for fundamental frequencies from 500 Hz to 1 000 Hz, and 2 % for frequencies from 250 Hz to 400 Hz inclusive and from 1 250 Hz upwards.

5.5 Masking noise

The masking noise signal shall be generated by passing random white noise through a bandpass filter one-third octave wide, centred logarithmically on the test-tone frequencies given in table 1.

5.6 Masking transducer

The masking noise signal shall be delivered to the ear not under test by means of a supra-aural or insert earphone of a pattern conforming to one of the specifications in ISO 389:1991 or ISO 389-2, respectively.

5.7 Fitting of masking transducer

If a supra-aural earphone is used for delivering the masking noise, it shall be applied to the ear not under test of the test subject by means of a headband exerting a nominal force of 4,5 N, and designed not to interfere with the headband holding the bone vibrator which is worn simultaneously. If an insert earphone is used for delivering the masking noise, it shall be applied to the ear not under test as specified in ISO 389-2.

5.8 Datum level of masking noise

The masking noise, applicable to the mean otologically normal young person, shall be presented at the datum level specified in 3.10.

NOTE 10 A constant hearing level of 40 dB in each one-third-octave band is approximately equal to the datum level as defined, although, in principle, the value depends slightly on the band centre frequency (due to the variable width of critical bandwidths). The difference between the hearing level of the noise band and that of the pure tone referred to in 3.10 is approximately 5 dB; it represents the amount by which masking noise in a critical bandwidth may exceed a pure tone at the 50 % correct detection level of the pure tone (see ISO 389-4).

The datum level may be expressed as the sound pressure level, in decibels, relative to 20 μPa by adding 40 dB to the RETSPL values specified in ISO 389:1991 or ISO 389-2, respectively for the pattern of earphone used as the masking transducer.

Annex A
(informative)

Note on the derivation of RETFL values

Source of data

The RETFL values specified in this part of ISO 389 are obtained from the results of three independent experimental investigations communicated to ISO/TC 43, *Acoustics*. Brief particulars of the tests are given in table A.1.

Table A.1 — Investigations on RETFL values

Test data	Investigation		
	Ref. [1]	Ref. [2]	Ref. [3]
Type of vibrator	B-71[1]	B-71[1]	KH-70 [2] AROW> Type of masking earphone TDH39 [3] TDH39 [3] DT48 [4]
Level of masking noise	30 dB effective[5]	25 dB and 40 dB sensation level	40 dB effective[5] at 125 Hz, 250 Hz; 30 dB effective[5] at higher frequencies
Number of ears tested	60	136	50
Number of subjects	60	68	25
Frequencies tested, Hz	250, 500, 1 000, 2 000, 3 000, 4 000	250, 500, 1 000, 2 000, 3 000, 4 000	125, 250, 500, 750, 1 000, 1 500, 2 000, 3 000, 4 000, 5 000, 6 000, 6 300, 8 000

1) Manufactured by Radioear Corporation, USA.
2) Manufactured by Grahnert Präcitronic, GmbH, Germany.
3) Manufactured by Telephonics Corporation, USA.
4) Manufactured by Beyer AG, Germany.
5) "Effective masking level" as defined in ref. [4], appendix A4.

The values for the bone-conduction threshold of hearing used in the development of this part of ISO 389 were not corrected for deviations of the test subject's air-conduction hearing threshold levels from 0 dB. Further details of the derivation of RETFL values are given in ref. [2].

Annex B
(informative)

Guidance on the application of the reference zero to the calibration of bone-conduction audiometers

B.1 General

When a bone-conduction audiometer is calibrated in accordance with this part of ISO 389 and under the conditions stipulated in clauses 4 and 5, where applicable, to measure the hearing of young otologically normal subjects, a mean hearing threshold level of 0 dB should be obtained if the ambient noise levels in the test room and the procedures used for the threshold determination comply with ISO 8253-1.

B.2 Choice and fitting of bone vibrator

The plane, circular contact area should be 175 $mm^2 \pm 25$ mm^2, as specified in IEC 645-1. The addition of a slightly rounded edge (for example of radius 0,5 mm) to the vibrator tip prevents discomfort. In general, the inertia-reaction types of vibrator derived from hearing aid designs have only limited output for acceptable distortion at low frequencies, and are not usually suitable for audiometry below 250 Hz; the larger button-type vibrators tend to be superior in this respect, but may produce more unwanted sound radiation at high frequencies due to their larger size.

The headband used should provide a static force of 5,4 N ± 0,5 N.

NOTE 11 A headband providing a force of 5,4 N for a mean head width of 145 mm (for mastoid application) or 190 mm (for forehead application) will usually comply within the above tolerance for adult test populations.

B.3 Calibration of the bone vibrator

The vibrator should be attached to the mechanical coupler with a static force of 5,4 N ± 0,5 N, as specified in IEC 645-1. The bone vibrator and mechanical coupler should both be brought to the proper operating temperature of 23 °C ± 1 °C, as specified in IEC 373. Because of the high thermal capacity of the mechanical coupler, a period of several hours may be required to bring the system to thermal equilibrium before calibration. Any deviation from this temperature can only be allowed for if data for the temperature dependence of the performance of the specific type of bone vibrator on the mechanical coupler are available.

B.4 Choice and fitting of masking transducer

It is convenient to use the same earphone for delivering the masking noise as is used to determine the subject's air-conduction threshold in the ear not under test. If a supra-aural earphone is used, the headband force should be 4,5 N ± 0,5 N. These procedures enable the hearing level of the masking noise to be set correctly using the pure-tone air-conduction calibration of the earphone in accordance with ISO 389:1991 or of ISO 389-2.

B.5 Masking noise source

The datum conditions of this part of ISO 389 specify noise with a one-third-octave bandwidth derived from random noise having uniform spectral density (white noise). Tolerance on the bandwidth (defined by the 3dB down points of the spectral density) of $^{+1/6}_{0}$ octave is recommended. For generating one-third-octave band masking noise from wide-band white noise, the filter characteristics should conform to the specifications of IEC 225.

Annex C
(informative)

Interim differences in reference equivalent threshold force levels between forehead and mastoid location of vibrator

Interim differences in reference equivalent threshold force levels between forehead and mastoid locations of the vibrator are given in table C.1. They are derived from determinations of the threshold of hearing by bone conduction on otologically normal persons under the conditions described in clause 5.

NOTE 12 The values given in table C.1 are obtained from the results of four experimental investigations communicated to ISO/TC 43. Brief particulars of these tests are given in table C.2.

Table C.1 — Interim differences in reference equivalent threshold force levels between forehead and mastoid location of vibrator

Frequency Hz	**RETFL (forehead) minus RETFL (mastoid)**[1] dB
250	12,0
315 [2]	12,5
400 [2]	13,5
500	14,0
630 [2]	13,5
750 [3]	13,0
800 [2]	12,0
1 000	8,5
1 250 [2]	10,0
1 500 [3]	11,0
1 600 [2]	11,0
2 000	11,5
2 500 [2]	12,0
3 000	12,0
3 150 [2]	11,5
4 000	8,0
5 000 [3]	11,0
6 000 [3]	11,0
6 300 [3]	10,0
8 000 [3]	10,0

1) Values rounded to the nearest 0,5 dB.

2) Values for these frequencies are interpolated.

3) Values for these frequencies are derived from the results from one laboratory only.

Table C.2 — Investigations of RETFL (forehead) minus RETFL (mastoid) values

Test data	Investigation			
	Ref. [5]	Ref. [6]	Ref. [3]	Ref. [7]
Type of vibrator	B-71	B-71	KH-70	B-71
Number of ears tested	26	30	50	50
Number of subjects	26	30	25	25
Frequencies tested, Hz	250, 500, 1 000, 2 000, 3 000, 4 000 [1]	250, 500, 1 000, 2 000, 3 000, 4 000	125, 250, 500, 750, 1 000, 1 500, 2 000, 3 000, 4 000, 5 000, 6 000, 6 300, 8 000	250, 500, 750, 1 500, 2 000, 3 000, 4 000

1) The result at 4 000 Hz was not taken into account because airborne sound radiation of the bone vibrator had not been considered.

Annex D
(informative)

Bone-conduction threshold of hearing for frequencies below 250 Hz

Bone-conduction threshold measurements at frequencies below 250 Hz are only of limited use, partly because of the high signal distortion of present inertia-reaction types of bone vibrators (see B.2 in annex B) and partly because of a possible misinterpretation of test results on subjects with hearing loss due to vibrotactile sensation. However, reference equivalent threshold force levels for mastoid location of the bone vibrator and differences in reference equivalent threshold force levels between forehead and mastoid location of the vibrator for frequencies from 125 Hz to 200 Hz have been determined (see annexes A and C) and are given for information in table D.1. They are derived from a determination of the threshold of hearing by bone conduction of otologically normal persons under the conditions described in 5.1 to 5.3 and 5.5 to 5.8. The total harmonic distortion of the test signal used did not exceed 2 % as measured in accordance with 5.4.

Table D.1 — Reference equivalent threshold force levels for mastoid location and differences in reference equivalent threshold force levels between forehead and mastoid location of vibrator

Frequency Hz	**RETFL (mastoid)**[1] (Reference value: 1 μN) dB	**RETFL (forehead) minus RETFL (mastoid)**[1] dB
125	82,5	7,0
160 [2]	77,5	8,5
200 [2]	72,5	10,5

1) Values rounded to the nearest 0,5 dB.
2) Values for these frequencies are interpolated.

Annex E
(informative)

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[8] ISO 389-4:1994, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 4: Reference levels for narrow-band masking noise.*

[9] ISO 8253-1:1989, *Acoustics — Audiometric test methods — Part 1: Basic pure tone air and bone conduction threshold audiometry.*

[10] IEC 225:1966, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

[11] IEC 645-1:1992, *Audiometers — Part 1: Pure-tone audiometers.*