Reaffirmed by ANSI
October 15, 2003

Reaffirmed by ANSI
October 28, 2008

ANSI S3.1-1999

(Revision of
ANSI S3.1-1991)

American National Standard

Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms

Secretariat

Acoustical Society of America

Approved 3 August 1999

American National Standards Institute, Inc.

Abstract

This Standard specifies maximum permissible ambient noise levels (MPANLs) allowed in an audiometric test room that produce negligible masking (⩽2 dB) of test signals presented at reference equivalent threshold levels specified in ANSI S3.6-1996 *American National Standard Specification of Audiometers*. The MPANLs are specified from 125 to 8000 Hz in octave and one-third octave band intervals for two audiometric testing conditions (ears covered and ears not covered) and for three test frequency ranges (125 to 8000 Hz, 250 to 8000 Hz, and 500 to 8000 Hz). The Standard is intended for use by all persons testing hearing and for distributors, installers, designers, and manufacturers of audiometric test rooms. This standard is a revision of ANSI S3.1-1991 *American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms*.

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Foreword

[This Foreword is for information only and is not an integral part of ANSI S3.1-1999 *American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms.*]

This Standard is a revision of ANSI S3.1-1991 *American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms*. The 1991 Standard specified maximum permissible ambient noise levels (MPANLs) from 125 to 8000 Hz in octave and one-third octave bands allowed in an audiometric test room that would produce negligible masking of pure tones presented at reference equivalent threshold sound pressure levels specified in ANSI S3.6-1989 for two audiometric conditions (ears covered using a supra-aural earphone and ears not covered) and for three test frequency ranges (125–8000 Hz, 250–8000 Hz, and 500–8000 Hz). The MPANLs were derived using reference equivalent threshold sound pressure levels measured in a NBS 9-A coupler.

This revision also specifies MPANLs from 125 to 8000 Hz in octave and one-third octave bands allowed in an audiometric test room that would produce negligible masking of pure tones for two audiometric conditions and three test frequency ranges. However, the MPANLs specified in this revision were derived using a different computational method based on sound field thresholds, principles of masking for a given threshold shift, power-law summation of masking, and earphone attenuation values. Since the new computational method does not use NBS 9-A coupler based measurements as done in 1991, MPANLs have been specified for an insert as well as for a supra-aural earphone. The present Standard allows slightly more low frequency and slightly less very high frequency ambient noise in an audiometric test room than specified in 1991.

The annexes detail the derivation of the MPANLs and provide information for interim low frequency MPANLs, high frequency ambient noise levels, techniques for physical measurement of ambient noise, supra-aural earphones encased in passive noise-reducing enclosures, and general considerations in planning for an audiometric test room.

Further experimental work concerning the influence of masking on hearing thresholds is encouraged, especially masking of low frequency noise on higher frequency hearing thresholds, very low and high frequency earphone attenuation, and the attenuation provided by passive noise-reducing earphone enclosures. As a result of this research, a more precise specification of permissible ambient noise levels may be developed.

This Standard, a revision of ANSI S3.1-1991 *American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms*, was developed under the jurisdiction of Accredited Standards Committee S3, Bioacoustics, which has the following scope:

> *Standards, specifications, methods of measurement and test, and terminology, in the fields of psychological and physiological acoustics, including aspects of general acoustics, shock and vibration which pertain to biological safety, tolerance, and comfort.*

At the time this Standard was submitted to Accredited Standards Committee S3, Bioacoustics, for final approval, the membership was as follows:

Working Group S3/WG56, Criteria for Background Noise for Audiometric Testing, which assisted Accredited Standards Committee S3, Bioacoustics, in the development of this Standard, had the following membership:

T. Frank, *Chair*

I. M. Blood	J. M. Lovrinic	G. A. Studebaker
E. H. Berger	E. Singer	L. A. Wilber
J. D. Durrant		

Suggestions for improvements will be welcomed. Send suggestions for improvement in writing to Accredited Standards Committee S3, Bioacoustics, in care of the ASA Standards Secretariat, 120 Wall Street, 32nd floor, New York, New York 10005-3993, USA.

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American National Standard

Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms

1 Scope, purpose, and applications

1.1 Scope

Hearing measurements in an audiometric test room may be conducted for different audiometric purposes over different test frequency ranges. However, if the ambient noise level is excessively high, some hearing threshold levels measured in that environment will be inaccurate. This occurs because excessively high ambient noise will create an elevation of hearing threshold levels. This is a psychoacoustic phenomenon called masking.

Exclusion of all ambient noise from an audiometric test room is not feasible nor practical from structural and cost considerations. However, to ensure that hearing tests are not influenced by excessive ambient noise masking, there is a need to specify maximum permissible ambient noise levels (MPANLs) that can be allowed in an audiometric test room. This is true particularly when testing is done at sound pressure levels for pure tones corresponding to 0 dB hearing level. Further, there is a need to specify MPANLs for different audiometric conditions, test frequency ranges, and earphone types that will permit testing at reference equivalent threshold levels specified in ANSI S3.6-1996 *American National Standard Specification for Audiometers*.

This Standard includes the specification and measurement of MPANLs in an audiometric test room. Within this Standard, MPANLs are specified for octave and one-third octave band intervals from 125 to 8000 Hz for the audiometric conditions of testing with ears covered using a supra-aural and insert earphone and ears not covered for the test frequency ranges 125 to 8000 Hz, 250 to 8000 Hz, and 500 to 8000 Hz.

1.2 Purpose

The purpose of this Standard is to specify MPANLs in an audiometric test room and measurement procedures that will produce negligible masking ($\leqslant$2 dB) of pure tones presented at reference equivalent threshold levels as specified in ANSI S3.6-1996 *American National Standard Specifications for Audiometers* for different audiometric conditions and test frequency ranges.

This Standard is intended for use by all persons conducting hearing tests to ensure that ambient noise in an audiometric test room will not have a masking effect or influence on hearing measurements. This Standard is also intended for distributors, installers, designers, and manufacturers so that they can plan and construct appropriate acoustical treatment for the reduction of ambient noise in audiometric test rooms.

1.3 Applications

This Standard is a revision of ANSI S3.1-1991 *American National Standard Maximum Permissible Ambient Noise Level for Audiometric Test Rooms.* This Standard pertains to all audiometric testing conditions, particularly to those conditions that require measurement of hearing thresholds. Specifically, the ears covered MPANLs shall apply when both ears are covered by an earphone in a supra-aural cushion or when an insert earphone is placed in each ear canal, as would be the usual case for pure tone air conduction audiometry. The ears not covered MPANLs shall apply when audiometric testing is conducted with one ear not covered by an earphone, as would be typical for pure tone bone conduction audiometry. The ears not covered MPANLs also shall apply when audiometric testing is conducted with both ears not covered, as would be typical for sound field audiometry.

The Standard assumes that ambient noise masking of signals below reference equivalent threshold levels is tolerable. This assumption is not appropriate in applications where hearing thresholds lower than reference equivalent threshold levels must be measured. However, the audibility of all signals presented at levels equal to or greater than reference equivalent threshold levels must be such that the threshold of an average normally hearing listener will be free of any significant effects from ambient noise masking.

This Standard specifies that ambient noise in an audiometric test room shall be measured at octave or one-third octave band intervals within the inclusive range from 125 to 8000 Hz and shall not exceed MPANLs in reference to the audiometric condition ears covered using a supra-aural or insert earphone or ears not covered. Further, the MPANLs shall apply when hearing test frequencies are within the inclusive ranges 125 to 8000 Hz, 250 to 8000 Hz, or 500 to 8000 Hz.

This Standard specifies that MPANLs should be adjusted appropriately when hearing thresholds for pure tones are measured above and below 0 dB HL.

The MPANLs are expressed in decibels (re: 20 μPa) and are based upon psychophysical data. Inherent in the development and application of the MPANLs are *individual variations* in the ability of listeners to detect signals in the presence of noise, differences in the stimulus signal at the tympanic membrane, and differences in the amount of attenuation provided by earphones.

The MPANLs specified in this Standard are based upon the presumption that negligible threshold shift ($\leqslant$2 dB) will occur for most listeners when pure tone thresholds are obtained in the presence of noise having an effective level near the listener's unmasked thresholds. Equivalently, this means that threshold elevation will be limited to 2 dB when testing is conducted at reference equivalent threshold levels in the presence of the MPANLs permitted by this Standard.

2 References

2.1 Normative references

The following Standards contain provisions which, through reference in this text, constitute provisions of this American National Standard. At the time of approval by the American National Standards Institute, Inc. (ANSI), the editions indicated were valid. Because Standards are revised from time to time, users should consult the latest revision approved by the American National Standards Institute. For purposes of this Standard, the use of the latest revision of a referenced Standard is not mandatory. Information on recent editions is available from the ASA Standards Secretariat.

[1] ANSI S1.1-1994 *American National Standard Acoustical Terminology*.

[2] ANSI S1.4-1983 (R 1994) *American National Standard Specification for Sound Level Meters*.

[3] ANSI S1.4A-1985 Amendment to S1.4-1983.

[4] ANSI S1.6-1984 (R 1994) *American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements*.

[5] ANSI S1.11-1986 (R 1993) *American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters*.

[6] ANSI S3.6-1989 *American National Standard Specification of Audiometers*.

[7] ANSI S3.6-1996 *American National Standard Specification of Audiometers*.

[8] ANSI S3.20-1995 *American National Standard Bioacoustical Terminology*.

[9] ANSI S3.21-1978 (R 1992) *American National Standard Method for Manual Pure Tone Audiometry*.

[10] ANSI S12.6-1997 *American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors*.

2.2 Informative references

[11] Berger, E. H. and Killion, M. C. (1989) ''Comparison of the noise attenuation of three audiometric earphones, with additional data on masking near threshold,'' *J. Acoust. Soc. Am.* **86**, 1392–1403.

[12] Berry, B. F. (1973) ''Ambient noise limits for audiometry,'' *National Physical Laboratory Acoustics* Report AC 60.

[13] Frank, T. and Wright, D. C. (1990) ''Attenuation provided by four different audiometric earphone systems,'' *Ear and Hearing* **11**, 70–78.

[14] Wright, D. C. and Frank, T. (1992) ''Attenuation values for a supra-aural earphone for children and insert earphone for children and adults,'' *Ear and Hearing* **13**, 454-459.

3 Definitions of terms

For the purposes of this Standard, the following terms apply.

3.1 audiometric test room. Enclosed space used for testing hearing.

NOTE - An audiometric test room may also be known as an audiometric test area, hearing test space, or hearing test room. An example would be a prefabricated room known as an audiometric test booth or sound-treated room.

3.2 supra-aural earphone. Earphone that presses against the pinna so that the electroacoustic transducer is close to the pinna.

NOTE – A typical example would be a Telephonic TDH type earphone mounted in MX41/AR or Type 51 cushions connected to a headband so that the application force is between 4 to 5 N as described in clause 9.1 of ANSI S3.6-1996.

3.3 insert earphone. Earphone consisting of a body worn transducer, sound tube, nipple adaptor, and a foam eartip.

NOTE – A typical example would be an Etymotic Research-3A or EARtone 3A as described in clause 9.3 of ANSI S3.6-1996.

3.4 insertion depth. Position of the outer edge of a foam eartip of an insert earphone relative to the opening of the ear canal after the eartip has been inserted and allowed to expand in the ear canal.

NOTES

1 The foam eartip has various outside diameters but a nominal length of 12 mm as described in clause 9.3 of ANSI S3.6-1996.

2 An insertion depth of 0 mm would mean that the outer edge of the foam eartip is flush with the opening of the ear canal. An insertion depth of 3 mm would mean that the outer edge of the foam eartip is 3 mm inside the opening of the ear canal.

3.5 ears covered. Listening situation where both ears are covered simultaneously by earphones mounted in supra-aural cushions held in place by a headband or when foam eartips of insert earphones have been inserted into each ear canal with an insertion depth of 0–3 mm.

NOTE – An example would be determining pure tone air conduction hearing thresholds using Telephonic TDH type earphones in Model 51 cushions or Etymotic Research 3A or EARtone 3A insert earphones.

3.6 ears not covered. Listening situation where either one or both ears are not covered with an earphone in a supra-aural cushion or a foam eartip of an insert earphone has not been inserted into the ear canal.

NOTES

1 An example of where both ears are not covered would be for determining sound field hearing thresholds.

2 An example of where only one ear is not covered would be for determining pure tone bone conduction hearing thresholds when a bone vibrator is placed on the mastoid of one ear and an earphone is placed on the other ear for the purpose of masking.

3.7 equivalent threshold level. For monaural listening, at a specified frequency, for a specified type of transducer, and for a stated force of application of the transducer to the human head or insertion depth in the ear canal, the vibrational level or sound pressure level set up by that transducer in a specified coupler or artificial ear when the transducer is activated by voltage which, with the transducer applied to the ear concerned, would correspond with the threshold of hearing. Unit, decibel (dB).

3.8 reference equivalent threshold level. At a specified frequency, for a specified type of transducer, for a specified type of coupler or artificial ear, the mean value of the equivalent threshold levels of an adequately large number of otologically normal listeners between the ages of 18 and 30 years inclusive. Unit, decibel (dB).

NOTES

1 Reference equivalent threshold sound pressure levels for a supra-aural and insert earphone are given in tables 6 and 7 respectively in ANSI S3.6-1996.

2 Reference equivalent threshold force levels are given in table 8 in ANSI S3.6-1996.

3.9 hearing level. For a specified signal, amount in decibels by which the hearing threshold level for a listener, for either one or two ears, differs from a specified reference equivalent threshold level. Abbreviation, HL; unit, decibel (dB).

NOTES

1 Typically, a pure tone audiometer is calibrated so that an output of 0 dB HL, for a specified transducer at a specified frequency, is equal to the reference threshold level for that transducer (by air or bone conduction). Thus, if a listener had a hearing threshold equal to the reference equivalent threshold level, the listener's threshold would be 0 dB HL (audiometer output at the listener's threshold) or the average threshold of otologically normal listeners.

2 If a listener had a hearing threshold of 40 dB higher than the reference equivalent threshold level, the listener's threshold would be 40 dB HL (audiometer output at the listener's threshold) or 40 dB higher (less sensitive) than the average threshold of otologically normal listeners.

3 If a listener had a hearing threshold 10 dB lower than the reference equivalent threshold level, the listener's threshold would be −10 dB HL (audiometer output at the listener's threshold) or 10 dB lower

Table 1 — Ears Covered: Octave band MPANLs for supra-aural earphones and for insert earphones for three test frequency ranges; in dB re: 20 μPa to nearest 0.5 dB.

Oct Band Intervals[c]	Supra-aural Earphone[a] 125 to 8000 Hz	Supra-aural Earphone[a] 250 to 8000 Hz	Supra-aural Earphone[a] 500 to 8000 Hz	Insert Earphone[b] 125 to 8000 Hz	Insert Earphone[b] 250 to 8000 Hz	Insert Earphone[b] 500 to 8000 Hz
125	35.0	39.0	49.0	59.0	67.0	78.0
250	25.0	25.0	35.0	53.0	53.0	64.0
500	21.0	21.0	21.0	50.0	50.0	50.0
1000	26.0	26.0	26.0	47.0	47.0	47.0
2000	34.0	34.0	34.0	49.0	49.0	49.0
4000	37.0	37.0	37.0	50.0	50.0	50.0
8000	37.0	37.0	37.0	56.0	56.0	56.0

[a]As described in clause 3.2.
[b]As described in clauses 3.3 and 3.4.
[c]Table A.1 provides mid-octave MPANLs for 750, 1500, 3000, and 6000 Hz.

(more sensitive) than the average threshold of otologically normal listeners.

3.10 hearing threshold level. For a given listener and specified signal, the minimum sound pressure level or force level that is capable of evoking an auditory sensation in a specified fraction of trials. Sound reaching the ears from other sources is assumed to be negligible. Unit, decibel (dB).

NOTES

1 The characteristics of the test signal, the manner in which it is presented to the listener, and the place at which the sound pressure level or force level is measured should be specified.

2 The pure tone threshold measurement procedure described in ANSI S3.21-1978 (R 1992) recommends that the threshold be defined as the lowest input level at which responses occur in at least 50% of ascending trials in a series.

3.11 pure tone. A sound wave, the instantaneous sound pressure of which is a simple sinusoidal function of time.

3.12 ambient noise. All encompassing noise normally associated with a given environment being usually a composite of sounds from many sources near and far.

NOTES

1 An example would be a narrowband noise that contains a region in the frequency spectrum whose level is at least 10 dB greater than the level of the neighboring frequency region and whose effective bandwidth is the same as or less than one critical band at the frequency of concern.

2 Another example would be a wideband noise that contains no spectral maxima.

3 Another example would be any type of unwanted noise that would create a nuisance or perceptual confusion for the listener undergoing a hearing test.

3.13 normally hearing listener. A person who has air conduction thresholds ≤0 dB HL from 125–8000 Hz in each ear when tested in an audiometric test room having MPANLs less than or equal to those specified in this Standard for the frequency range to be employed in the test room.

4 Recommended ambient noise levels and measurements

4.1 Maximum permissible ambient noise levels (MPANLs). The MPANLs allowed in an audiometric test room are shown in tables 1–3. Table 1 shows octave band and table 2 shows one-third octave band MPANLs for ears covered testing using a supra-aural or insert earphone for each test frequency range. Table 3 shows octave and one-third octave band MPANLs for ears not covered testing for each test frequency range.

NOTES

1 See Annex A for information concerning the derivation of the MPANLs.

2 If the ambient noise levels measured in an audiometric test room are equal to those in tables 1–3, an elevation in a hearing threshold level for a pure tone no greater than 2 dB may occur when testing is done at reference equivalent threshold levels specified in ANSI S3.6-1996.

Table 2 — Ears Covered: One-third octave band MPANLs for supra-aural earphones and for insert earphones for three test frequency ranges; in dB re: 20 μPa to the nearest 0.5 dB.

	Supra-aural Earphone[a]			Insert Earphone[b]		
1/3 OB Intervals	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz
125	30.0	34.0	44.0	54.0	62.0	73.0
250	20.0	20.0	30.0	48.0	48.0	59.0
500	16.0	16.0	16.0	45.0	45.0	45.0
800	19.0	19.0	19.0	44.0	44.0	44.0
1000	21.0	21.0	21.0	42.0	42.0	42.0
1600	25.0	25.0	25.0	43.0	43.0	43.0
2000	29.0	29.0	29.0	44.0	44.0	44.0
3150	33.0	33.0	33.0	46.0	46.0	46.0
4000	32.0	32.0	32.0	45.0	45.0	45.0
6300	32.0	32.0	32.0	48.0	48.0	48.0
8000	32.0	32.0	32.0	51.0	51.0	51.0

[a]As described in clause 3.2.
[b]As described in clauses 3.3 and 3.4.

3 See Annex C for interim low frequency ($<$125 Hz) ambient noise levels.

The MPANLs in tables 1 and 2 for ears covered exceed the levels in table 3 for ears not covered by the average attenuation provided by a typical audiometric earphone in a supra-aural cushion supported by a headband and by an insert earphone. To decrease the chance that an individual listener may have a threshold shift $>$2 dB when testing is done in the ears covered test condition, the MPANLs shown in tables 1 and 2 could be reduced by lowering the amount of earphone attenuation. The reduction would be equal to the mean earphone attenuation value minus one standard deviation as reported in Annex A, clause A.3. Whenever possible the ambient noise levels in an audiometric test room should be lower than those shown in tables 1–3.

NOTE – See Annex A.3 for information concerning earphone attenuation.

Table 3 — Ears Not Covered: Octave and one-third octave band MPANLs for three test frequency ranges; in dB re: 20 μPa to the nearest 0.5 dB.

	Octave Band[a]			One-Third Octave Band		
Center Freq.	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz
125	29.0	35.0	44.0	24.0	30.0	39.0
250	21.0	21.0	30.0	16.0	16.0	25.0
500	16.0	16.0	16.0	11.0	11.0	11.0
800	–	–	–	10.0	10.0	10.0
1000	13.0	13.0	13.0	8.0	8.0	8.0
1600	–	–	–	9.0	9.0	9.0
2000	14.0	14.0	14.0	9.0	9.0	9.0
3150	–	–	–	8.0	8.0	8.0
4000	11.0	11.0	11.0	6.0	6.0	6.0
6300	–	–	–	8.0	8.0	8.0
8000	14.0	14.0	14.0	9.0	9.0	9.0

[a]Table A.1 provides mid-octave MPANLs for 750, 1500, 3000, and 6000 Hz.

4.2 Measurement instrumentation. The measurement instrumentation shall be a sound level meter and octave or one-third octave band filter or equivalent filter or frequency analysis system (e.g., spectrum analyzer). The sound level meter shall meet the requirements for a Type I sound level meter specified in ANSI S1.4-1983 (R 1994). The filter shall meet the requirements for either an octave band or one-third octave band filter or equivalent as specified in ANSI S1.11-1986 (R 1993).

The sound level meter and filter combination, including the microphone, shall have a self-noise more than 3 dB below the maximum permissible ambient noise sound pressure levels specified in tables 1 and 3 for octave bands or in tables 2 and 3 for one-third octave band intervals from 125 to 8000 Hz. If the measured ambient noise sound pressure level is between 10 and 3 dB greater than the self-noise of the sound level meter and filter combination, an appropriate correction accounting for the instrumentation self-noise shall be applied.

NOTE – See Annex E for a description of techniques for physical measurement.

4.3 Conditions for ambient noise measurements. During all measurements, the ambient noise conditions in an audiometric test room shall represent the worst possible conditions under which hearing tests might be conducted. All possible noise sources shall be considered and those that may interfere with the hearing tests shall be operating. This would include in-take and out-take exhaust fans and other ventilation systems, lights, audiometer, amplifiers, and other instrumentation located in the audiometric test room. Those noises which occur only occasionally and which are readily avoided in the normal testing protocol need not be considered. However, if hearing testing is being conducted when an occasional noise occurs that was not present during the measurement, steps should be taken to ensure that the noise did not influence the hearing test results.

4.4 Measurement of ambient noise sound pressure levels. Measurements of the ambient noise sound pressure levels shall be conducted annually or whenever any new noise source is operating within or in the vicinity of the audiometric test room according to the procedures described in the following paragraphs.

Measurements shall be conducted in the audiometric test room with the microphone of the sound level meter placed at the center of the location or locations that could be occupied by a listener's head. Octave or one-third octave band measurements shall be conducted within the inclusive range of 125 to 8000 Hz. Specifically, octave band measurements shall be conducted at 125, 250, 500, 1000, 2000, 4000, and 8000 Hz. One-third octave band measurements shall be conducted at 125, 250, 500, 800, 1000, 1600, 2000, 3150, 4000, 6300, and 8000 Hz. The microphone orientation shall be that producing the highest readings for each frequency band. If the person making the measurements is in the audiometric test room, that person shall be positioned so as not to reduce the level of the ambient noise reaching the microphone. Whenever possible and practical, it is recommended that one-third octave band measurements be obtained.

The most desirable and recommended way to measure ambient noise in an audiometric test room is through the use of a sound level meter and filter combination. However, if a sound level meter and filter combination is not available, the following procedure may be substituted only when the audiometric condition to be employed is ears covered.

A psychoacoustic check of the ambient noise levels for ears covered testing in the audiometric test room shall be performed using at least two normally hearing listeners as defined in clause 3.13. The normally hearing listeners shall be placed in the usual location in the audiometric test room and fitted with the earphones in the standard manner during a time in which hearing measurements would normally be conducted and under conditions described in clause 4.3. The hearing level dial of the audiometer shall be placed at 0 dB for each test frequency to be employed in the actual testing. The normally hearing listeners shall correctly respond at least two times to each test frequency pure tone at 0 dB and carefully listen for beats, any evidence of ambient noise masking, and for direct acoustic radiation from the audiometer or any instrumentation that may be located in the audiometric test room. The audiometric test room is satisfactory for testing hearing at reference equivalent threshold levels if each normally hearing listener responded to each test frequency pure tone at 0 dB and did not report hearing any other sound that could possibly mask or interfere with hearing measurements.

4.5 Ambient noise check. The normally hearing listeners should assure themselves that the audiometric test room under consideration does not contain any sound that would in any way annoy, distract, or confuse a listener during normal testing conditions as specified in clause 4.3.

4.6 Vibration. The normally hearing listeners should assure themselves that vibration cannot be transmitted directly to the ear by bone conduction. At low frequencies relatively intense vibration may be present in an audiometric test room. With the audiometer tone off, the normally hearing listeners should explore all the various positions that the listener to be tested will be allowed to assume. For example, touching the elbow to a table or resting the head on a chair back may produce a path for bone conducted sound. If such a path for vibrational energy exists, it should be eliminated or each listener should specifically be advised to avoid the offending position.

4.7 Speech threshold testing. It is assumed that any audiometric test room meeting the requirements in tables 1–3 for the test frequency range 125 to 8000 Hz for the ears not covered or ears covered condition is also adequate for speech threshold testing under the same conditions.

5 Compliance with Standard

The ambient noise levels in an audiometric test room shall be measured as in clause 4.4 using instrumentation as in clause 4.2 and conditions as in clause 4.3. In addition, the audiometric test room shall be checked for ambient noises as in clause 4.5 and for possible vibration as in clause 4.6. The measured ambient noise levels shall be compared with the levels shown in tables 1–3 in reference to the audiometric testing conditions (ears covered or ears not covered) and test frequency ranges (125 to 8000, 250 to 8000, or 500 to 8000 Hz) to be employed in the audiometric test room. If the measured ambient noise levels do not exceed the appropriate levels shown in tables 1–3 and the criteria specified in clauses 4.5 and 4.6 are met, the audiometric test room is acceptable for testing hearing at reference equivalent threshold levels.

If one or more of the measured ambient noise levels exceeds the levels in tables 1–3 corresponding to the audiometric condition and test frequency range to be employed, the audiometric test room would not be appropriate for testing hearing at reference equivalent threshold levels. Therefore, procedures should be instituted to reduce the level of the excessive ambient noise to conform to the MPANLs shown in tables 1–3 (see Annex G).

Audiometry for hearing conservation purposes is not recommended if one or more of the measured ambient noise sound pressure levels in an audiometric test room exceeds the levels shown in tables 1 or 2 for ears covered and test frequency range 500 to 8000 Hz.

If hearing thresholds for pure tones are measured at hearing levels above or below 0 dB, the MPANLs shown in tables 1–3 should be adjusted appropriately. MPANLs for testing at hearing levels above 0 dB are derived by arithmetically adding the amount by which the hearing level is above 0 dB to the MPANLs shown in tables 1–3.

NOTE – For example, if a hearing screening is conducted at a hearing level of 20 dB, then 20 dB should be added to the MPANLs in tables 1–3.

MPANLs for testing at hearing levels below 0 dB are derived by arithmetically subtracting the amount by which the hearing level is less than 0 dB from the MPANLs in tables 1–3.

NOTE – For example, if the hearing level to be measured is −10 dB, then 10 dB should be subtracted from the MPANLs shown in tables 1–3.

For hearing threshold or screening tests that employ a single frequency or a more limited test frequency range than described in this Standard, the MPANLs in the audiometric test room shall not exceed the levels shown in tables 1–3 for the audiometric condition and the lowest test frequency within the test frequency ranges corresponding to the single or to the lowest frequency range to be employed.

NOTES

1 For example, if hearing threshold testing is done at reference equivalent threshold levels using the audiometric condition of ears covered at 1000, 2000, and 4000 Hz, the maximum permissible ambient noise sound pressure levels in the audiometric test room shall not exceed the levels shown in tables 1 or 2 for ears covered for the test frequency range 500 to 8000 Hz.

2 As another example, if hearing screening is done at 20 dB above reference equivalent threshold levels using the audiometric condition of ears covered at 1000, 2000, and 4000 Hz, the maximum permissible ambient noise sound pressure levels in the audiometric test room shall not exceed the levels shown in

tables 1 or 2 plus 20 dB for ears covered for the test frequency range 500 to 8000 Hz.

Therefore, if the measured ambient noise sound pressure levels in the audiometric test room do not exceed the levels in table 3 and test frequency range 125 to 8000 Hz, the audiometric test room is acceptable for any audiometric condition or test frequency range specified in this Standard.

Annex A
(Informative)
Derivation of ambient noise levels

A.1 Overview

Berger and Killion (1989) reported masked thresholds for pure tones in different levels of ambient noise for normally hearing subjects fitted with supra-aural and insert earphones. They also reported masked threshold shifts derived by a computational formula. Their computational formula can be summarized as:

$$\mathrm{MT}=10\ \log(10^{\mathrm{EML}/10}+1) \qquad (\mathrm{A.1.1})$$

where MT is the masked pure tone threshold. EML is effective masking level and is computed to account for the level of the ambient noise, earphone attenuation, and internal physiological noise which limits the absolute threshold. Berger and Killion (1989) reported very good agreement between the actual and predicted masked threshold shifts at each frequency for each level of ambient noise and earphone type.

The computational formula reported by Berger and Killion (1989) for predicting the influence of a masking noise on a pure tone threshold is shown in equation A.1.2.

$$\mathrm{MT}=10\ \log(10^{[N-(\mathrm{TB}-\mathrm{CR})-\mathrm{MAFD}]/10}+1) \quad (\mathrm{A.1.2})$$

where N is the level of the noise (or masking) contained in a one-third octave band at the ear. This can be considered as the ambient noise added to the internal physiological noise of the ear on a power-law summation basis in accordance with the findings of French and Steinberg (1947) verified by a comparison to empirical data by Berger (1986) and Berger and Kerivan (1983). TB is the total energy in the band and is a correction factor for conversions between levels expressed in one-third octave band levels to an equivalent pressure spectrum level. TB is computed as 10 log(BW) where BW is the bandwidth of a one-third octave band and is defined as 0.232(f_c), where f_c is the filter center frequency. CR is the critical ratio for masking [Hawkins and Stevens (1950); Sharf (1970)]. For the purposes of the computational formula (equation A.1.2), CR is the threshold level of a pure tone minus the pressure spectrum level of broadband masking noise as reported by Killion (1976, Table I). MAFD stands for minimum audible field diffuse and can be thought of as the psychoacoustic measure that describes a listener's hearing sensitivity when a signal is presented in a diffuse sound field via a loudspeaker. Overall, this is the monaural minimum audible pressure at the eardrum minus the ratio of the eardrum pressure response (P_D) to diffuse-field sound pressure levels (P_{DF}) as averaged from Killion and Monser (1980), Kuhn (1979), and Shaw (1980).

NOTE – The term inside the square brackets in equation A.1.1 is the effective masking level, as used by Hawkins and Stevens (1950).

A.2 Computational formula for determining the MPANLs and its derivation

Equation A.1.2 can be rearranged to determine one-third octave band MPANLs and is shown as equation A.2.1.

$$N=10\ \log(10^{[\mathrm{MAFD}-\mathrm{CR}+\mathrm{MTS}]/10} - 10^{[\mathrm{MAFD}-\mathrm{CR}]/10})+\mathrm{EA}+\mathrm{TB}. \quad (\mathrm{A.2.1})$$

Equation A.2.1 shows the computational formula for determining the one-third octave band MPANLs (N) for a given masked threshold shift (MTS) with a given earphone attenuation (EA).

NOTE – The MTS or masked threshold shift is a constant 2 dB. This was done so that the MPANLs would produce negligible masking ($\leqslant$2 dB) of pure tones presented at reference equivalent threshold levels as specified in ANSI S3.6-1996 *American National Standard Specifications for Audiometers.*

The MPANLs shown in tables 1 and 2 for ears covered were derived using equation A.2.1 and the MAFD, CR, MTS, and EA-SA (earphone attenuation for supra-aural earphone, see clause A.3) or EA-IE (earphone attenuation for insert earphone, see clause A.3) values shown in table A.1. The MPANLs shown in table 3 for ears not cov-

Table A.1 — Derivation of the MPANLs for ears not covered and ears covered using a supra-aural earphone and insert earphone for the test frequency range 125 to 8000 Hz as reported in tables 1–3. Values in parentheses are interpolated or extrapolated from existing data.

	Frequency (Hz)										
Source	125	250	500	750	1000	1500	2000	3000	4000	6000	8000
MAFD[a]	30.0	18.0	10.0	(7.5)	5.0	(5.0)	5.0	(3.5)	2.0	(4.0)	6.0
CR[a]	18.2	17.1	17.1	17.6	18.0	19.0	19.9	21.5	23.1	25.4	27.7
MTS[a, b]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
EA-SA[c]	6.0	4.0	5.0	(9.0)	12.5	(16.0)	19.5	25.0	25.5	24.0	23.0
EA-IE[c]	29.9	31.4	33.7	(33.9)	34.0	(34.1)	34.1	37.9	38.6	40.7	42.7
1/3OB ENC[d]	24.1	16.2	11.2	10.0	8.3	9.1	9.4	8.1	6.2	7.7	8.6
1/3OB EC-SA[d]	30.1	20.2	16.2	19.0	20.8	25.1	28.9	33.1	31.7	31.7	31.6
1/3OB EC-IE[d]	54.0	47.6	44.9	43.9	42.3	43.2	43.5	46.0	44.8	48.4	51.0
OB ENC[d]	29.1	21.2	16.2	15.0	13.3	14.1	14.4	13.1	11.2	12.7	13.6
OB EC-SA[d]	35.1	25.2	21.2	24.0	25.8	30.1	33.9	38.1	36.7	36.7	36.6
OB EC-IE[d]	59.0	52.6	49.9	48.9	47.3	48.2	48.5	51.0	49.8	53.4	56.0

[a]See clause A.1 for definition of terms.
[b]See clause A.1 for definition of term, constant 2 dB.
[c]See clause A.2 for definition of terms, clause A.3 for references.
[d]See clause A.2 for definition of terms.

ered were derived using equation A.2.1 and the MAFD, CR, and MTS values shown in table A.1.

Table A.1 also shows the one-third octave band MPANLs for ears not covered (1/3OB ENC), ears covered using a supra-aural earphone (1/3OB EC-SA), and ears covered using an insert earphone (1/3OB EC-IE). Furthermore, table A.1 shows the octave band MPANLs for ears not covered (OB ENC), ears covered using a supra-aural earphone (OB EC-SA), and ears covered using an insert earphone (OB EC-IE).

The derivation of the one-third and octave band MPANLs shown in table A.1 was for the test frequency range 125 to 8000 Hz. Table A.1 can also be used to show the derivation of the MPANLs for the test frequency ranges 250 to 8000 Hz and 500 to 8000 Hz, keeping in mind that the levels at the frequencies below the lowest test frequency (125 Hz for the 250 to 8000 Hz test frequency range and 125 and 250 Hz for the 500 to 8000 Hz test frequency range) need to be corrected for the upward spread of masking as described in clause A.4.

A.3 Earphone attenuation

The earphone attenuation values used to derive the ears covered MPANLs were obtained using experimenter fitting and methods specified in ANSI S12.6-1984 (R 1990). The mean earphone attenuation values were derived by averaging the values reported in several studies where each study contributed equally to the mean attenuation values. The mean supra-aural earphone attenuation values were those reported for a TDH-type earphone in MX41/AR cushions by Arlinger (1986), Berger and Killion (1989), and Frank and Wright (1990) and in Model 51 cushions by Frank and Wright (1990). The mean insert earphone attenuation values were those reported using an insertion depth of 0–3 mm by Berger and Killion (1989), Frank and Wright (1990), and Wright and Frank (1992).

NOTE – The earphone attenuation values used in this Standard were obtained using the procedures described in ANSI S12.6-1984 (R 1990). Since then, ANSI S12.6 has been revised as ANSI S12.6-1997 *American National Standard Methods for Measuring Real-Ear Attenuation of Hearing Protectors*. Method A in ANSI S12.6-1997 would correspond most closely to the procedures described in ANSI S12.6-1984 (R 1990).

The ears covered MPANLs shown in tables 1 and 2 were derived using mean earphone attenuation values. Thus, if the attenuation supplied by an earphone for an individual listener is less than the mean value, the listener might experience a threshold shift greater than 2 dB when testing is conducted at reference equivalent threshold levels

Table A.2 — Average standard deviations of the attenuation provided by a supra-aural and insert earphone. Values in parentheses are interpolated or extrapolated from existing data.

	Frequency (Hz)										
Earphone[a]	125	250	500	750	1000	1500	2000	3000	4000	6000	8000
Supra-aural	5.4	4.8	5.9	(5.6)	5.3	(5.3)	5.4	5.6	5.9	7.9	7.0
Insert	6.2	5.9	5.5	(5.0)	4.4	(3.9)	3.4	3.1	3.9	4.0	3.8

[a]See clause A.3 for a description of earphone types.

in the presence of the MPANLs shown in tables 1 and 2. To decrease the chance that individual listeners will experience a threshold shift greater than 2 dB because they have less than average attenuation, the MPANLs can be lowered by reducing the amount of earphone attenuation. An appropriate reduction would be equal to the mean attenuation value minus one standard deviation as is common practice for specifying the attenuation of hearing protectors. This reduction would cover about 84% of all listeners. Table A.2 shows the average standard deviation for a supra-aural and insert earphone as reported in those studies used to derive the mean earphone attenuation values. In practice, the standard deviations shown in table A.2 would be subtracted from the MPANLs shown in tables 1 and 2. The net effect would be that the MPANLs would be lower (more stringent) for ears covered testing.

A.4 MPANLs below the test frequency ranges of 250 to 8000 Hz and 500 to 8000 Hz

High levels of low frequency ambient noise can create an elevation of hearing threshold levels for higher frequency pure tones. This phenomenon is known as upward spread of masking. Unfortunately, there is very limited data concerning upward spread of masking caused by low frequency noise on higher frequency pure tone hearing thresholds.

For both ears covered and ears not covered, the maximum permissible ambient noise level at 125 Hz for the 250 to 8000 Hz test frequency range and at 125 and 250 Hz for the 500 to 8000 Hz test frequency range was derived so that the upward spread of masking would produce negligible masking for the lowest frequency pure tone within the test frequency range. This was done by assuming that the slope for the upward spread of masking function is 14 dB per octave below the lowest test frequency. This value (14 dB/octave) was chosen because it approximates the slope of the upward spread of masking function reported by Berry (1973). As such, the maximum permissible ambient noise level one octave below the lowest test frequency (125 Hz for the 250 to 8000 Hz range and 250 Hz for the 500 to 8000 Hz range) is equal to the lowest test frequency maximum permissible ambient noise level plus 14 dB. Accordingly, two octaves below the lowest test frequency level (125 Hz for the 500 to 8000 Hz range) the maximum permissible ambient noise level is equal to the lowest test frequency ambient noise sound pressure level plus 28 dB.

A.5 References

[A.1] ANSI S12.6-1984 (R 1990) *American National Standard Method for the Measurement of Real-Ear Attenuation of Hearing Protectors*.

[A.2] ANSI S12.6-1997 *American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors*.

[A.3] Arlinger, S. D. (1986) ''Sound attenuation of TDH 39 earphones in a diffuse field of narrowband noise,'' *J. Acoust. Soc. Am.* **79**, 189-191.

[A.4] Berger, E. H. (1986) ''Methods of measuring the attenuation of hearing protective devices,'' *J. Acoust. Soc. Am.* **79**, 1655–1687.

[A.5] Berger, E. H. and Kerivan, J. E. (1983) ''Influence of physiological noise and the occlusion effect on the measurement of real-ear attenuation at threshold,'' *J. Acoust. Soc. Am.* **74**, 81–94.

[A.6] Berger, E. H. and Killion, M. C. (1989) ''Comparison of the noise attenuation of three audiometric earphones, with additional data on masking near threshold,'' *J. Acoust. Soc. Am.* **86**, 1392–1403.

[A.7] Berry, B. F. (1973) ''Ambient noise limits for audiometry,'' *National Physical Laboratory Acoustics* Report AC 60.

[A.8] Frank, T. and Wright, D. C. (1990) ''Attenuation provided by four different audiometric earphone systems,'' *Ear and Hearing* **11**, 70–78.

[A.9] French, N. R. and Steinberg, J. C. (1947) ''Factors governing the intelligibility of speech sounds,'' *J. Acoust. Soc. Am.* **19**, 90–119.

[A.10] Hawkins, J. E. and Stevens, S. S. (1950) ''The masking of pure-tones and speech by white noise,'' *J. Acoust. Soc. Am.* **22**, 6–13.

[A.11] Killion, M. C. (1976) ''Noise of ears and microphones,'' *J. Acoust. Soc. Am.* **59**, 424–433.

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[A.13] Kuhn, G. F. (1979) ''The pressure transformation from a diffuse sound field to the external ear and to the body and head surface,'' *J. Acoust. Soc. Am*. **65**, 991–1000.

[A.14] Sharf, B. (1970) ''Critical bands,'' in *Foundations of Modern Auditory Theory*, Volume 1, J. V. Tobis (ed.), Academic Press, New York, NY.

[A.15] Shaw, E. A. G. (1980) ''The acoustics of the external ear,'' in *Acoustical Factors Affecting Hearing Aid Performance*, G. A. Studebaker and I. Hochberg (eds.), University Park, Baltimore, MD.

[A.16] Wright, D. C. and Frank, T. (1992) ''Attenuation values for a supra-aural earphone for children and insert earphone for children and adults,'' *Ear and Hearing* **13**, 454–459.

Annex B
(Informative)
Present compared with previous (1991) ambient noise levels

The major difference between the present and 1991 MPANLs is that the present MPANLs were derived using directly measured ear canal sound pressure levels corrected to determine sound field threshold levels. In 1991, NBS 9-A coupler-based reference thresholds were converted to ear canal sound pressure levels and then converted to sound field threshold levels. As such for the ears covered audiometric condition, the 1991 method was limited to specifying MPANLs using only supra-aural earphones having NBS 9-A reference threshold sound pressure levels. The present computational method corrects this problem and allows for the specification of MPANLs using any earphone type having reference threshold sound pressure levels specified in ANSI S3.6-1996 from125 to 8000 Hz as long as the earphone type attenuation values are known.

Table B.1 shows the octave and B.2 the one-third

Table B.1 — Differences between the present and the 1991 octave band MPANLs for ears covered and ears not covered for each test frequency range; in dB re: 20 μPa to the nearest 0.5 dB. Positive values indicate that the MPANLs in this Standard are higher than those reported in 1991.

	Ears Covered (Supra-aural Earphone)			Ears Not Covered		
Center Freq.	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz
125	1.0	2.5	1.5	1.0	2.5	1.5
250	2.5	2.5	1.5	2.5	2.5	1.5
500	1.5	1.5	1.5	1.5	1.5	1.5
1000	−0.5	−0.5	−0.5	−1.0	−1.0	−1.0
2000	6.0	6.0	6.0	5.5	5.5	5.5
4000	2.5	2.5	2.5	2.0	2.0	2.0
8000	−6.5	−6.5	−6.5	−6.5	−6.5	−6.5

Table B.2 — Differences between the present and the 1991 one-third octave band MPANLs for ears covered and ears not covered for each test frequency range; in dB re: 20 μPa to the nearest 0.5 dB. Positive values indicate that the MPANLs in this Standard are higher than those reported in 1991.

	Ears Covered (Supra-aural Earphone)			Ears Not Covered		
Center Freq.	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz
125	1.0	2.5	1.5	1.0	2.5	1.5
250	2.5	2.5	1.5	2.5	2.5	1.5
500	1.5	1.5	1.5	1.5	1.5	1.5
800	2.5	2.5	2.5	2.5	2.5	2.5
1000	−0.5	−0.5	−0.5	−1.0	−1.0	−1.0
1600	3.5	3.5	3.5	3.5	3.5	3.5
2000	6.0	6.0	6.0	5.5	5.5	5.5
3150	4.5	4.5	4.5	4.5	4.5	4.5
4000	2.5	2.5	2.5	2.0	2.0	2.0
6300	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0
8000	−6.5	−6.5	−6.5	−6.5	−6.5	−6.5

octave band differences between the present and the 1991 MPANLs. The present MPANLs are slightly higher for the lower frequencies and slightly lower for the very highest frequencies. Stated differently, the present Standard allows slightly more low frequency ambient noise and slightly less very high frequency ambient noise than specified in 1991.

Annex C
(Normative)
Interim low frequency ambient noise levels

C.1 General

An audiometric test room should not contain excessively high levels of low frequency ambient noise. As described in clause A.4, upward spread of masking due to high levels of low frequency ambient noise could create an elevation of hearing thresholds for higher frequency pure tones. Due to minimal information regarding low frequency (<125 Hz) thresholds and earphone attenuation values, definitive MPANLs for frequencies <125 Hz cannot be provided in this Standard. However, assuming that the slope for the upward spread of masking function is 14 dB/octave below the lowest test frequency, interim low frequency MPANLs are shown in tables C.1–C.3. The levels shown in table C.1 are for octave band and in table C.2 for one-third octave band MPANLs for ears covered using a supra-aural and insert earphone for each test frequency range. Table C.3 shows the octave and one-third octave band maximum permissible ambient noise sound pressure levels for the audiometric test condition ears open for each test frequency range.

Information concerning the amount of attenuation supplied by hearing protection devices for frequencies <125 Hz has been reported by Berger (1996).

C.2 Reference

[C.1] Berger, E. H. (1996) ''Protection from infrasonic and ultrasonic noise exposure,'' EARLog 14, E-A-R Hearing Protection Productions, Indianapolis, IN.

Table C.1 — Ears Covered: Interim octave band MPANLs using a supra-aural and insert earphone for each test frequency range; in dB re: 20 μPa to the nearest 0.5 dB.

	Supra-aural Earphone			Insert Earphone		
Oct. Band Intervals	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz
31.5	63.0	67.0	77	87.0	95.0	106.0
63	49.0	53.0	63	73.0	81.0	92.0

Table C.2 — Ears Covered: Interim one-third octave band MPANLs using a supra-aural and insert earphone for each test frequency range; in dB re: 20 μPa to the nearest 0.5 dB.

	Supra-aural Earphone			Insert Earphone		
1/3 OB Intervals	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz
31.5	58.0	62.0	72.0	82.0	90.0	101.0
63	44.0	48.0	58.0	68.0	76.0	87.0

Table C.3 — Ears Not Covered: Interim octave and one-third octave band MPANLs for each test frequency range; in dB re: 20 μPa to the nearest 0.5 dB.

	Octave Band			One-third Octave Band		
Oct. Band Intervals	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz	125 to 8000 Hz	250 to 8000 Hz	500 to 8000 Hz
31.5	57.0	63.0	72.0	52.0	58.0	67.0
63	43.0	49.0	58.0	38.0	44.0	53.0

Annex D
(Informative)
High frequency ambient noise levels

D.1 General

MPANLs allowed in an audiometric test room for hearing testing at frequencies above 8000 Hz are not provided in this Standard. This occurs because of minimal information concerning earphone attenuation values above 8000 Hz and the influence of the upward spread of masking or direct masking of lower or high frequency ambient noise on high frequency ($>$8000 Hz) thresholds.

Information concerning the amount of attenuation supplied by hearing protection devices for frequencies up to 16 kHz has been reported by Berger (1996).

D.2 Reference

[D.1] Berger, E. H. (1996) ''Protection from infrasonic and ultrasonic noise exposure,'' EARLog 14, E-A-R Hearing Protection Productions, Indianapolis, IN.

Annex E
(Informative)
Techniques for physical measurement

E.1 Instrument noise

As described in clause 4.2, the sound level meter filter combination should have a self-noise not exceeding (<3 dB) the MPANLs in tables 1–3. However, the measurement of ambient noise levels in an audiometric test room may be compromised by the self-noise of the sound level meter filter combination. The self-noise may be produced by the sound level meter filter combination, the microphone, or by both. Typically, low frequency self-noise is due to the sound level meter filter combination and high frequency self-noise is due to the microphone.

When it is suspected that the measured ambient noise sound pressure levels exceed those in tables 1–3 because of instrumentation self-noise, several procedures should be considered. One procedure would be to measure the ambient noise sound pressure level with two sound level meter filter combinations, where one would be the instrument in question and the other would be an instrument known to have an acceptable self-noise. The difference between the measurements would reflect the self-noise and possibly other differences between the two sound level meter filter combinations.

Another procedure would be to cover the microphone with an isolator cavity or replace the microphone with a dummy microphone and measure the inherent self-noise. If the measured self-noise is not at least 3 dB less than the appropriate levels in tables 1–3, a correction for the self-noise should be made. If the measured self-noise of the sound level meter filter combination exceeds the appropriate values in tables 1–3, that particular instrument should not be used for the purposes of the foregoing standard.

NOTES

1 The isolator cavity should have sufficient volume to allow unimpeded motion of the microphone diaphragm. In some cases a hearing aid coupler may be used if the sound inlet is sealed off. A properly constructed cavity will produce an attenuation of about 30 to 40 dB or more at audiometric frequencies allowing for a direct determination of the self-noise of the sound level meter filter combination in most cases.

2 A dummy microphone may be constructed by carefully shielding an electrical impedance that is approximately equal to the electrical source impedance of the microphone. It is important that both the real and the imaginary parts of the microphone impedance be simulated by the dummy microphone. This should be determined for the particular microphone being used. Care should be taken that any dc bias applied to the microphone in actual use is present during the impedance measurement. It should be remembered that using this technique will not allow measurement of the self-noise that may be originating from the microphone.

E.2 Conditions of physical measurements

As described in clause 4.3, the ambient noise level measurements should be made under the noisiest conditions in which actual hearing testing may be made in the audiometric test room. When applicable the following conditions should also be observed:

(1) The same number of people should be present both inside and outside the audiometric test room as during routine testing activities (this is particularly important for group testing where several subjects are both inside and outside the audiometric test room).

(2) Air conditioning and ventilation equipment in the vicinity of the audiometric test room should be turned on.

(3) The ambient noise measurements should be made at the same time of day when ambient noise is maximum.

(4) Additional noise measurements should be made during intermittent noises such as those produced by typewriters, telephone bells, and footfalls to determine if these noises would interfere with testing hearing.

E.3 Infrequent noise

As described in clause 4.3, an occasional noise such as that produced by an aircraft flying over or by a train passing by may be tolerated provided the audiometric test will always be interrupted during these infrequent noise conditions.

Annex F
(Informative)
Passive noise-reducing enclosures

F.1 General

Mounting a supra-aural earphone in a passive noise-reducing enclosure has been suggested as an alternative to using typical audiometric earphones and cushion types when hearing testing is done in excessive ambient noise test environments. The theory is that the passive noise-reducing enclosures will attenuate excessive ambient noise at the listener's ear to an acceptable level so that the results of hearing testing would not be influenced by excessive ambient noise in the test environment.

Typically, a passive noise-reducing earphone enclosure consists of a plastic dome which houses a typical audiometric earphone and cushion which fits over the outer ear similar to an earmuff used for personal hearing protection.

The attenuation provided by a passive noise-reducing earphone enclosure has been reported by Murray and Waugh (1988), Berger and Killion (1989), Frank and Wright (1990), and Franks, Engel, and Themann (1992) using standardized methodology. The results of these studies revealed discrepancies concerning the amount of low frequency attenuation. Because of conflicting findings and limited research specifying attenuation characteristics, MPANLs for hearing testing with passive noise-reducing earphone enclosures cannot be reported at this time.

F.2 References

[F.1] Berger, E. H. and Killion, M. C. (1989) ''Comparison of the noise attenuation of three audiometric earphones, with additional data on masking near threshold,'' *J. Acoust. Soc. Am.* **86**, 1392–1403.

[F.2] Frank, T. and Wright, D. C. (1990) ''Attenuation provided by four different audiometric earphone systems,'' *Ear and Hearing* **11**, 70–78.

[F.3] Franks, J. R., Engel, D. P., and Themann, C. L. (1992) ''Real ear attenuation at threshold for three audiometric headphone devices: Implications for maximum permissible ambient noise level standards,'' *Ear and Hearing* **13**, 2–10.

[F.4] Murray, N. M. and Waugh, D. (1988) ''Estimated maximum acceptable background noise levels for audiometric testing when using sound excluding enclosures,'' *Australian J. Audio.* **10**, 7–10.

Annex G
(Informative)
General considerations in the planning of an audiometric test room

G.1 General

If the ambient noise levels in an audiometric test room are greater than those specified in tables 1, 2, or 3, it will be necessary to provide a quieter environment for testing hearing. This may be done by building or modifying an existing enclosure to exclude sound to the requisite amount or by selecting an alternate site. It is desirable to investigate all possibilities and to select the most economical or practical combination.

The detailed design of an audiometric test room for sound reduction is complex. This Annex gives some general rules which should be observed. This information will be helpful when preliminary plans are made. Detailed plans should be made only with expert help and study (Franks and Lankford, 1984).

G.2 General features of an audiometric test room

While the primary and necessary requirement of an audiometric test room is MPANLs that do not exceed the levels shown in table 1, 2, or 3, it is also very desirable to have a minimum amount of distraction for the listener. It is strongly recommended that individual audiometric test rooms, or at least large sections of a room, be acoustically and visually well separated from each other, be provided for each listener, and that the floor of each room should be covered with carpet or a cushioning material to reduce impact and scraping noises. An absorptive acoustical treatment for walls and ceiling is recommended to provide an appropriate atmosphere for the test and to secure maximum absorption and attenuation of sounds arising inside the room and those arriving from outside. Comfort is important; therefore, the furniture should be comfortable and ventilation should be provided. It is also important to employ a ventilating system that does not produce noise that exceeds the levels specified. The ballast used for fluorescent lights should be located outside the test room.

G.3 Noise reduction by room modification

The addition of absorptive material to an audiometric test room is effective by itself only where conditions are nearly acceptable as found. When the walls of the proposed audiometric test room are heavy and the noise transmitted through the floor and ceiling is unimportant, the major source of the ambient noise in the room may be acoustical leaks around doors, windows, pipes, and ducts. It may be necessary to install acoustical treatment in ventilating ducts leading to and from the room and maintain low air velocities to minimize grill noise. A leading source of ambient noise is the ventilating system, particularly fan and fan motor noise.

G.4 Noise reduction by isolation

Large amounts of noise reduction can be obtained only by providing a completely enclosed testing space. The characteristics of a sound isolator (a wall, ceiling, or floor) differ from those of a sound absorber. The isolator must be nonporous, and it is effective principally in proportion to its weight per square foot of surface. This effect increases slowly by weight, and large sound reductions are obtained economically only by the use of double-walled structures wherein a complete separation between walls is maintained throughout by an air space or resilient connections.

G.5 Audiometric room selection

The final acoustic criterion for the adequacy of an audiometric test room is that the ambient noise levels not exceed those specified in table 1, 2, or 3 for the audiometric condition and the frequency range to be employed. In the case of structural modifications, the criterion should be specified in terms of these ambient noise levels. If new construction or prefabricated rooms are to be located in existing space, an estimation of the expected noise levels in the audiometric test room can be made by subtracting the noise reduction to be provided by the new structure from the existing ambient noise levels. It is assumed that the noise radiated by the floor is negligible or that a floating floor is to be installed, that a ceiling construction will be provided that is equivalent to the walls in noise reduction and permits no excessive transmission of impact sounds from above, that the doors and windows will maintain the effectiveness of the walls and ceiling, and that the ventilation system, if it is to be used during testing, will not introduce ambient noise levels into the room in excess of the appropriate levels.

To determine the noise reduction required, octave or one-third octave band sound pressure levels from 125 to 8000 Hz should be measured in the area where the test room is to be placed using the method described in clause 4.4. It would also be desirable to measure the octave or one-third octave band sound pressure levels at 31.5 and 63 Hz (see Annex C). The difference between the measured levels minus the MPANLs shown in tables 1, 2, or 3 for the audiometric condition and test frequency range to be employed are the minimum noise reduction levels required. If the audiometric test room will be used for diagnostic and other types of audiometry, it is strongly recommended that the ears not covered and test frequency range from 125 to 8000 Hz MPANLs shown in table 3 be used. If the audiometric test room is to be used only for the purposes of hearing conservation testing, it is recommended that the ears covered and test frequency range from 500 to 8000 Hz MPANLs shown in tables 1 or 2 be used.

Audiometric test room manufacturers can provide the amount of noise reduction supplied by prefabricated test rooms they manufacture. Noise reduction of an audiometric test room is measured by generating very high level acoustic signals outside the audiometric test room as per the American Society for Testing and Materials (ASTM) Standard E596-1996. The sound pressure level of these signals is measured outside and inside the audiometric test room. The difference between the outside and the inside measurements is the minimum noise reduction afforded by the audiometric test room. Often, users will find that the noise reduction afforded by the audiometric test room is less than stated by the manufacturer. Usually, this occurs because the ambient noise levels outside the audiometric test room were less than or not the same type of signal described in ASTM E596-1996 for establishing noise reduction levels.

Because the noise reduction provided by a given prefabricated test room can depend in a complex manner on the size and the acoustical properties of the larger room in which the test room is to be located and the distance between the existing walls and the room, the noise reduction amounts of prefabricated test rooms are approximate values. In addition, construction and assembly factors may introduce a degree of variability in noise reduction. For these reasons, a safety factor of at least 5 to 10 dB should be added to the estimated minimum amount of noise reduction.

G.6 References

[G.1] American Society for Testing and Materials, *Standard Method for Laboratory Measurement of the Noise Reduction of Sound-Isolating Enclosures.* ASTM Designation E596-1996.

[G.2] Franks, J. R. and Lankford, J. E. (1984) ‘‘Noise reduction characteristics of prefabricated sound-isolating enclosures: A laboratory, field measurement, and theoretical analysis,’’ *Ear and Hearing* **5**, 2–12.

OTHER ACOUSTICAL STANDARDS AVAILABLE FROM THE STANDARDS SECRETARIAT OF THE ACOUSTICAL SOCIETY OF AMERICA

• **ASA NOISE STDS INDEX 3-1985** Index to Noise Standards

S1 STANDARDS ON ACOUSTICS

• **ANSI S1.1-1994** American National Standard Acoustical Terminology
• **ANSI S1.4-1983** (**R 1997**) American National Standard Specification for Sound Level Meters
• **ANSI S1.4A-1985** Amendment to S1.4-1983
• **ANSI S1.6-1984** (**R 1997**) American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements
• **ANSI S1.8-1989** (**R 1997**) American National Standard Reference Quantities for Acoustical Levels
• **ANSI S1.9-1996** American National Standard Instruments for the Measurement of Sound Intensity
• **ANSI S1.10-1966** (**R 1997**) American National Standard Method for the Calibration of Microphones
• **ANSI S1.11-1986** (**R 1993**) American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters
• **ANSI S1.12-1967** (**R 1997**) American National Standard Specification for Laboratory Standard Microphones
• **ANSI S1.13-1995** American National Standard Measurement of Sound Pressure Levels in Air
• **ANSI S1.14-1998** American National Standard Recommendations for Specifying and Testing the Susceptibility of Acoustical Instruments to Radiated Radio-frequency Electromagnetic Fields, 25 MHz to 1 GHz
• **ANSI S1.15-1997/Part 1** American National Standard Measurement Microphones, Part 1: Specifications for Laboratory Standard Microphones
• **ANSI S1.18-1999** American National Standard Template Method for Ground Impedance
• **ANSI S1.20-1988** (**R 1993**) American National Standard Procedures for Calibration of Underwater Electroacoustic Transducers
• **ANSI S1.22-1992** (**R 1997**) American National Standard Scales and Sizes for Frequency Characteristics and Polar Diagrams in Acoustics
• **ANSI S1.25-1991** (**R 1997**) American National Standard Specification for Personal Noise Dosimeters (Revision of ANSI S1.25-1978)
• **ANSI S1.26-1995** American National Standard Method for the Calculation of the Absorption of Sound by the Atmosphere
• **ANSI S1.40-1984** (**R 1997**) American National Standard Specification for Acoustical Calibrators
• **ANSI S1.42-1986** (**R 1992**) American National Standard Design Response of Weighting Networks for Acoustical Measurements
• **ANSI S1.43-1997** American National Standard Specifications for Integrating-Averaging Sound Level Meters

S2 STANDARDS ON MECHANICAL VIBRATION AND SHOCK

• **ANSI S2.2-1959** (**R 1997**) American National Standard Methods for the Calibration of Shock and Vibration Pickups
• **ANSI S2.3-1964** (**R 1997**) American National Standard Specifications for a High-Impact Shock Machine for Electronic Devices
• **ANSI S2.4-1976** (**R 1997**) American National Standard Method for Specifying the Characteristics of Auxiliary Analog Equipment for Shock and Vibration Measurements
• **ANSI S2.5-1962** (**R 1997**) American National Standard Recommendations for Specifying the Performance of Vibration Machines
• **ANSI S2.7-1982** (**R 1997**) American National Standard Balancing Terminology
• **ANSI S2.8-1972** (**R 1997**) American National Standard for Describing the Characteristics of Resilient Mountings
• **ANSI S2.9-1976** (**R 1997**) American National Standard Nomenclature for Specifying Damping Properties of Materials
• **ANSI S2.10-1971** (**R 1997**) American National Standard Methods for Analysis and Presentation of Shock and Vibration Data
• **ANSI S2.11-1969** (**R 1997**) American National Standard for the Selection of Calibrations and Tests for Electrical Transducers used for Measuring Shock and Vibration
• **ANSI S2.13-1996/Part 1** American National Standard Mechanical Vibration of Non-Reciprocating Machines—Measurements on Rotating Shafts and Evaluation—Part 1: General Guidelines
• **ANSI S2.14-1973** (**R 1997**) American National Standard for Specifying the Performance of Shock Machines
• **ANSI S2.15-1972** (**R 1997**) American National Standard Specification for the Design, Construction, and Operation of Class HI (High-Impact) Shock-Testing Machine for Lightweight Equipment
• **ANSI S2.16-1997** American National Standard Vibratory Noise Measurements and Acceptance Criteria for Shipboard Equipment
• **ANSI S2.17-1980** (**R 1997**) American National Standard Techniques of Machinery Vibration Measurement
• **ANSI S2.19-1999** American National Standard Mechanical Vibration−Balance Quality Requirements of Rigid Rotors, Part 1: Determination of Permissible Residual Unbalance, Including Marine Applications
• **ANSI S2.20-1983** (**R 1997**) American National Standard for Estimating Airblast Characteristics for Single Point Explosions in Air, With a Guide to Evaluation of Atmospheric Propagation and Effects
• **ANSI S2.21-1998** American National Standard Method for Preparation of a Standard Material for Dynamic Mechanical Measurements
• **ANSI S2.22-1998** American National Standard Resonance Method for Measuring Dynamic Mechanical Properties of Viscoelastic Materials
• **ANSI S2.23-1998** American National Standard Single Cantilever Beam Method for Measuring the Dynamic Mechanical Properties of Viscoelastic Materials
• **ANSI S2.31-1979** (**R 1997**) American National Standard Method for the Experimental Determination of Mechanical Mobility. Part I: Basic Definitions and Transducers
• **ANSI S2.32-1982** (**R 1997**) American National Standard Methods for the Experimental Determination of Mechanical Mobility. Part II: Measurements Using Single-Point Translation Excitation
• **ANSI S2.34-1984** (**R 1997**) American National Standard Guide to the Experimental Determination of Rotation Mobility Properties and the Complete Mobility Matrix
• **ANSI S2.38-1982** (**R 1997**) American National Standard Field Balancing Equipment—Description and Evaluation

• **ANSI S2.40-1984** (**R 1997**) American National Standard Mechanical Vibration of Rotating and Reciprocating Machinery—Requirements for Instruments for Measuring Vibration Severity

• **ANSI S2.41-1985** (**R 1997**) American National Standard Mechanical Vibration of Large Rotating Machines With Speed Range from 10 to 200 rev/s—Measurement and Evaluation of Vibration Severity *in situ*

• **ANSI S2.42-1982** (**R 1997**) American National Standard Procedures for Balancing Flexible Rotors

• **ANSI S2.43-1984** (**R 1997**) American National Standard Criteria for Evaluating Flexible Rotor Balance

• **ANSI S2.45-1983** (**R 1997**) American National Standard Electrodynamic Test Equipment for Generating Vibration—Methods of Describing Equipment Characteristics

• **ANSI S2.46-1989** (**R 1997**) American National Standard Characteristics to be Specified for Seismic Transducers

• **ANSI S2.47-1990** (**R 1997**) American National Standard Vibration of Buildings—Guidelines for the Measurement of Vibrations and Evaluation of Their Effects on Buildings

• **ANSI S2.48-1993** (**R 1997**) American National Standard Servo-Hydraulic Test Equipment for Generating Vibration—Methods of Describing Characteristics

• **ANSI S2.58-1983** (**R 1997**) American National Standard Auxiliary Tables for Vibration Generators—Methods of Describing Equipment Characteristics

• **ANSI S2.60-1987** (**R 1997**) American National Standard Balancing Machines—Enclosures and Other Safety Measures

• **ANSI S2.61-1989** (**R 1997**) American National Standard Guide to the Mechanical Mounting of Accelerometers

S3 STANDARDS ON BIOACOUSTICS

• **ANSI S3.1-1999** American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms

• **ANSI S3.2-1989** (**R 1999**) American National Standard Method for Measuring the Intelligibility of Speech Over Communication Systems

• **ANSI S3.4-1980** (**R 1997**) American National Standard Procedure for the Computation of Loudness of Noise

• **ANSI S3.5-1997** American National Standard Methods for Calculation of the Speech Intelligibility Index

• **ANSI S3.6-1996** American National Standard Specification for Audiometers

• **ANSI S3.7-1995** (**R 1999**) American National Standard Method for Coupler Calibration of Earphones

• **ANSI S3.13-1987** (**R 1997**) American National Standard Mechanical Coupler for Measurement of Bone Vibrators

• **ANSI S3.14-1977** (**R 1997**) American National Standard for Rating Noise with Respect to Speech Interference

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• **ANSI S3.20-1995** (**R 1999**) American National Standard Bioacoustical Terminology

• **ANSI S3.21-1978** (**R 1997**) American National Standard Method for Manual Pure-Tone Threshold Audiometry

• **ANSI S3.22-1996** American National Standard Specification of Hearing Aid Characteristics

• **ANSI S3.25-1989** (**R 1999**) American National Standard for an Occluded Ear Simulator

• **ANSI S3.29-1983** (**R 1996**) American National Standard Guide to the Evaluation of Human Exposure to Vibration in Buildings

• **ANSI S3.32-1982** (**R 1999**) American National Standard Mechanical Vibration and Shock Affecting Man—Vocabulary

• **ANSI S3.34-1986** (**R 1997**) American National Standard Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand

• **ANSI S3.35-1985** (**R 1997**) American National Standard Methods of Measurement of Performance Characteristics of Hearing Aids Under Simulated *in-situ* Working Conditions

• **ANSI S3.36-1985** (**R 1996**) American National Standard Specification for a Manikin for Simulated *in situ* Airborne Acoustic Measurements

• **ANSI S3.37-1987** (**R 1997**) American National Standard Preferred Earhook Nozzle Thread for Postauricular Hearing Aids

• **ANSI S3.39-1987** (**R 1996**) American National Standard Specifications for Instruments to Measure Aural Acoustic Impedance and Admittance (Aural Acoustic Immittance)

• **ANSI S3.40-1989** (**R 1999**) American National Standard Guide for the Measurement and Evaluation of Gloves Which are Used to Reduce Exposure to Vibration Transmitted to the Hand

• **ANSI S3.41-1990** (**R 1996**) American National Standard Audible Emergency Evacuation Signal

• **ANSI S3.42-1992** (**R 1997**) American National Standard Testing Hearing Aids with a Broad-Band Noise Signal

• **ANSI S3.44-1996** American National Standard Determination of Occupational Noise Exposure and Estimation of Noise-Induced Hearing Impairment

• **ANSI S3.45-1999** Procedures for Testing Basic Vestibular Function

• **ANSI S3.46-1997** American National Standard Methods of Measurement of Real-Ear Performance Characteristics of Hearing Aids

S12 STANDARDS ON NOISE

• **ANSI S12.1-1983** (**R 1996**) American National Standard Guidelines for the Preparation of Standard Procedures for the Determination of Noise Emission from Sources

• **ANSI S12.2-1995** American National Standard Criteria for Evaluating Room Noise

• **ANSI S12.3-1985** (**R 1996**) American National Standard Statistical Methods for Determining and Verifying Stated Noise Emission Values of Machinery and Equipment

• **ANSI S12.5-1990** (**R 1997**) American National Standard Requirements for the Performance and Calibration of Reference Sound Sources

• **ANSI S12.6-1997** American National Standard Method for the Measurement of the Real-Ear Attenuation of Hearing Protectors (Revision of ANSI S12.6-1984)

• **ANSI S12.7-1986** (**R 1998**) American National Standard Methods for Measurements of Impulse Noise

• **ANSI S12.8-1998** American National Standard Methods for Determining the Insertion Loss of Outdoor Noise Barriers

• **ANSI S12.9-1988/Part 1** (**R 1998**) American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 1

• **ANSI S12.9-1992/Part 2** (**R 1998**) American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 2: Measurement of Long-Term, Wide-Area Sound

• **ANSI S12.9-1993/Part 3** (**R 1998**) American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 3: Short-Term Measurements with an Observer Present

• **ANSI S12.9-1996/Part 4** American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 4: Noise Assessment and Prediction of Long-Term Community Response

- **ANSI S12.9-1998/Part 5** American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 5: Sound Level Descriptors for Determination of Compatible Land Use
- **ANSI S12.10-1985 (R 1997)** American National Standard Methods for the Measurement and Designation of Noise Emitted by Computer and Business Equipment (Revision of ANSI S1.29-1979)
- **ANSI S12.11-1987 (R 1997)** American National Standard Methods for the Measurement of Noise Emitted by Small Air-Moving Devices
- **ANSI S12.12-1992 (R 1997)** American National Standard Engineering Method for the Determination of Sound Power Levels of Noise Sources Using Sound Intensity
- **DRAFT ANSI S12.13-1991** Draft American National Standard Evaluating the Effectiveness of Hearing Conservation Programs
- **ANSI S12.14-1992 (R 1997)** American National Standard Methods for the Field Measurement of the Sound Output of Audible Public Warning Devices Installed at Fixed Locations Outdoors
- **ANSI S12.15-1992 (R 1997)** American National Standard for Acoustics—Portable Electric Power Tools, Stationary and Fixed Electric Tools, and Gardening Appliances—Measurement of Sound Emitted
- **ANSI S12.16-1992 (R 1997)** American National Standard Guidelines for the Specification of Noise of New Machinery
- **ANSI S12.17-1996** American National Standard Impulse Sound Propagation for Environmental Noise Assessment
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- **ANSI S12.34-1988 (R 1997)** American National Standard Engineering Methods for the Determination of Sound Power Levelsof Noise Sources for Essentially Free-Field Conditions over a Reflecting Plane (Revision of ANSI S1.34-1980)
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- **ANSI S12.36-1990 (R 1997)** American National Standard Survey Methods for the Determination of Sound Power Levels of Noise Sources (Revision of ANSI S1.36-1979)
- **ANSI S12.42-1995** American National Standard Microphone-in-Real-Ear and Acoustic Test Fixture Methods for the Measurement of Insertion Loss of Circumaural Hearing Protection Devices
- **ANSI S12.43-1997** American National Standard Methods for Measurement of Sound Emitted by Machinery and Equipment at Workstations and Other Specified Positions
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