

Indian Standard

METHOD FOR MEASUREMENT OF REAL-EAR
PROTECTION OF HEARING PROTECTORS AND
PHYSICAL ATTENUATION OF EARMUFFS

(*First Revision*)

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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Indian Standard

METHOD FOR MEASUREMENT OF REAL-EAR PROTECTION OF HEARING PROTECTORS AND PHYSICAL ATTENUATION OF EARMUFFS

(First Revision)

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(*First Revision*)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 7 April 1980, after the draft finalized by the Acoustics Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard specifies the definitions, requirements and procedures for the measurement of acoustical performance of personal hearing protective devices. This standard is not appropriate to the evaluation of hearing-protective devices designed to operate exclusively against impulsive noise.

0.3 This standard was first published in 1971. The revision has been undertaken to bring it in line with the corresponding ANSI publication. The principal changes are the inclusion of a method for the measurement of physical attenuation of earmuff devices and the substitution of narrow bands of noise for discrete tones as the test stimuli. The physical measurement method is intended for production test and engineering design, it is not suitable for earplug testing.

0.4 In preparing this standard, assistance has been derived from ANSI S3-19-1974 ' Method for the measurement of real-ear protection of hearing protectors and physical attenuation of earmuffs ' issued by American National Standards Institute.

0.5 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard specifies the psychophysical procedures, physical requirements, and means of reporting results for measuring the protective and attenuation characteristics of wearable devices that are used to protect the auditory system against excessive sound.

1.2 Real-Ear Protection Method — Procedures described in the real-ear (primary) method are performed by psychoacoustic tests on human subjects and are designed to measure real-ear protection at hearing threshold for completely developed hearing protectors. This primary method is described in 3.

1.3 Physical Attenuation Method — Procedures described in the physical attenuation (supplemental) method are performed by physical tests on a dummy head and also may be used to measure sound attenuation at relatively high sound pressure levels (*see* Note). The supplemental method applies to earmuff-type devices and provides data for use in earmuff design and production quality control, as well as for various other attenuation performance specification purposes.

NOTE — A real-head physical attenuation method (that is, microphone under an earcup worn by subject), as has sometimes been applied in research and development work, is not standardized in this document. Data and experience with this method have been examined and found to be insufficient for development of a uniform procedure suitable for standardization at this time.

1.4 Applications — This standard applies to communication units, special helmets including safety helmets, pressure suits and other systems with sound-protective features, and hearing-protective devices used in combination with one another, that is, earplugs plus earmuffs. Earplugs may not be evaluated by this method. Neither the primary nor the supplemental method is applicable for testing nonlinear devices, amplitude-sensitive devices, and other hearing-protective devices with features designed to operate exclusively against impulsive noises. These devices are included only to the extent that their performance complies with the requirements of the standard. Standard methods for the real-ear evaluation of these devices are not established, consequently, the effectiveness of their special features cannot be adequately described in a uniform manner.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Hearing Protector — A device that is worn to prevent the harmful effects of sound on the auditory system.

2.1.1 Earplug — A hearing protector worn within the external ear canal (aural) or in the concha against the entrance to the external ear canal (semi-aural).

2.1.2 Earmuff — A hearing protector usually comprised of headband and earcups with a soft outer ring intended to fit snugly against the pinna (supra-aural) or the sides of the head around the pinna (circumaural).

2.1.3 Communication Headset — A device (earplug or earmuff) designed primarily for communication which may also provide or be used for hearing protection.

2.1.4 Helmet — A device, sometimes functioning as a hearing protector, that usually covers a substantial part of the head.

2.2 Open Threshold of Audibility — The minimum effective sound pressure level for a specified signal that is capable of evoking an auditory sensation when a hearing protector is not worn.

2.3 Occluded Threshold of Audibility — The minimum effective sound pressure level, for a specified signal, that is capable of evoking an auditory sensation when the hearing protector under test is worn.

2.4 Real-Ear Protection at Threshold — The mean value (in decibels) of the occluded threshold (hearing protector in place) of audibility minus the open threshold of audibility (ears open and uncovered) for all listeners on all trials under otherwise identical test conditions.

2.5 Dummy Head — A device that approximates certain physical characteristics and dimensions of an average adult male, human head and is used for measuring the attenuation of circumaural hearing protectors.

2.6 Earmuff Attenuation — The algebraic difference (in decibels) between the band pressure levels of the test signals measured at the microphone of the dummy head with and without the earmuff in position.

2.7 Random Incidence Field — A sound field in which the angle of arrival of sound at a given point is random in time.

2.8 Reverberation Time — The time that would be required for the meansquare sound pressure level, originally in a steady state, to fall 60 dB after the source is stopped.

3. REAL-EAR METHOD (PRIMARY)

3.1 Physical Requirements

3.1.1 Acoustic Environments of Test Room

3.1.1.1 Ambient noise — The ambient noise (with instrumentation on and no test signal present) at the position of the listener in the test room shall not exceed the values given in Table 1, measured with the listener absent from the room.

TABLE 1 MAXIMUM PERMISSIBLE AMBIENT NOISE*

FREQUENCY LIMITS (H_2)			OCTAVE-BAND LEVEL IN DECIBELS REF TO 20 $\mu\text{Pa}\dagger$
Lower	Upper	Centre	
90	180	125	24
180	355	250	18
355	710	500	16
710	1 400	1 000	16
1 400	2 800	2 000	14
2 800	5 600	4 000	9
5 600	11 200	8 000	30

*The levels in Table 1 were obtained from the calculations in Appendix A. The octave band levels specified above are based on preferred centre frequencies in accordance with IS : 6964-1973 \ddagger , in order to correspond with third-octave band test signals employed in this standard.

$\dagger\text{Pa} = \text{MN/m}^2$.

\ddagger Octave, half-octave and third octave band filters for analysis of sound and vibration.

3.1.1.2 Test sounds — Third-octave bands of noise shall be used as test sounds for measuring real-ear protection at threshold for at least the bands with the following centre frequencies: 125, 250, 500, 1 000, 2 000, 3 150, 4 000, 6 300 and 8 000 Hz. Test signals interrupted or pulsed a maximum of one time per second with a 50 percent duty cycle and without audible transients are required for the psychophysical procedures. When hearing protectors provide small or negative protection at some test bands, measurements should also be taken at the third-octave bands immediately adjacent to these bands and results reported in the data.

3.1.1.3 Sound field characteristics — An acceptable sound field as approximated by the following conditions is desired:

- The sound shall be generated in a room whose reverberation time in the test space (without subject) shall be between 0.5 and 1.6 seconds for each of the test bands, and
- The sound pressure level measured at six positions relative to the centre of the subjects' head (without subjects), ± 10 cm in front-back dimensions and ± 15 cm in the up-down and right-left dimensions, shall remain within a range of 6 dB for all test bands (see 3.1.1.2). The difference in sound pressure level between the right-left positions shall not exceed 2 dB.

3.1.1.4 Sound field measurement — A directional (cosine or cardioid) microphone that exhibits in its free field polar response at least 10 dB front-to-side and front-to-back rejection for each test band shall be used to measure the sound field at the test space. The sound field shall be considered to approximate a random incidence field if, when the microphone is rotated about the centre of the test space through 360° in each of the three perpendicular planes of the room, the observed sound pressure level in each test band remains within the variation allowed in Table 2.

Any audible noise in the room is likely to cause masking over a portion of the range of test signals. This will elevate the open threshold and result in erroneously small values of real-ear protection for the device under test. Many rooms that cannot meet the limiting ambient noise continuously will be suitable if test periods are selected during times of minimum noise. In case extraneous noise becomes audible in such rooms, means should be employed whereby the listener may signal the tester to stop the test.

Physiological noises may occur under earmuff devices at sufficient levels to cause masking over the low-frequency portion of the range of test signals. This will elevate the occluded threshold and result in erroneously high values of real-ear protection for the device under test.

TABLE 2 ALLOWABLE RANDOM INCIDENCE FIELD RESPONSE VARIATION FOR CORRESPONDING MICROPHONE FREE-FIELD REJECTION*

MICROPHONE FREE-FIELD REJECTION (dB)	ALLOWABLE RANDOM INCIDENCE FIELD RESPONSE VARIATION
> 25	6
20	5
15	4
10	3
< 10, microphone not suitable	

*The variation in microphone response as the microphone is rotated in a random incidence field is related to the directional characteristics of the microphone and the degree of randomness of the field. Allowable sound field response variations must be presented in terms of the free-field directional response characteristic of the microphone. Table 2 presents the free-field rejection values of directional microphones and corresponding allowable sound field variations for purposes of this standard. The microphone free-field rejection may be obtained by measurement or from the microphone manufacturer.

3.1.2 Test Apparatus — Test equipment shall include a white noise generator, third-octave band filter set, control circuits (on-off switch and calibrated attenuators), loudspeakers with power amplifier, and a head-positioning device.

3.1.2.1 White noise generator — The signal source shall generate a signal voltage whose spectrum level measured in a band 1 Hz wide is uniform within ± 2 dB over the frequency range of 50 to 10 000 Hz.

3.1.2.2 Third-octave filter set — A third-octave filter set whose particular band-widths, band-edge frequencies, and other characteristics conform to those as specified shall be used. The mode of operation of the filters in changing from one contiguous band to another shall be a discrete step function; a gradual, continuously adjustable mode of change is not acceptable. Only filter sets allowing direct access to band outputs prior to summing shall be used.

3.1.2.3 Control circuits

- a) Attenuators that provide a test signal range of at least 90 dB in each test frequency band shall be used. Attenuation steps shall be 2.5 dB or smaller. The attenuators shall be calibrated at levels at which the system is used, in the minimum steps, when connected in the system. Corrections for measured departures from linearity shall be applied to the data.
- b) Procedures which employ an attenuation network that is operated manually by the subject shall have some calibrated means to vary the signal presented to the subject attenuator. Performance characteristics of attenuation networks shall be at least equal to the requirements of (a).
- c) The signal on-off switch shall operate in such a manner that no transient or extraneous noises are audible to the normal ear. After operation of the switch, the time required for the sound pressure level of the test signal to rise from -20 to -1 dB, with reference to its final steady value, shall be not less than 0.02 second and not more than 0.10 second, and the time required for the sound pressure of the signal to fall by 20 dB shall be not less than 0.005 second and not more than 0.10 second. This requirement is consistent with IS : 9098-1979* and shall be met by the electronic system feeding the loudspeakers.

*Specification for pure tone audiometers.

3.1.2.4 Loudspeakers

- a) The loudspeakers used in conjunction with the apparatus described in 3.1.2 shall provide a sound field such that at any test band the sound pressure level at the listener's position can be varied from at least 20 dB above the occluded threshold of hearing to 10 dB below the open threshold of hearing. For most protective devices, this is equivalent to a level of 70 dB above to a level of 10 dB below (*see Note*) the threshold of audibility; and

NOTE — This may be calculated on the basis of a electrical calibration.

- b) At least one loudspeaker shall be placed on the surface of each of the three major planes (ceiling-floor plane and two opposing wall planes) of the room (*see Notes 1 and 2*). Each loudspeaker shall be housed in a configuration that approaches an 'infinite' baffle. No loudspeaker shall have its axis oriented directly towards the subject (minimum orientation of 5° off).

NOTE 1 — In order to achieve the desired sound field, it may be necessary to employ as many as nine loudspeakers, three in each room plane. A simple installation is to mount three individual speakers.

NOTE 2 — Loudspeakers on each of the three single sheets of plywood (at least 1.9 cm thick), one for each of the three room planes (axes) shall be installed. At least one 30.5 cm or larger diameter loudspeaker should be employed in each room plane. Base reflex, ducted port, acoustic suspension, etc, loudspeaker systems should not be used.

3.1.2.5 Head-positioning device — Some means shall be used to provide a reference for maintaining the listener's head in a constant position (it should not a head rest, however a plumb bob to the nose of the listener has proved acceptable). This device shall not transmit to the listener's head any vibrations that might affect the measurements or present a reflective or absorptive surface that might alter the level of the sound at the ears of the subject.

3.1.3 Distortion — The entire system shall produce less than 5 percent total harmonic distortion, measured at the position of the subject's head while the stimulus system is operated at maximum sound pressure level, with discrete tone inputs corresponding to the centre frequencies of the test band ranging from 250 to 6 300 Hz. When the test room is excited with a test band at maximum sound pressure level, the levels measured in adjacent bands shall be consistent with the filter characteristics specified for the third-octave band filter.

3.1.4 Earmuff Device Force Measurement — Some means shall be provided for the measurement of force exerted against the sides of the head by earmuff devices mouted on suspension systems. The measurements shall represent the force found in new, unused, hearing protectors separated to

a distance of 14.35 cm between earcups (medium head width) and 13.08 cm between the inside of the headband and an imaginary line through the pivot points of the attachments of the headband to the earcups (medium head height). These data shall be reported along with the real-ear protection data.

3.2 Listeners

3.2.1 Listeners to be used in the tests described in the following section shall have hearing threshold levels in either ear no higher than 10 dB at the 250-1 000 Hz test frequencies and no higher than 20 dB at any other test frequency as measured by a standard audiometer, as specified.

3.2.2 No listener shall be selected as a subject for these tests whose variability for the open threshold of audibility described under **3.3.2** is such that the range on three successive open threshold measurements at any test band between the 250 and 4 000 Hz bands is greater than 6 dB.

3.2.3 Listeners who satisfy the other requirements of this standard and who do obtain an adequate fit with the test item (**3.3.3.1**) may not be dismissed for reporting small amounts of protection. In reporting the results, listeners for whom an adequate fit cannot be obtained should be noted, but should not be included in the evaluation.

3.3 Test Procedures

3.3.1 Instructions to Listeners

3.3.1.1 Listeners shall be completely informed regarding the test situation and procedure.

3.3.1.2 The listener shall be seated in such way that, using the head-positioning reference device, the listener's head will be placed in the same 'fixed' position in the sound field for all repeated measurements.

3.3.2 Open Threshold of Audibility

3.3.2.1 Procedure

- a) In order to allow for accommodation to the test situation, listeners shall be seated in the test room, with no signals present, for a minimum period of 5 minutes prior to the initial trial of a test session, after which time the threshold determinations may begin. The listener should not have been exposed to excessive noise for at least 1 hour prior to the test.

- b) The listener's ears shall be uncovered and unprotected. The control attenuation for each of the test bands listed in 3.1.1.2 shall be varied until a level is reached at which the signal is just audible (*see* Note). This level shall be the open threshold of audibility. An open threshold for all test bands shall be measured immediately before or after each set of occluded thresholds, the order to be alternated.

NOTE — A recommended procedure is to present the signal at an audible level, to decrease the level until the signal is not heard, and then to increase the level until the tone is just heard. Threshold level is considered to be the lowest level of the signal which is heard on at least 50 percent of the trials during three or four ascents and descents across this lowest-level value.

- c) Any psychophysical or audiometric technique suitable for threshold determinations of individual signals within the limits of 3.1.1.2 shall be used, and the same technique shall be used for measuring the open and the occluded thresholds.
- d) Some means shall be provided to vary each presentation so that the level of the test signal presented to the subject attenuator shall differ from trial to trial. The total value recorded for each trial shall be the variation introduced by the experimenter, combined with the subject's response and shall be reflected in the subject's attenuator setting.

3.3.2.2 Recording data — The final results of the hearing protection test will be exposed in terms of the difference between attenuator settings, that is, the mean-occluded minus the mean-open threshold levels in decibels. Therefore, only attenuator settings (which represent threshold levels) need to be recorded.

3.3.3 Determining Occluded Threshold of Audibility

3.3.3.1 Fitting hearing protectors — The fitting of hearing-protective devices is critical to acoustic fit and the amount of hearing protection obtained; therefore, the method of installation for occluded threshold determinations shall be reported as 'subject (average) fit' or 'experimenter (best) fit'. Eyeglasses should not be worn during earmuff evaluations. Special studies of earmuff effectiveness with eyeglasses should be clearly identified.

- a) *Subject fit* — The experimenter should give each listener precise instructions on fitting the hearing protectors, in accordance with instructions from the manufacturer, and should select a proper size hearing protector for the listener. Earplugs shall be inserted and earmuffs shall be put on by the listener. In addition, the following shall be complied with:

- i) After the hearing protector has been installed, a white noise shall be introduced whose overall sound pressure level at the listener's position is 60 to 70 dB with reference to 20 μ Pa. The listener shall be instructed to manipulate the hearing protector until satisfied that the noise is minimal.
 - ii) After the test is begun, further manipulation of the hearing protector in order to gain attenuation improvement at a specific test signal is prohibited.
- b) *Experimenter fit* — When optimum protector performance is desired, the experimenter shall personally check each hearing protector installation to assure a good fit and acoustic seal after 3.3.3.1 (a) (i) is completed. When he deems necessary, the experimenter shall re-insert earplugs and re-adjust other protectors to a 'best' fit prior to testing, but not after the test has begun. The results obtained using this fitting procedure shall be reported as 'experimenter fit' protection.

3.3.3.2 Occluded threshold levels — After the hearing protector has been installed in accordance with 3.3.3.1, a threshold of audibility for the test signals shall be measured in exactly the same way as prescribed for the open thresholds (3.3.2). These levels shall be the occluded thresholds.

3.3.3.3 Number of hearing protector units — A minimum of two individual units of a hearing protector model, that is manufactured in standard sizes shall be used alternately in the execution of this test.

3.4 Processing and Reporting the Data

3.4.1 Minimum Samples — The real-ear protection at threshold for each listener shall be based, for each test signal, on measures of open thresholds made on no less than three separate trials and on measures of occluded thresholds made on no less than three separate trials. Each separate trial shall include a refit of the hearing protector. Frequent rest periods shall be provided to the subject during the threshold determinations. Measurements shall be made on not less than ten subjects.

3.4.2 Measurements to be Reported — The measurements shall be summarized for at least each of the nine specified test signals (one-third-octave band) in terms of a grand mean and a standard deviation of the protection values. Standard deviations (σ) shall be computed using the formula:

$$\sigma = \sqrt{\frac{\sum d^2}{N - 1}}$$

where d is the difference between the grand mean and an individual observation and N is the number of observations (30, ten subjects with three measures each). There will be as many real-ear protections and standard deviations as there are test signals, and the data shall, therefore, be summarized in a table or graph that displays real-ear protection at threshold and standard deviation as a function of the frequency of the one-third-octave test bands of noise.

3.4.2.1 When hearing protection data are presented in graphic form, a paper shall be used whose frequency scale along the abscissa is in equal intervals of one-third-octave band centre frequencies and whose hearing protection scale along the ordinate is linear in decibels. The length for a decade of third octaves shall be equal to the length for 25 dB.

3.4.2.2 The method used to establish that the ambient noise level in the test room did not mask thresholds of audibility (3.1.1.1) shall be described.

3.4.2.3 Listeners shall be described in terms of age, sex, and manner of selection.

3.4.2.4 The psychophysical procedure used for obtaining thresholds (3.3.2 and 3.3.3) shall be described.

3.4.2.5 The manner of hearing protector installation shall be described as subject fit or experimenter fit and also noted on the graphic or tabular displays of the protection data.

3.4.2.6 The earmuff force measurements shall be described and noted on the graphic or tabular displays, or both, of the hearing protection data.

4. PHYSICAL METHOD (SUPPLEMENTAL)

4.1 Physical Requirements

4.1.1 Test Room

4.1.1.1 Acoustic test field — A random incidence sound field, as approximated by the following conditions, is desired for each third-octave band test frequency from 80 to 10 000 Hz:

- a) A broad-band electrical noise source, whose spectrum level in 1 Hz bands is uniform within ± 2 dB over the frequency range of 50 to 12 500 Hz, shall be presented to a third-octave contiguous filter set ranging from 80 to 10 000 Hz centre frequency to provide the test signals. Each of the test bands beginning at 125 Hz and extending to 8 000 Hz centre frequency shall be measured.

- b) The band pressure level at the microphone for each test band frequency shall be not less than 85 dB with reference to 20 μ Pa and shall be at least 60 dB higher than the level of the test room ambient noise in each test frequency band.
- c) The random incidence characteristics of the sound field shall be determined in accordance with 3.1.1.4. The sound field used in the primary method is adequate for the physical measures when the band pressure level requirement of (b) is satisfied.

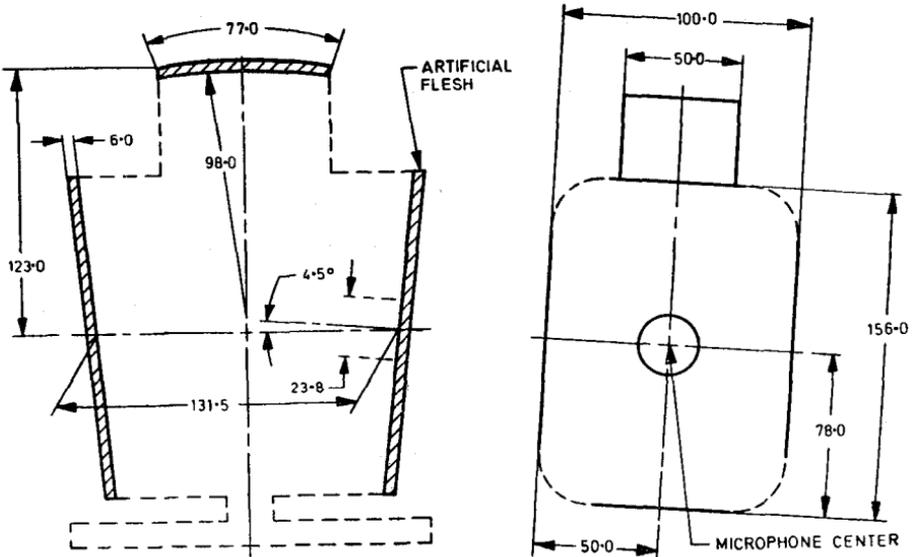
4.1.2 Apparatus

4.1.2.1 Dummy head — The dummy head shall be constructed in accordance with the critical surface dimensions as shown in Fig. 1. The two non-parallel surfaces, representing the sides of the human head, and the curved surface representing the top of the human head shall be covered with artificial flesh. There shall also be provided, in one or both surfaces, as shown in Fig. 1, a centrally located mounting means that shall accept a laboratory standard type microphone or a microphone normally used on sound level meter. Adapters shall be used with microphones having outside diameters less than 23.774 ± 0.005 mm. The diaphragm of the microphone shall be co-planar with the outer surface of the artificial flesh.

NOTE — Alternate types of headform may also be used but the results for different types of headform may not give the same results as with the real-ear method.

- a) The acoustic isolation of the dummy head shall be not less than 60 dB in any test frequency band in the range of interest. Isolation shall be determined as the difference at each test band between the output of the microphone uncovered and of the microphone covered with a thick-walled metal cup, grease sealed to the hard surface of the dummy head (before artificial flesh is attached). A sample test cup is shown in Fig. 2.
- b) The artificial flesh shall be fabricated to a thickness of 6.0 ± 1.0 mm and applied to the critical surface as shown in Fig. 1. The material, as applied, shall exhibit a reading of 20 ± 5 , when measured with a Shore '00' durometer, or the equivalent.

4.1.2.2 Observed sound pressure level apparatus — An automatic graphic level recorder (pen speed of 10 mm/s and paper speed of 25 mm/s have proved satisfactory) synchronized with either a stepping-type or a continuously swept third-octave filter set is the recommended instrument for measuring the sound pressure level. A manually scanned filter may be used with a voltmeter readout (slow meter response is mandatory). A simultaneous visual/graphic analyzer or a standard sound pressure level meter with third-octave band analyzer may also be employed. The



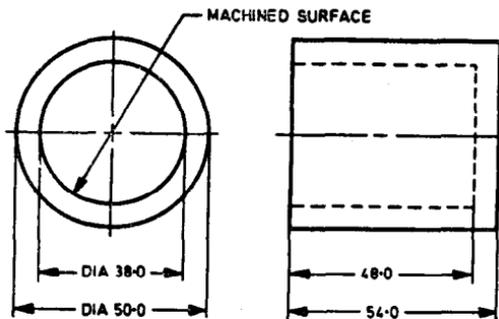
All dimensions in millimetres.

NOTE 1 — All dimensions are references to the hard surface beneath the artificial flesh.

NOTE 2 — Dashed lines indicate unspecified contour or structure.

NOTE 3 — Tolerance ± 2.0 mm unless otherwise noted.

FIG. 1 DUMMY HEAD



All dimensions in millimetres.

NOTE — One metal cup fabricated to the dimensions shown has provided adequate isolation in practice.

FIG. 2 ACOUSTIC ISOLATION TEST CUP

measuring system used shall be calibrated to measure band pressure level with reference to 20 μ Pa.

4.1.2.3 Headband force apparatus — The apparatus for the measurement of headband force is described in Fig. 3.

4.2 Test Procedures

4.2.1 Attenuation Measurement

4.2.1.1 Earmuff placement — The earmuff shall be positioned in the following manner:

The adjustable headband shall be extended to its largest size. The hearing protector shall be spread and placed on the dummy head with the circumaural seals centrally located on the appropriate surfaces. The headband shall be contracted so as to rest firmly upon the curved surface of the dummy head.

NOTE — Nape spring hearing protectors, or those that do not have rigid headband springs, shall be positioned on the dummy head in accordance with the manufacturer's instructions. The applicable conditions of 4.2.1.1 shall be met.

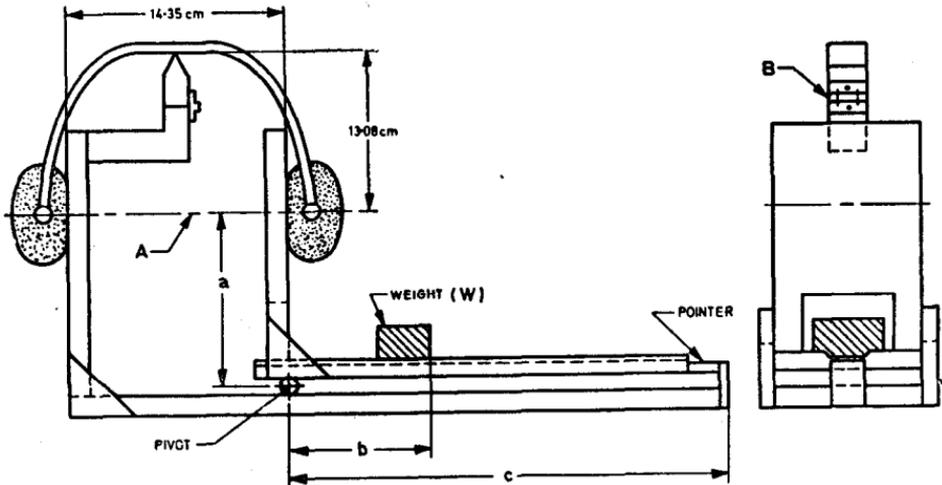
4.2.1.2 Measurement — The band pressure levels at the microphone shall be measured for the acoustic best field without earmuffs. The hearing protector shall be placed over the microphone in accordance with 4.2.1.1 and the band pressure levels measured again. Readings are taken at the preferred centre frequency when continuously swept filter sets are used.

- a) The measurements shall be taken for each earcup of the hearing protector in position, covering the test microphone.
- b) When the measured difference in band pressure levels between the right and left earcups is less than 5 dB, the arithmetic average of the two values shall be reported. When the measured difference between earcups is 5 dB or greater, the attenuation of each earcup shall be reported.

4.2.1.3 Hearing protector attenuation — The algebraic difference in band pressure level, in decibels, for each test frequency band with and without the hearing protector in place on the dummy head is considered to be the attenuation of the device.

4.3 Reporting the Data

4.3.1 The hearing protector attenuation data shall be presented in graphic form, with the data points connected by straight lines, on a paper whose frequency scale along the abscissa is in equal intervals of one-third octave band centre frequencies and whose attenuation scale along the ordinate is linear in decibels. The length for a decade of third-octaves shall



NOTE 1 — A: Centreline passes through pivot point of earcup attachment to headband.

NOTE 2 — B: After correct headband distance is obtained, move out of way for force measurement.

NOTE 3 — *Construction* — Almost any material can be used provided that the units are made sufficiently rigid. The only critical dimensions are the earcup separation distance (14.35 cm) and the headband extension distance (13.08 cm). For best results, dimension a should be 12.0 cm to 15.0 cm and dimension c should be 30.5 cm. A good free-working hinge with a small centre pin is satisfactory as the pivot point. Weight is recommended to be about 900 g.

NOTE 4 — *Calibration* — With the pointer aligned, the distance between the two faces must be read 14.35 ± 0.2 cm. If the construction is such that the weight can be moved over the pivot point, then the zero force location is found by positioning the weight where it just balances. The force (F) at any location at a distance b that the weight has moved from the zero point is found by $F = \frac{bW}{a}$. A scale of grams can be marked.

NOTE 5 — *Operation* — The earmuff to be measured is positioned so that the points of attachment of the headband to the earcups are located at the centreline marks (13.08 cm) and the headband contacts the vertical post. The post is moved away, and the weight is positioned to where the pointers are aligned. The force is read from the scale which converts weight location into grams. When the pointers are aligned, the distance of 14.35 cm is automatically satisfied.

NOTE 6 — *Accuracy* — The positioning of the earcup must be done with care in order to ensure that the point of attachment of the cup to the headband is the distance a from the pivot point. Practically, this is the largest source of error. With care, the position will be in error less than 0.3 cm for a maximum measurement error of $0.3 \text{ cm} \div 12 \text{ cm} = 2.6\%$ (2.1% for $a = 15 \text{ cm}$). Actual measurements of ten different hearing protectors by three different persons have shown that 95% of the measurements will be within ± 5 g.

FIG. 3 FORCE MEASUREMENT SYSTEM

be equal to the length for 25 dB. The ordinate shall be labelled in 14 equal intervals of 5 dB ranging from 60 dB at the abscissa to -10 dB. Subdivision of the ordinate is acceptable.

4.3.2 The graph shall be clearly labelled to indicate a physical measurement method. The date, model number, headband force, individual conducting the test, and any other appropriate data shall be included on the graph.

APPENDIX A

(Table 1)

CALCULATION OF MAXIMUM PERMISSIBLE NOISE LEVELS

A-1. The maximum permissible noise levels in the octave bands contained in Table 1 of the standard were calculated applying the data in Table 3 to the following formula:

$$L_N = T + C_N - C_B$$

where the masking level is assumed to be zero,

T = hearing threshold levels at (ref 20 μ Pa),

$C_N = 10 \log_{10} (NB/1 \text{ Hz})$,

and

C_B = critical band for two-ear listening.

**TABLE 3 DATA FOR CALCULATING MAXIMUM PERMISSIBLE
NOISE LEVELS**

FREQUENCY (Hz)	NOISE BAND (Hz)	T (dB)	C_N (dB)	C_B (dB)	L_N (dB)
(1)	(2)	(3)	(4)	(5)	(6)
125	90 — 180	20.8	19.5	16.0	24
250	180 — 355	11.2	22.4	15.5	18
500	355 — 710	6.0	25.5	15.5	16
1 000	710 — 1 400	4.2	28.4	16.5	16
2 000	1 400 — 2 800	1.0	31.5	18.5	14
4 000	2 800 — 5 600	- 3.9	34.5	21.0	9*
8 000	5 600 — 11 200	15.3	37.5	23.0	30

*Reduced from 10 to 9 dB to be equal to level in band centred at 3 000 Hz.
