
AMERICAN NATIONAL STANDARD

Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Precision methods for reverberation test rooms (a Nationally Adopted International Standard)

ANSI/ASA S12.51-2012 / ISO 3741:2010

Accredited Standards Committee S12, Noise

Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114 E
Melville, NY 11747-3177

The American National Standards Institute, Inc. (ANSI) is the national coordinator of voluntary standards development and the clearinghouse in the U.S.A. for information on national and international standards.

The Acoustical Society of America (ASA) is an organization of scientists and engineers formed in 1929 to increase and diffuse the knowledge of acoustics and to promote its practical applications.



AMERICAN NATIONAL STANDARD

Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms

(a nationally adopted international standard)

Secretariat:

Acoustical Society of America

Approved on February 23, 2012 by:

American National Standards Institute, Inc.

Abstract

This American National Standard specifies methods for determining the sound power level or sound energy level of a noise source from sound pressure levels measured in a reverberation test room. The sound power level (or, in the case of noise bursts or transient noise emission, the sound energy level) produced by the noise source, in frequency bands of width one-third-octave, is calculated using those measurements, including corrections to allow for any differences between the meteorological conditions at the time and place of the test and those corresponding to a reference characteristic impedance. Measurement and calculation procedures are given for both a direct method and a comparison method of determining the sound power level and the sound energy level.

AMERICAN NATIONAL STANDARDS ON ACOUSTICS

The Acoustical Society of America (ASA) provides the Secretariat for Accredited Standards Committees S1 on Acoustics, S2 on Mechanical Vibration and Shock, S3 on Bioacoustics, S3/SC 1 on Animal Bioacoustics, and S12 on Noise. These committees have wide representation from the technical community (manufacturers, consumers, trade associations, organizations with a general interest, and government representatives). The standards are published by the Acoustical Society of America as American National Standards after approval by their respective Standards Committees and the American National Standards Institute (ANSI).

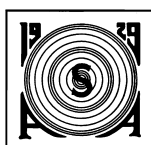
These standards are developed and published as a public service to provide standards useful to the public, industry, and consumers, and to Federal, State, and local governments.

Each of the Accredited Standards Committees (operating in accordance with procedures approved by ANSI) is responsible for developing, voting upon, and maintaining or revising its own Standards. The ASA Standards Secretariat administers Committee organization and activity and provides liaison between the Accredited Standards Committees and ANSI. After the Standards have been produced and adopted by the Accredited Standards Committees, and approved as American National Standards by ANSI, the ASA Standards Secretariat arranges for their publication and distribution.

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered and that a concerted effort be made towards their resolution.

The use of an American National Standard is completely voluntary. Their existence does not in any respect preclude anyone, whether he or she has approved the Standards or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the Standards.

NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken periodically to reaffirm, revise, or withdraw this Standard.



Acoustical Society of America
ASA Secretariat
35 Pinelawn Road, Suite 114E
Melville, New York 11747-3177
Telephone: 1 (631) 390-0215
Fax: 1 (631) 390-0217
E-mail: asastds@aip.org

© 2012 by Acoustical Society of America. This standard may not be reproduced in whole or in part in any form for sale, promotion, or any commercial purpose, or any purpose not falling within the provisions of the U.S. Copyright Act of 1976, without prior written permission of the publisher. For permission, address a request to the Standards Secretariat of the Acoustical Society of America.

Contents

1	Scope	1
1.1	General	1
1.2	Types of noise and noise sources	1
1.3	Reverberation test room.....	1
1.4	Measurement uncertainty.....	2
2	Normative references	2
3	Terms and definitions.....	2
4	Reference meteorological conditions	7
5	Reverberation test room.....	7
5.1	General	7
5.2	Volume and shape of test room	7
5.3	Sound absorption of test room.....	7
5.4	Criteria for background noise	8
5.5	Atmospheric temperature, humidity and pressure	10
6	Instrumentation and measurement equipment	11
6.1	General	11
6.2	Calibration	11
7	Definition, location, installation, and operation of noise source under test.....	12
7.1	General	12
7.2	Auxiliary equipment.....	12
7.3	Noise source location.....	12
7.4	Installation and mounting conditions.....	12
7.5	Operation of source during test.....	13
8	Measurements in the reverberation test room	14
8.1	General	14
8.2	Initial location of the noise source under test.....	14
8.3	Microphone positions	14
8.4	Measurement of sound pressure levels	16
8.5	Measurement of single event time-integrated sound pressure levels	19
8.6	Measurement of sound pressure levels from the reference sound source for the comparison method	20
8.7	Measurement of reverberation time	21
8.8	Measurement of meteorological conditions	21
9	Determination of sound power levels and sound energy levels.....	21
9.1	Determination of sound power levels.....	21
9.2	Determination of sound energy levels.....	26
9.3	A-weighted sound power level and sound energy level.....	30
10	Measurement uncertainty.....	30
10.1	Methodology.....	30
10.2	Determination of σ_{omc}	31
10.3	Determination of σ_{R0}	32
10.4	Typical upper bound values of σ_{R0}	33
10.5	Total standard deviation σ_{tot} and expanded measurement uncertainty, U	34
11	Information to be recorded.....	34
11.1	General	34
11.2	Noise source under test	34

11.3	Test environment	35
11.4	Instrumentation	35
11.5	Acoustical data	35
12	Test report	36
Annex A (informative)	Guidelines for the design of reverberation test rooms	37
A.1	General	37
A.2	Volume of reverberation test room	37
A.3	Shape of reverberation test room	37
A.4	Absorption of reverberation test room	38
Annex B (informative)	Guidelines for the design of rotating diffusing vanes	39
Annex C (normative)	Reverberation test room qualification procedure for the measurement of broad-band sound	40
C.1	Introduction	40
C.2	Instrumentation and equipment	40
C.3	Test procedure	40
C.4	Calculation	41
C.5	Qualification	41
Annex D (normative)	Reverberation test room qualification procedure for the measurement of discrete-frequency components	42
D.1	Introduction	42
D.2	General	43
D.3	Instrumentation and measurement equipment	43
D.4	Loudspeaker test	43
D.5	Room test	44
D.6	Computational procedure	44
D.7	Qualification	45
D.8	Multiple source locations	45
Annex E (informative)	Extension of frequency range to frequencies below 100 Hz	47
E.1	Additional frequency range	47
E.2	Supplement to Table 6	47
E.3	Supplement to Table 1 (Minimum volume of the reverberation test room as a function of the lowest frequency band of interest)	47
E.4	Supplement to Table 4 (Minimum number of microphone positions for the measurement of sound pressure level) and Table 5 (Minimum number of source locations for the measurement of sound pressure level)	47
E.5	Supplement to Table C.1	48
E.6	Supplement to Tables D.1 and D.2	48
Annex F (normative)	Calculation of octave band sound power levels and sound energy levels, A- weighted sound power levels and A-weighted sound energy levels from one-third-octave band levels	50
F.1	Sound power levels	50
F.2	Sound energy levels	51
F.3	Values of k and C_k for use in calculations	52
Annex G (informative)	Guidelines on the development of information on measurement uncertainty	54
G.1	General	54
G.2	Considerations on the total standard deviation σ_{tot}	54
G.3	Considerations on σ_{omc}	55
G.4	Considerations on σ_{R0}	56
G.5	Combined standard uncertainty	67
G.6	Measurement uncertainty based on reproducibility data	67

Tables

Table 2 —Absolute maximum background noise levels in test room	10
Table 3 — Allowable limits in the variation of atmospheric temperature and relative humidity during measurements in the reverberation test room	11
Table 4 —Minimum number of microphone positions for the measurement of sound pressure levels.....	18
Table 5 —Minimum number of source locations and value, K_S , for the measurement of sound pressure levels	19
Table 6 —Typical upper bound values of the standard deviation of reproducibility of the method, σ_{R0} , for A-weighted sound power levels and sound energy levels determined in accordance with this American National Standard	34
Table A.1 — Recommended room dimension ratios for right cuboid rooms	38
Table C.1 — Maximum allowable standard deviation of L_{pi}	41
Table D.1 — Maximum allowable sample standard deviations, s_f	42
Table D.2 — Test frequencies for alternative qualification of reverberation test room for measuring sound power levels and sound energy levels of noise sources emitting significant discrete-frequency components	46
Table E.1 — Standard deviations of reproducibility and typical total standard deviations of sound power levels and sound energy levels below 100 Hz.....	47
Table E.2 — Maximum allowable standard deviation of L_{pi}	48
Table E.3 —Maximum allowable sample standard deviations, s_f	48
Table E.4 — Test frequencies for alternative qualification of reverberation test room for measuring sound power levels and sound energy levels of noise sources emitting significant discrete-frequency components	49
Table F.1 — Values of k and C_k for mid-band frequencies of one-third-octave bands.....	53
Table G.1 — Examples of calculated total standard deviations σ_{tot} for three different cases.....	56
Table G.2 — Uncertainty budget for determinations of σ_{R0} for sound power level and sound energy level using the direct method, valid for A-weighted measurements of a source with a relatively flat frequency spectrum	60

Foreword

[This Foreword is for information only, and is not a part of the American National Standard ANSI/ASA S12.51-2012 / ISO 3741:2010 American National Standard Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms.]

This standard comprises a part of a group of definitions, standards, and specifications for use in noise. It was developed and approved by Accredited Standards Committee S12, Noise, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S12 is as follows:

Standards, specifications, and terminology in the field of acoustical noise pertaining to methods of measurement, evaluation, and control, including biological safety, tolerance, and comfort, and physical acoustics as related to environmental and occupational noise.

This standard is a revision of ANSI S12.51-2002 (R 2007) / ISO 3741:1999, which has been technically revised.

This Standard is identical to International Standard ISO 3741, Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms, which was prepared by Technical Committee ISO/TC 43 Subcommittee SC 1, Noise. However, in conformance with ANSI and ISO rules, the words "American National Standard" replace the words "International Standard" where they appear in the ISO document, decimal points were substituted in place of the decimal commas used in ISO documents, and American English spelling is used in place of British English spelling.

The ANSI or ANSI/ASA equivalents for the ISO standards in the ISO 3740 series and other referenced nationally adopted standards are given below:

- ANSI S12.5 / ISO 6926 is an identical national adoption of ISO 6926;
- ANSI/ASA S12.50/ISO 3740 is an identical national adoption of ISO 3740;
- ANSI/ASA S12.51/ISO 3741 is an identical national adoption of ISO 3741;
- ANSI/ASA S12.53/Part 1/ISO 3743-1 is an identical national adoption of ISO 3743-1;
- ANSI/ASA S12.53/Part 2/ISO 3743-2 is an identical national adoption of ISO 3743-2;
- ANSI/ASA S12.54/ISO 3744 is an identical national adoption of ISO 3744;
- ANSI S12.55/ISO 3745 is an identical national adoption of ISO 3745;
- ANSI/ASA S12.56/ISO 3746 is an identical national adoption of ISO 3746; and
- ANSI/ASA S12.57/ISO 3747 is an identical national adoption of ISO 3747.

At the time this Standard was submitted to Accredited Standards Committee S12, Noise for approval, the membership was as follows:

W.J. Murphy, *Chair*
R.D. Hellweg, *Vice-Chair*

S.B. Blaeser, *Secretary*

3M Occupational Health & Environmental Safety Division E.H. Berger

Acoustical Society of America R.D. Hellweg
..... D. Lubman (Alt.)

Air-Conditioning, Heating and Refrigeration Institute S. Lind
..... D. Abbate (Alt.)

Air Movement & Control Association	J.A. Brooks M. Stevens (Alt.)
Alcoa Inc.	W.D. Gallagher
American Academy of Audiology	D. Ostergren S. Gordon-Salant (Alt.)
American Academy of Otolaryngology - Head and Neck Surgery	R.A. Dobie L.A. Michael (Alt.)
American Industrial Hygiene Association	D. Driscoll S.N. Hacker (Alt.)
American Speech-Language-Hearing Association	L.A. Wilber V. Gladstone (Alt.)
Caterpillar, Inc.	K.G. Meitl
Compressed Air and Gas Institute	R.C. Johnson D.R. Bookshar (Alt.)
Council for Accreditation in Occupational Hearing Conservation	VACANT L.D. Hager (Alt.)
Emerson Electric – Copeland Corporation	A.T. Herfat G. Williamson (Alt.)
ETS – Lindgren Acoustic Systems	D. Winker M. Black (Alt.)
ExxonMobil	B. Moulton
G.R.A.S. Sound & Vibration	J. Sondergaard B. Schustrich (Alt.)
General Motors	D.B. Moore
Harley-Davidson Motor Company	D. Jaeger
Information Technology Industry Council	W.M. Beltman J. Rosenberg (Alt.)
Institute of Noise Control Engineering	R.J. Peppin B. Tinianov (Alt.)
International Safety Equipment Association	J. Birkner C.Z. Fargo (Alt.)
John Deere	K.B. Washburn K. Cone (Alt.)
National Council of Acoustical Consultants	J. Erdreich G.E. Winzer (Alt.)
National Hearing Conservation Association	J. Cissna
National Institute for Occupational Safety and Health	W.J. Murphy E. Zechmann (Alt.)

National Institute of Standards and Technology – National Voluntary Laboratory Accreditation Program	B.A. Sandoval
National Park Service	G.R. Stanley K. Fristrup (Alt.)
Noise Control Engineering, Inc.	M.A. Bahtiarian R. Fischer (Alt.)
Noise Pollution Clearinghouse	L. Blomberg
North American Insulation Manufacturers Association	H. Alter
PCB Group	K. Cox L. Harbaugh (Alt.)
Power Tool Institute, Inc.	W.D. Spencer M. Hickok (Alt.)
Quest Technologies, Inc.	M. Wurm P.J. Battenberg (Alt.)
Schomer and Associates, Inc.	P.D. Schomer
Sierra Club – National Parks and Monuments Committee	D.J. Hingson
Sperian Hearing Protection, LLC	B. Witt T. Schulz (Alt.)
U.S. Access Board	M.K. Mazz
U.S. Air Force	R.L. McKinley H. Gallagher (Alt.)
U.S. Army Aeromedical Research Lab	W.A. Ahroon
U.S. Army Construction Engineering Research Laboratory	M.J. White M. Swearington (Alt.)
U.S. Army Public Health Command	C. Stewart M. Grantham (Alt.)
U.S. Army Research Laboratory, Human Research and Engineering Directorate	J. Gaston M.S. Binseel (Alt.)
U.S. Department of Transportation	A. Konheim
U.S. Naval Surface Warfare Center - Carderock	M. Craun VACANT (Alt.)
Université du Québec ETS	J. Voix F. Laville (Alt.)

Individual Experts of Accredited Standards Committee S12, Noise, were:

P.K. Baade	R.D. Hellweg	R.J. Peppin
E.H. Berger	W.W. Lang	J. Schmitt
B.M. Brooks	D. Lubman	P.D. Schomer
A.J. Campanella	D. Michaud	L.C. Sutherland
K.M. Eldred	N.P. Miller	W.R. Thornton
L.S. Finegold	W.J. Murphy	L.A. Wilber
R.D. Godfrey	M.A. Nobile	G.E. Winzer

Working Group S12/WG 23, Determination of Sound Power, which assisted Accredited Standards Committee S12, Noise, in the development of this standard, had the following membership.

B.M. Brooks, Co-Chair
J. Schmitt, Co-Chair

M.C. Black	K. Cunefare	M.A. Nobile
S. Bly	R.D. Hellweg	M. O'Connell
A.J. Campanella	A.T. Herfat	P.D. Schomer
D.A. Collings	S. Keith	J. Weinstein
	G.C. Maling	

Suggestions for improvements of this standard will be welcomed. They should be sent to Accredited Standards Committee S12, Noise, in care of the Standards Secretariat of the Acoustical Society of America, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177. Telephone: 631-390-0215; FAX: 631-390-0217; E-mail: asastds@aip.org.

Introduction

This American National Standard is one of the series ISO 3740^[2] to ISO 3747^[8], which specify various methods for determining the sound power levels and sound energy levels of noise sources including machinery, equipment and their sub-assemblies. The selection of one of the methods from the series for use in a particular application depends on the purpose of the test to determine the sound power level or sound energy level and on the facilities available. General guidelines to assist in the selection are provided in ISO 3740^[2]. ISO 3740^[2] to ISO 3747^[8] give only general principles regarding the operating and mounting conditions of the machinery or equipment for the purposes of the test. It is important that test codes be established for individual kinds of noise sources, in order to give detailed requirements for mounting, loading, and operating conditions under which the sound power levels or sound energy levels are to be obtained.

The methods given in this American National Standard require the source under test to be mounted in a reverberation test room having specified acoustical characteristics. The methods are then based on the premise that the sound power or sound energy of the source under test is directly proportional to the mean-square sound pressure averaged in space and time, and otherwise depends only on the acoustical and geometric properties of the room and on the physical constants of air.

For a source emitting sound in narrow bands of frequency or at discrete frequencies, a precise determination of the radiated sound power level or sound energy level in a reverberation test room requires greater effort than for a source emitting sound more evenly over a wide range of frequencies, because:

- a) the space- and time-averaged sound pressure along a short microphone path, or as determined with an array of a small number of microphones, is not always a good estimate of the space- or time-averaged mean-square pressure throughout the room;
- b) the sound power or sound energy radiated by the source is more strongly influenced by the normal modes of the room and by the position of the source within the room.

The increased measurement effort in the case of a source emitting narrow bands of sound or discrete tones consists of either the optimization and qualification of the test room or the use of a greater number of source locations and microphone positions (or increased path length for a moving microphone). The addition of low-frequency absorbers or the installation of rotating diffusers in the test room can help to reduce the measurement effort.

The methods specified in this American National Standard permit the determination of the sound power level and the sound energy level in one-third-octave frequency bands, from which octave band data, A-weighted frequency data, and total unweighted sound can be computed.

This American National Standard describes methods of accuracy grade 1 (precision grade) as defined in ISO 12001. The resulting sound power levels and sound energy levels include corrections to allow for any differences that might exist between the meteorological conditions under which the tests are conducted and reference meteorological conditions. For applications in reverberant environments where reduced accuracy is acceptable, reference can be made to ISO 3743-1^[3], ISO 3743-2^[4] or ISO 3747^[8].

Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms

1 Scope

1.1 General

This American National Standard specifies methods for determining the sound power level or sound energy level of a noise source from sound pressure levels measured in a reverberation test room. The sound power level (or, in the case of noise bursts or transient noise emission, the sound energy level) produced by the noise source, in frequency bands of width one-third-octave, is calculated using those measurements, including corrections to allow for any differences between the meteorological conditions at the time and place of the test and those corresponding to a reference characteristic impedance. Measurement and calculation procedures are given for both a direct method and a comparison method of determining the sound power level and the sound energy level.

In general, the frequency range of interest includes the one-third-octave bands with mid-band frequencies from 100 Hz to 10 000 Hz. Guidelines for the application of the specified methods over an extended frequency range in respect to lower frequencies are given in Annex E. This American National Standard is not applicable to frequency ranges above the 10 000 Hz one-third-octave band.

NOTE For higher frequencies, the methods specified in ISO 9295 can be used.

1.2 Types of noise and noise sources

The methods specified in this American National Standard are suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001.

The noise source under test can be a device, machine, component or sub-assembly. This American National Standard is applicable to noise sources with a volume not greater than 2 % of the volume of the reverberation test room. For a source with a volume greater than 2 % of the volume of the test room, it is possible that the achievement of results as defined in ISO 12001:1996, accuracy grade 1 (precision grade) is not feasible.

NOTE In specific cases, the source volume can be increased to a maximum of 5 % of the room volume. In such cases, the relevant noise test code indicates the possible consequences on the measurement uncertainty.

1.3 Reverberation test room

The test rooms that are applicable for measurements made in accordance with this American National Standard are reverberation test rooms meeting specified requirements (see Clause 5).

1.4 Measurement uncertainty

Information is given on the uncertainty of the sound power levels and sound energy levels determined in accordance with this American National Standard, for measurements made in specific frequency bands and for the A-weighted sum of all frequency bands. The uncertainty conforms to ISO 12001:1996, accuracy grade 1 (precision grade).

2 Normative references

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

ISO 3382-2, *Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms*

ISO 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*

ISO 6926, *Acoustics — Requirements for the performance and calibration of reference sound sources for the determination of sound power levels*

ISO 12001:1996, *Acoustics — Noise emitted by machinery and equipment — Rules for the drafting and presentation of a noise test code*

ISO/IEC Guide 98-3, *Uncertainty in measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

IEC 60942:2003, *Electroacoustics — Sound calibrators*

IEC 61183, *Electroacoustics — Random-incidence and diffuse-field calibration of sound level meters*

IEC 61260:1995, *Electroacoustics — Octave-band and fractional-octave-band filters*

IEC 61672-1:2002, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

sound pressure

p

difference between instantaneous pressure and static pressure

NOTE 1 Adapted from ISO 80000-8:2007^[21], 8-9.2.

NOTE 2 Sound pressure is expressed in pascals.

3.2 sound pressure level

L_p

ten times the logarithm to the base 10 of the ratio of the square of the sound pressure, p , to the square of a reference value, p_0 , expressed in decibels

$$L_p = 10 \lg \frac{p^2}{p_0^2} \text{ dB} \quad (1)$$

where the reference value, p_0 , is 20 μPa

[ISO/TR 25417:2007^[20], 2.2]

NOTE 1 If specific frequency and time weightings as specified in IEC 61672-1 and/or specific frequency bands are applied, this is indicated by appropriate subscripts; e.g. L_{pA} denotes the A-weighted sound pressure level.

NOTE 2 This definition is technically in accordance with ISO 80000-8:2007^[21], 8-22.

3.3 time-averaged sound pressure level

$L_{p,T}$

ten times the logarithm to the base 10 of the ratio of the time average of the square of the sound pressure, p , during a stated time interval of duration, T (starting at t_1 and ending at t_2), to the square of a reference value, p_0 , expressed in decibels

$$L_{p,T} = 10 \lg \left[\frac{\frac{1}{T} \int_{t_1}^{t_2} p^2(t) dt}{p_0^2} \right] \text{ dB} \quad (2)$$

where the reference value, p_0 , is 20 μPa

NOTE 1 In general, the subscript “ T ” is omitted since time-averaged sound pressure levels are necessarily determined over a certain measurement time interval.

NOTE 2 Time-averaged sound pressure levels are often A-weighted, in which case they are denoted by $L_{pA,T}$, which is usually abbreviated to L_{pA} .

NOTE 3 Adapted from ISO/TR 25417:2007^[20], 2.3.

3.4 single event time-integrated sound pressure level

L_E

ten times the logarithm to the base 10 of the ratio of the integral of the square of the sound pressure, p , of an isolated single sound event (burst of sound or transient sound) over a stated time interval T (starting at t_1 and ending at t_2) to a reference value, E_0 , expressed in decibels

$$L_{E,T} = 10 \lg \left[\frac{\int_{t_1}^{t_2} p^2(t) dt}{E_0} \right] \text{ dB} \quad (3)$$

where the reference value, E_0 , is $(20 \mu\text{Pa})^2 \text{ s} = 4 \times 10^{-10} \text{ Pa}^2 \text{ s}$

NOTE 1 This quantity can be obtained by $L_{p,T} + 10 \lg \frac{T}{T_0} \text{ dB}$, where $T_0 = 1 \text{ s}$.

NOTE 2 When used to measure sound immission, this quantity is usually called “sound exposure level” (see ISO/TR 25417:2007^[20]).

3.5 measurement time interval

T

portion or a multiple of an operational period or operational cycle of the noise source under test for which the time-averaged sound pressure level is determined

NOTE Measurement time interval is expressed in seconds.

3.6 reverberation test room

test room meeting the requirements of this American National Standard

3.7 reverberant sound field

that portion of the sound field in the test room over which the influence of sound received directly from the source is negligible

3.8 reverberation time

T_n

duration required for the space-averaged sound energy density in an enclosure to decrease $10^{-n/10}$ (i.e. by $n \text{ dB}$) after the source emission has stopped

[ISO 80000-8:2007^[21], 8-29]

NOTE 1 Reverberation time is expressed in seconds.

NOTE 2 The reverberation time is frequency dependent.

NOTE 3 For the purposes of this American National Standard, $n = 60$, and the symbol used is T_{60} .

3.9 sound absorption coefficient

α

at a given frequency and for specified conditions, the relative fraction of sound power incident upon a surface which is not reflected

NOTE For the purposes of this American National Standard, sound absorption coefficients are calculated in accordance with ISO 354^[1].

3.10 equivalent sound absorption area

A

product of the area and sound absorption coefficient of a surface

NOTE Equivalent sound absorption area is expressed in square metres.

3.11 reference sound source sound source meeting specified requirements

NOTE For the purposes of this American National Standard, the requirements are those specified in ISO 6926:1999, Clause 5.

3.12 frequency range of interest for general purposes, the frequency range of one-third-octave bands with nominal mid-band frequencies from 100 Hz to 10 000 Hz

NOTE For special purposes, the frequency range can be extended or reduced, provided that the test environment and instrumentation otherwise meet all requirements of this American National Standard. The frequency range can be extended downwards as far as the 50 Hz one-third-octave band (see Annex E), but cannot be extended upwards beyond the 10 000 Hz band. Any reduced or extended frequency range is clearly indicated as such in the report.

3.13 background noise noise from all sources other than the noise source under test

NOTE Background noise includes contributions from airborne sound, noise from structure-borne vibration, and electrical noise in the instrumentation.

3.14 background noise correction

K_1

correction applied to the measured sound pressure levels in the reverberation test room to account for the influence of background noise

NOTE 1 Background noise correction is expressed in decibels.

NOTE 2 The background noise correction is frequency dependent; the correction in the case of a frequency band is denoted K_{1f} , where f denotes the relevant mid-band frequency.

3.15 sound power

P

through a surface, product of the sound pressure, p , and the component of the particle velocity, u_n , at a point on the surface in the direction normal to the surface, integrated over that surface

[ISO 80000-8:2007^[21], 8-16]

NOTE 1 Sound power is expressed in watts.

NOTE 2 The quantity relates to the rate per time at which airborne sound energy is radiated by a source.

3.16 sound power level

L_W

ten times the logarithm to the base 10 of the ratio of the sound power of a source, P , to a reference value, P_0 , expressed in decibels

$$L_W = 10 \lg \frac{P}{P_0} \text{ dB} \quad (4)$$

where the reference value, P_0 , is 1 pW

NOTE 1 If a specific frequency weighting as specified in IEC 61672-1 and/or specific frequency bands are applied, this is indicated by appropriate subscripts; e.g. L_{WA} denotes the A-weighted sound power level.

NOTE 2 This definition is technically in accordance with ISO 80000-8:2007^[21], 8-23.

[ISO/TR 25417:2007^[20], 2.9]

3.17 sound energy

J

integral of the sound power, P , over a stated time interval of duration T (starting at t_1 and ending at t_2)

$$J = \int_{t_1}^{t_2} P(t) dt \quad (5)$$

NOTE 1 Sound energy is expressed in joules.

NOTE 2 The quantity is particularly relevant for non-stationary, intermittent sound events.

[ISO/TR 25417:2007^[20], 2.10]

3.18 sound energy level

L_J

ten times the logarithm to the base 10 of the ratio of the sound energy, J , to a reference value, J_0 , expressed in decibels

$$L_J = 10 \lg \frac{J}{J_0} \text{ dB} \quad (6)$$

where the reference value, J_0 , is 1 pJ

NOTE If a specific frequency weighting as specified in IEC 61672-1 and/or specific frequency bands are applied, this is indicated by appropriate subscripts; e.g. L_{JA} denotes the A-weighted sound energy level.

[ISO/TR 25417:2007^[20], 2.11]

4 Reference meteorological conditions

Reference meteorological conditions for the purpose of determining the sound power level and sound energy level are:

- a) air temperature: 23.0 °C;
- b) static pressure: 101.325 kPa;
- c) relative humidity: 50 %.

5 Reverberation test room

5.1 General

The reverberation test room shall be large enough and have a low enough total sound absorption to provide an adequate reverberant sound field for all frequency bands within the frequency range of interest. Guidelines for the design of rooms suitable for use in determining sound power levels and sound energy levels in accordance with this American National Standard are given in Annex A. Guidelines for the design of rotating diffusing vanes in the room are given in Annex B.

5.2 Volume and shape of test room

The recommended minimum volume of the room is given in Table 1. All test rooms should be qualified using Annex C. For test rooms with volumes less than the values shown in Table 1 for the frequency range of interest, or with a volume exceeding 300 m³, the adequacy of the room for broadband measurements shall be demonstrated using the procedure specified in Annex C. A room qualification procedure for the measurement of discrete-frequency components is specified in Annex D, which also specifies a general room qualification procedure as an alternative to qualification of individual sources (using 8.4.2 or 8.5.2). Information is given in Annex E to assist in testing at frequencies below 100 Hz.

Table 1 — Recommended minimum volume of the reverberation test room as a function of the lowest frequency band of interest

Lowest one-third-octave band frequency of interest Hz	Minimum volume of the reverberation test room m ³
100	200
125	150
160	100
≥200	70

5.3 Sound absorption of test room

The sound absorption of the test room primarily affects the minimum distance to be maintained between the noise source under test and the microphone positions. It also influences the sound radiation of the source and the frequency response characteristics of the test space. For these reasons, the sound absorption of the test room shall be neither too large nor extremely small (see Annex A).

Over the frequency range of interest, all room surfaces within one wavelength of the noise source under test shall be designed to be reflective with an absorption coefficient less than 0.06. If low-frequency panel absorbers are required as per Annex C and/or Annex D, these devices may be mounted within one wavelength (at the lowest frequency of interest) of the noise source under test, but not closer than 1.5 m. The remaining surfaces shall have absorptive properties such that the reverberation time, T_{60} (for measurement, see 8.7), in seconds, in each one-third-octave band below 6.3 kHz, without the source under test in place, is numerically greater than the ratio of V and S :

$$T_{60} > \frac{V}{S} \quad (7)$$

where

V is the volume, expressed in cubic metres, of the reverberation test room;

S is the total surface area, expressed in square metres, of the test room.

If the requirement for the reverberation time given by Inequality (6) is not met, the adequacy of the room for broadband measurements shall be established by the procedure specified in Annex C.

NOTE Above 5 kHz, much of the absorption in the room is due to air. Keeping the relative humidity above 50 % helps to avoid excessive air absorption.

5.4 Criteria for background noise

5.4.1 Relative criteria for background noise

5.4.1.1 General

The time-averaged sound pressure level of the background noise in each frequency band within the frequency range of interest, measured and averaged (see 9.1.3 and 9.2.3) over the microphone positions or traverses, shall be below the corresponding time-averaged sound pressure level of the noise source under test by at least:

- a) 6 dB for one-third-octave bands of mid-band frequency 200 Hz and below and 6 300 Hz and above;
- b) 10 dB for one-third-octave bands of mid-band frequency from 250 Hz to 5 000 Hz.

If these requirements are met, the background noise criteria of this American National Standard are satisfied.

NOTE 1 The same criteria are applied to single event time-integrated sound pressure levels: the measurement time interval for the time average is the same as the measurement time interval associated with the single event.

NOTE 2 The noise associated with the microphone traversing mechanism, if one is used for the measurements, is considered to be part of the background noise. In such cases, the background noise is measured with the traversing mechanism operating.

5.4.1.2 Relative background noise criteria for frequency band measurements

The requirements of 5.4.1.1 may not be achievable in all frequency bands, even when the background noise levels in the test room are extremely low and well controlled. Therefore, any band within the frequency range of interest in which the A-weighted sound power level or sound energy level (see

Annex F) of the noise source under test (after correcting for background noise in accordance with 9.1.2 or 9.2.2) is at least 15 dB below the highest A-weighted band sound power or sound energy level may be excluded from the frequency range of interest for the purposes of determining compliance with the above criterion for background noise.

5.4.1.3 Relative background noise criteria for A-weighted measurements

If the A-weighted sound power level or sound energy level is to be determined and reported, the following steps shall be followed to determine whether this quantity meets the background noise criteria of this American National Standard:

- a) the A-weighted sound power level or sound energy level is computed in accordance with the procedures in this American National Standard using the data from every frequency band within the frequency range of interest;
- b) the computation is repeated, but excluding those bands for which $\Delta L_p < 6$ dB for one-third-octave bands of mid-band frequency 200 Hz and below and 6 300 Hz and above, and for which $\Delta L_p < 10$ dB for one-third-octave bands of mid-band frequency from 250 Hz to 5 000 Hz.

If the difference between these two levels is less than 0.5 dB, the A-weighted sound power level or sound energy level determined from the data for all bands may be considered as conforming to the background noise criteria of this American National Standard.

5.4.2 Absolute criteria for background noise

If it can be demonstrated that the background noise levels in the test room at the time of the measurements are less than or equal to those given in Table 2 for all bands within the frequency range of interest, the measurements can be taken as having met the background noise requirements of this American National Standard, even if the 6 dB or 10 dB requirements are not met for all bands. It can be assumed that the source emits little or no measurable noise in these frequency bands, and that the data reported represent an upper bound to the sound power level or sound energy level in these bands.

In the case where some of the measured levels from the source under test are less than or equal to those given in Table 2, the frequency range of interest may be restricted to a contiguous range of frequencies that includes both the lowest and highest frequencies at which the sound pressure level from the noise source exceeds the corresponding value in Table 2. In such cases, the applicable frequency range of interest shall be reported.

5.4.3 Statement of non-conformity with background noise criteria

If neither the relative criteria of 5.4.1 nor the absolute criteria in 5.4.2 are met, the report shall clearly state that the background noise requirements of this American National Standard have not been met, and shall identify the particular frequency bands that do not meet the criteria. Furthermore, the report shall not state or imply that the measurements have been made “in full conformity” with this American National Standard.

Table 2 —Absolute maximum background noise levels in test room

One-third-octave mid-band frequency Hz	Maximum band sound pressure level dB
50	42
63	39
80	36
100	33
125	30
160	27
200	24
250	21
315	18
400	15
500	12
630	11
800	11
1 000	10
1 250	10
1 600	10
2 000	10
2 500	10
3 150	10
4 000	10
5 000	10
6 300	10
8 000	10
10 000	10

5.5 Atmospheric temperature, humidity and pressure

In the region where the microphones are located, the variations of atmospheric temperature and relative humidity shall be within the limits shown in Table 3.

Measurements of atmospheric pressure shall be made to within ± 1.5 kPa.

The limits of Table 3 are generally sufficient. However, other temperature and humidity conditions may be specified in noise test codes for specific equipment types, especially if the operation of the equipment or noise emission levels depend on ambient conditions. In such cases, those conditions shall be applied.

Table 3 — Allowable limits in the variation of atmospheric temperature and relative humidity during measurements in the reverberation test room

Ranges of temperature θ °C	Ranges of relative humidity %		
	< 30 %	30 % to 50 %	> 50 %
	Allowable limits for temperature and relative humidity		
$-5 \leq \theta < 10$	$\pm 1\text{ °C}, \pm 3\%$	$\pm 1\text{ °C}, \pm 5\%$	$\pm 3\text{ °C}, \pm 10\%$
$10 \leq \theta < 20$	$\pm 1\text{ °C}, \pm 3\%$	$\pm 3\text{ °C}, \pm 5\%$	$\pm 3\text{ °C}, \pm 10\%$
$20 \leq \theta \leq 50$	$\pm 2\text{ °C}, \pm 3\%$	$\pm 5\text{ °C}, \pm 5\%$	$\pm 5\text{ °C}, \pm 10\%$

6 Instrumentation and measurement equipment

6.1 General

The instrumentation system, including the microphones and cables, shall meet the requirements of IEC 61672-1:2002, class 1, and the filters shall meet the requirements of IEC 61260:1995, class 1. The reference sound source, if employed for the comparison method (see 8.1), shall meet the requirements given in ISO 6926.

6.2 Calibration

The microphones shall be calibrated for random incidence as specified in IEC 61183.

Before and after each series of measurements, a sound calibrator meeting the requirements of IEC 60942:2003, class 1 shall be applied to each microphone to verify the calibration of the entire measuring system at one or more frequencies within the frequency range of interest. Without any further adjustment, the difference between the readings made before and after each series of measurements shall be less than or equal to 0.5 dB. If this value is exceeded, the results of the series of measurements shall be discarded.

The calibration of the sound calibrator, the compliance of the instrumentation system with the requirements of IEC 61672-1, the compliance of the filter set with the requirements of IEC 61260, and, if used, the compliance of the reference sound source with the requirements of ISO 6926, shall be verified at intervals in a laboratory making calibrations traceable to appropriate standards.

Unless national regulations dictate otherwise, it is recommended that the sound calibrator should be calibrated at intervals not exceeding 1 year, the reference sound source should be calibrated at intervals not exceeding 2 years, the compliance of the instrumentation system with the requirements of IEC 61672-1 should be verified at intervals not exceeding 2 years, and the compliance of the filter set with the requirements of IEC 61260 should be verified at intervals not exceeding 2 years.

7 Definition, location, installation, and operation of noise source under test

7.1 General

It is important to decide which components, sub-assemblies, auxiliary equipment, power sources, etc., constitute integral parts of the noise source whose sound power level or sound energy level is to be determined. It is important also to define the manner in which the source is installed and operated for the test, since both these factors can have a significant influence on the sound power or sound energy emitted. This clause describes the approach to be adopted in setting up the source for testing and in defining the conditions, so as to achieve an arrangement which is reproducible and which can be related clearly to the results obtained.

This American National Standard gives general specifications relating to noise source definition, installation and operation, but these are overridden by the instructions and specifications of a noise test code, if any exists, for the particular type of source under test.

7.2 Auxiliary equipment

Care shall be taken to ensure that any electrical conduits, piping or air ducts connected to the noise source under test do not radiate significant amounts of sound energy into the test environment.

If practicable, all auxiliary equipment necessary for the operation of the noise source under test that is not a part of it shall be located outside the reverberation test room. If this is impractical, care shall be taken to minimize any sound radiated into the room from such equipment. The noise source under test shall be taken to include all significant sources of sound emission, including auxiliary equipment which cannot either be removed or adequately quieted.

7.3 Noise source location

The noise source to be tested shall be installed in the reverberation test room at one or more locations relative to the boundary surfaces, as if it were in normal use. If a particular position is not otherwise specified, the source shall be placed on the floor at least 1.5 m from any wall of the room. If two or more source positions are necessary in accordance with 8.4.2.4 or Annex D, the distance between different positions shall be equal to or larger than the half wavelength of sound corresponding to the lowest mid-band frequency of measurement. In the case of a test room having a rectangular floor, the noise source under test shall be placed asymmetrically on the floor.

Tabletop equipment shall be placed on the floor of the reverberation test room, at least 1.5 m from any wall, unless a table or stand is considered essential for normal operation. In the latter case, the equipment shall be placed at the centre of the tabletop, and the source and table shall be regarded as an integral whole for the purpose of the test.

7.4 Installation and mounting conditions

In many cases, the sound power or sound energy emitted by a source is affected by the support or mounting conditions. Whenever a typical condition of mounting exists for the noise source under test, that condition shall be used or simulated, if feasible.

Mounting conditions specified or recommended by the manufacturer of the noise source under test shall be used unless otherwise specified in any relevant noise test code. If a typical mounting condition does not exist, or cannot be utilized for the test, or if there are several alternative possibilities, care shall be taken to ensure that the mounting arrangement does not induce a variability in the sound output of the

source which is atypical. Precautions shall be taken to reduce any sound radiated from the structure on which the noise source is mounted.

Many small sound sources, although themselves poor radiators of low-frequency sound, can, as a result of the method of mounting, radiate more low-frequency sound when their vibrational energy is transmitted to surfaces large enough to be efficient radiators. In such cases, resilient mounting shall be interposed, if possible, between the noise source under test and the supporting structure, so that the transmission of vibration to the support and the reaction of the source are both minimized. In this case, the mounting base should be rigid (i.e. have a sufficient high mechanical impedance) to prevent it from vibrating excessively and radiating sound. However, resilient mounts shall be used only if the noise source under test is resiliently mounted in typical field installations.

Coupling conditions, e.g. between prime movers and driven machines, can exert considerable influence on the sound radiation of the noise source under test. It may be appropriate to use a flexible coupling, but similar considerations apply to these as to resilient mounts.

Noise sources that are hand held in normal usage shall either be held by hand for the purpose of test, or suspended in such a way that no structure-borne sound is transmitted via any attachment that does not belong to the noise source under test. If the noise source under test requires a support for its operation during testing, the support structure shall be small, considered to be a part of the noise source under test, and as described in the relevant noise test code, if any exist.

Base-mounted machinery and equipment intended exclusively for mounting in front of a wall shall be installed on an acoustically hard floor surface in front of an acoustically hard wall. Wall-mounted machinery and equipment shall be placed on an acoustically hard wall.

7.5 Operation of source during test

The sound power or sound energy emitted by a source can be affected by the load applied, the running speed, and the conditions under which it is operating. The source shall be tested, wherever possible, under conditions that are reproducible and representative of the noisiest operation in typical usage. The specifications given in a noise test code, if any exists, shall be followed, but in the absence of a noise test code one or more of the following modes of operation shall be selected for the test(s):

- a) source under specified load and conditions;
- b) source under full load [if different from a)];
- c) source under no load (idling);
- d) source at maximum operating speed under defined conditions;
- e) source operating under conditions corresponding to maximum sound generation representative of normal use;
- f) source with simulated loading, under defined conditions;
- g) source undergoing a characteristic work cycle under defined conditions.

The source shall be stabilized in the desired operating condition, with any power source or transmission system running at a stable temperature, prior to the start of measurements for sound power level or sound energy level determination. The load, speed and operating conditions shall either be held constant during the test, or varied through a defined cycle in a controlled manner.

If the sound power or sound energy emission depends on secondary operating parameters, e.g. the type of material being processed or the design of cutting tool, those parameters shall be selected, as far as is practicable, that give the smallest variations and that are typical of normal use. If simulated loading conditions are used, they shall be chosen such that the sound power levels or sound energy levels of the source under test are representative of normal use.

The noise emission levels for certain equipment, e.g. electronic equipment with speed-controlled cooling fans or air-conditioning equipment containing compressors, may be greatly affected by the ambient temperature in the test room. If not otherwise specified, such as in an applicable test code, it is recommended that for such equipment the ambient temperature in the test room be set at a value typical of its operation, maintained to within ± 2 °C, and reported.

8 Measurements in the reverberation test room

8.1 General

Procedures are described for two alternative methods of determining sound power levels and sound energy levels:

- a) the method using the equivalent sound absorption area of the reverberation test room, referred to as the direct method;
- b) the method using a reference sound source of known sound power level, referred to as the comparison method.

Both methods are applicable over the range of one-third-octave bands with nominal mid-band frequencies from 100 Hz to 10 000 Hz, but for special purposes the range may be extended downwards in frequency as far as the one-third-octave of mid-band frequency 50 Hz (see 3.12), by following the guidelines given in Annex E.

8.2 Initial location of the noise source under test

For the direct method, the noise source under test shall be located in the reverberation test room at an initial position, selected in accordance with 7.3.

8.3 Microphone positions

For both the direct method and the comparison method, the numerical value of the minimum distance, $d_{\min}$, in metres, between the noise source under test and the nearest microphone position, for each frequency band of interest, shall be not less than:

$$d_{\min} = D_1 \sqrt{\frac{V}{T_{60}}} \quad (8)$$

where

$$D_1 = 0.08;$$

V is the volume, in cubic metres, of the reverberation test room;