BS EN ISO 389-3:2016

BSI Standards Publication

# Acoustics — Reference zero for the calibration of audiometric equipment

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

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The UK participation in its preparation was entrusted to Technical Committee EH/1/1, Hearing.

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Published by BSI Standards Limited 2016

ISBN 978 0 580 82086 1

ICS 11.040.01; 13.140

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 29 February 2016.

**Amendments/corrigenda issued since publication**

| Date | Text affected |
|---|---|

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

# EN ISO 389-3

February 2016

ICS 13.140

Supersedes EN ISO 389-3:1998

English Version

# Acoustics - Reference zero for the calibration of audiometric equipment - Part 3: Reference equivalent threshold vibratory force levels for pure tones and bone vibrators (ISO 389-3:2016)

Acoustique - Zéro de référence pour l'étalonnage d'équipements audiométriques - Partie 3: Niveaux de référence équivalents de force vibratoire liminaire pour les vibrateurs à sons purs et les ossivibrateurs (ISO 389-3:2016)

Akustik - Standard-Bezugspegel für die Kalibrierung audiometrischer Geräte - Teil 3: Äquivalente Bezugs-Schwellenkraftpegel für reine Töne und Knochenleitungshörer (ISO 389-3:2016)

This European Standard was approved by CEN on 2 January 2016.

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## European foreword

This document (EN ISO 389-3:2016) has been prepared by Technical Committee ISO/TC 43 "Acoustics" in collaboration with Technical Committee CEN/TC 211 “Acoustics” the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2016, and conflicting national standards shall be withdrawn at the latest by August 2016.

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# Contents

Page



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# Foreword

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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).

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The committee responsible for this document is ISO/TC 43, *Acoustics*.

This second edition cancels and replaces the first edition (ISO 389-3:1994), which has been technically revised. It also incorporates the Technical Corrigendum ISO 389-3:1994/Cor 1:1995.

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 vibratory 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 threshold of hearing for test signals of short duration*

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

— *Part 8: Reference equivalent threshold sound pressure levels for pure tones and circumaural earphones*

— *Part 9: Preferred test conditions for the determination of reference hearing threshold levels*


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# Introduction

Each part of ISO 389 specifies a specific reference zero for the calibration of audiometric equipment. ISO 389-1, ISO 389-2 and ISO 389-8 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 389-1, ISO 389-2 and ISO 389-8 in terms of reference equivalent threshold sound pressure levels (RETSPL), i.e. threshold sound pressure levels produced in an ear simulator or acoustic coupler of specified characteristics by supra-aural, circumaural 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 vibratory force levels (RETVFL), 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 RETVFL 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 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 cranial bones 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 vibratory 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 unimpaired 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 389-1, ISO 389-2 or ISO 389-8, 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 transmission through the external and middle ear and through the cranial bones, 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 RETVFL 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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INTERNATIONAL STANDARD ISO 389-3:2016(E)

# Acoustics — Reference zero for the calibration of audiometric equipment —

# Part 3: Reference equivalent threshold vibratory 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 vibratory force levels (RETVFL), corresponding to the threshold of hearing of young otologically normal persons by bone-conduction audiometry;

b) essential characteristics of the bone vibrator and the method of coupling to the test subject, and to the mechanical coupler;

c) essential characteristics of the masking noise and the baseline masking noise level 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.

RETVFL is the vibratory force level transmitted to a mechanical coupler of specified characteristics 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 Values for the differences in reference equivalent threshold vibratory force levels between location on the forehead and mastoid are included for information in Annex C.

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

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 389-1, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 1: Reference equivalent threshold sound pressure levels for pure tones and supra-aural earphones*

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

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

IEC 60318-6, *Electroacoustics — Simulators of human head and ear — Part 6: Mechanical coupler for the measurement of bone vibrators*

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## 3 Terms and definitions

For the purposes of this document, the definitions given in ISO 389-1 and ISO 389-2, and the following terms and 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**
**vibratory force level**
ten times the logarithm to base ten of the ratio of the mean square vibratory force by the square of the reference force, 1 μN

Note 1 to entry: The vibratory force level is expressed in decibels (dB).

**3.4**
**mechanical coupler**
device for calibrating bone vibrators, designed to present a specified mechanical impedance to a bone vibrator applied with a specified static force, and equipped with an electromechanical transducer to enable the vibratory force level at the surface contact between a bone vibrator and mechanical coupler to be determined

Note 1 to entry: A mechanical coupler is specified in IEC 60318–6.

**3.5**
**equivalent threshold vibratory force level**
vibratory force level 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 prominence, 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 prominence concerned, would correspond to the threshold of hearing

Note 1 to entry: The term is relevant for monaural listening only.

**3.6**
**reference equivalent threshold vibratory force level**
**RETVFL**
mean value of the equivalent threshold vibratory force levels at a specified frequency, of a sufficiently large number of ears of otologically normal persons, of both sexes, aged between 18 years and 25 years inclusive, expressing the threshold of hearing in a specified mechanical coupler for a specified configuration of bone vibrator

Note 1 to entry: The term was formerly referred to by the acronym RETFL.

**3.7**
**hearing level**
vibratory force level (or sound pressure level) at a specified frequency, for a specified model of transducer and for a specified manner of application, produced by the transducer in a specified mechanical coupler (or ear simulator or acoustic coupler) minus the appropriate reference equivalent threshold vibratory force level (or reference equivalent threshold sound pressure level) for bone conduction or air conduction, as applicable

Note 1 to entry: By extension, this definition may be applied to a narrow band of noise.


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**3.8**
**occlusion effect**
increase in level of a bone-conducted signal reaching the inner ear when an earphone or earplug is placed over, or at the entrance to the ear canal, thereby forming an enclosed air volume in the external ear

Note 1 to entry: The effect depends on the type of earphone or earplug used and is greatest at low frequencies.

Note 2 to entry: This is expressed in decibels (dB).

**3.9**
**masking**
<process> process by which the threshold of hearing of a sound is raised by the presence of another (masking) sound

**3.10**
**masking**
<quantity> amount by which the hearing threshold level is so raised

Note 1 to entry: This is expressed in decibels.

**3.11**
**baseline masking level**
level, expressed as hearing level of a band of noise delivered by air conduction for the purpose of masking, 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 a hearing threshold level of 0 dB by air conduction for that pure tone

Note 1 to entry: The value of 35 dB for the pure-tone test stimulus 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.

Note 2 to entry: 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.

Note 3 to entry: The term was formerly called “datum level of masking noise” in the earlier edition of this part of ISO 389.

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

**3.12**
**critical bandwidth**
bandwidth of a frequency band of sound, being a portion of a continuous noise spectrum of wider bandwidth, which effectively masks a tone coinciding with the centre frequency of the band

**3.13**
**vibrotactile threshold level**
vibratory force level at which a person gives a predetermined percentage of correct detection responses on repeated trials due to the sensation of vibration on the skin

Note 1 to entry: A 50 % correct detection rate is often used.

**3.14**
**white noise**
noise, having a power spectral density that is essentially independent of frequency

## 4 Reference equivalent threshold vibratory force levels (RETVFL)

Reference equivalent threshold vibratory force levels for location of the bone vibrator on the mastoid prominence are given in Table 1. They are derived from determinations of the threshold of hearing by

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bone conduction of otologically normal persons as measured on the mastoid prominence, under the conditions described in Clause 5 (see Annex A).

NOTE 1 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.

NOTE 2 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

## 5.1 General

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

## 5.2 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. A method to show conformity with this requirement is given in Annex B.

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.

## 5.3 Fitting of the bone vibrator

A headband shall be used to hold the vibrator on the mastoid prominence 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 vibratory force levels (RETVFL) for location of the vibrator on the mastoid prominence**

| **Frequency**<br>Hz | **RETVFL**[a]<br>**(reference: 1 µN)**<br>dB |
|---|---|
| 250 | 67,0 |
| 315[b] | 64,0 |
| 400[b] | 61,0 |
| 500 | 58,0 |
| 630[b] | 52,5 |
| 750[c] | 48,5 |
| 800[b] | 47,0 |
| 1 000 | 42,5 |
| 1 250[b] | 39,0 |

[a] Values rounded to the nearest 0,5 dB.

[b] Values for these frequencies are derived by interpolation.

[c] Values for these frequencies are derived from the results from one laboratory only.


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**Table 1** *(continued)*

| **Frequency**<br>Hz | **RETVFL**[a]<br>**(reference: 1 µN)**<br>dB |
|---|---|
| 1 500[c] | 36,5 |
| 1 600[b] | 35,5 |
| 2 000 | 31,0 |
| 2 500[b] | 29,5 |
| 3 000 | 30,0 |
| 3 150[b] | 31,0 |
| 4 000 | 35,5 |
| 5 000[c] | 40,0 |
| 6 000[c] | 40,0 |
| 6 300[c] | 40,0 |
| 8 000[c] | 40,0 |

[a] Values rounded to the nearest 0,5 dB.

[b] Values for these frequencies are derived by interpolation.

[c] Values for these frequencies are derived from the results from one laboratory only.

## 5.4 Mechanical coupler

The mechanical coupler shall comply with the specification in IEC 60318-6.

## 5.5 Test signal

The vibratory 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.

## 5.6 Masking noise

The masking noise signal shall be generated according to the specifications given in ISO 389-4, and centred on a test frequency given in Table 1.

## 5.7 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 389-1 or ISO 389-2, respectively.

## 5.8 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 static 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.

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## 5.9 Baseline masking level

For the purpose of determining RETVFL values, the masking noise, applicable to otologically normal persons having a hearing threshold level of 0 dB, shall be presented at the baseline masking level of 40 dB.

NOTE When using masking noise with a one-third-octave bandwidth, the baseline masking level is approximately constant at different frequencies, at 40 dB, although, in principle, the value depends slightly on the band centre frequency (due to variability in critical bandwidths). This value derives from the difference between the masking level and the level of the pure tone to be masked (referred to as the reference level for narrow-band masking noise in ISO 389-4), which is approximately 5 dB. However, a table showing this difference as a function of band centre frequency and noise bandwidth can be found in ISO 389-4. The reference level for narrow-band masking noise represents the amount by which masking noise in a critical band can exceed a pure tone at the 50 % correct detection level of the pure tone (see ISO 389-4).

The baseline masking level may be expressed as the sound pressure level, by adding 40 dB to the RETSPL values specified in ISO 389-1 or ISO 389-2, respectively for the pattern of earphone used as the masking transducer.


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# Annex A
(informative)

# Note on the derivation of RETVFL values

## A.1 Source of data

The RETVFL 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 RETVFL values**

| Test data | Investigation | | |
|---|---|---|---|
| | Reference [1] | Reference [2] | Reference [3] |
| Type of vibrator | B-71[a] | B-71[a] | KH-70[b] |
| Type of masking earphone | TDH39[c] | TDH39[c] | DT48[d] |
| Level of masking noise | 30 dB effective[e] | 25 dB and 40 dB sensation level | 40 dB effective[e] at 125 Hz, 250 Hz; 30 dB effective[e] 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 |

[a] Manufactured by Radioear Corporation, USA.

[b] Manufactured by Grahnert Präcitronic, GmbH, Germany.

[c] Manufactured by Telephonics Corporation, USA.

[d] Manufactured by Beyer AG, Germany.

[e] "Effective masking level" as defined in Reference [4], 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 RETVFL values are given in Reference [2].

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# 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 $mm^2$ ± 25 $mm^2$, as specified in IEC 60318-6. 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 bone 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 A headband providing a static 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 Unwanted sound from the bone vibrator

The influence on an audiometric test result of sound radiation from the bone vibrator is characterized using measurements on at least 16 ears from a sample of otologically normal test subjects whose hearing threshold levels shall not exceed 10 dB for the test frequencies 250 Hz to 8 kHz, as follows:

a) first, the bone conduction threshold is determined at 2 kHz and above at each frequency provided by the audiometer, in accordance with ISO 8253-1, with the test ear occluded with an earplug which provides a mean sound attenuation of at least 30 dB at the test frequencies, as measured in accordance with ISO 4869-1;

b) the mean value of the measured hearing thresholds across the sample of test subjects is calculated at each frequency.

c) steps a) and b) are repeated with the earplug removed;

d) the difference in the mean values for the occluded and unoccluded measurements determined in b) are calculated at each frequency

The influence should be regarded as negligible if the magnitude of differences calculated in d) do not exceed 3 dB.

## B.4 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, including the weight of the bone vibrator and of any unsupported components of the mechanism providing the


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coupling force, as specified in IEC 60318-6. The bone vibrator and mechanical coupler should both be brought to the proper operating temperature of 23 °C ± 1 °C, as specified in IEC 60318-6. 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.

It is important to mount the bone vibrator correctly on the mechanical coupler. The bone vibrator should be placed as close as possible to the centre of and perpendicular to the visco-elastic dome of the mechanical coupler. The angle of contact is controlled by visual examination by ensuring that the small opening angles between the curved surface of the dome and the flat contact surface of the bone vibrator are the same for all viewing angles.

## B.5 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 389-1 or ISO 389-2.

## B.6 Masking noise characteristics

The baseline masking conditions of this part of ISO 389 are derived from noise with a one-third-octave bandwidth, originating from random noise having uniform spectral density (white noise) that is passed through a band-pass filter. Tolerance on the bandwidth (defined by the 3 dB down points of the spectral density) of ± 1/6th-octave is recommended. For generating one-third-octave-band masking noise from wideband white noise, the filter characteristics should conform to the specifications of IEC 61260-1.

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# Annex C
(informative)

# Differences in reference equivalent threshold vibratory force levels between forehead and mastoid location of vibrator

Differences in reference equivalent threshold vibratory force levels between forehead and mastoid location 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 The values given in Table C.1 were 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 — Differences in reference equivalent threshold vibratory force levels between forehead and mastoid location of vibrator frequency**

| **Frequency**<br>Hz | **RETVFL (forehead) minus RETVFL (mastoid)**[a]<br>dB |
|---|---|
| 250 | 12,0 |
| 315[b] | 12,5 |
| 400[b] | 13,5 |
| 500 | 14,0 |
| 630[b] | 13,5 |
| 750[c] | 13,0 |
| 800[b] | 12,0 |
| 1 000 | 8,5 |
| 1 250[b] | 10,0 |
| 1 500[c] | 11,0 |
| 1 600[b] | 11,0 |
| 2 000 | 11,5 |
| 2 500[b] | 12,0 |
| 3 000 | 12,0 |
| 3 150[b] | 11,5 |
| 4 000 | 8,0 |
| 5 000[c] | 11,0 |
| 6 000[c] | 11,0 |
| 6 300[c] | 10,0 |
| 8 000[c] | 10,0 |

[a] Values rounded to the nearest 0,5 dB.

[b] Values for these frequencies are interpolated.

[c] Values for these frequencies are derived from the results from one laboratory only.


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

| Test data | Investigation | | | |
|---|---|---|---|---|
| | **Reference [5]** | **Reference [6]** | **Reference [3]** | **Reference [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[a] | 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 |

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

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# Annex D
(informative)

# Bone-conduction threshold of hearing for frequencies below 250 Hz

Bone-conduction threshold measurements at frequencies below 250 Hz are of limited use, partly because of the high signal distortion of present inertia-reaction types of bone vibrators (see B.2) and partly because of a possible misinterpretation of test results on subjects with hearing loss due to vibrotactile sensation. However, reference equivalent threshold vibratory force levels for the mastoid location of the bone vibrator and differences in the reference equivalent threshold vibratory force levels between the forehead and mastoid locations 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 were derived from a determination of the threshold of hearing by bone conduction of otologically normal persons under the conditions described in Clause 5.

The total harmonic distortion of the test signal used did not exceed 2 % as measured in accordance with 5.5.

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

| **Frequency**<br>Hz | **RETVFL (mastoid)**[a]<br>**(reference: 1 µN)**<br>dB | **RETVFL (forehead) minus RETVFL (mastoid)**[a]<br>dB |
|---|---|---|
| 125 | 82,5 | 7,0 |
| 160[b] | 77,5 | 8,5 |
| 200[b] | 72,5 | 10,5 |

[a] Values rounded to the nearest 0,5 dB.

[b] Values for these frequencies are interpolated.


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