INTERNATIONAL STANDARD

ISO 3741

Fourth edition
2010-10-01

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

Acoustique — Détermination des niveaux de puissance et des niveaux d'énergie acoustiques émis par les sources de bruit à partir de la pression acoustique — Méthodes de laboratoire en salles d'essais réverbérantes

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Reference number
ISO 3741:2010(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3741 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This fourth edition cancels and replaces the third edition (ISO 3741:1999), which has been technically revised. It also incorporates the Technical Corrigendum ISO 3741:1999/Cor.1:2001.

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Introduction

This International 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 source, 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 International 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:

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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 International 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 International 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].

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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 International 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 International Standard is not applicable to frequency ranges above the 10 000 Hz one-third-octave band.

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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 International 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 International 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 International 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 International 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).

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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*

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

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3 Terms and definitions

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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

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

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.

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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

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

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 $L_{p\mathrm{A},T}$, which is usually abbreviated to $L_{p\mathrm{A}}$.

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

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3.4
single event time-integrated sound pressure level

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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

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

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

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

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3.6
reverberation test room
test room meeting the requirements of this International 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 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 International 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

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

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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 International 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 International 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

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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.

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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

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$$L_W = 10 \lg \frac{P}{P_0} \text{ dB} \tag{4}$$

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)

$$J = \int_{t_1}^{t_2} P(t)\, \mathrm{d}t \tag{5}$$

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]

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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. $L_{J\text{A}}$ 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 %.

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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 International 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 m^3, 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.

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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:

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$$T_{60} > \frac{V}{S} \tag{7}$$

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;

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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 International 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 International Standard:

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a) the A-weighted sound power level or sound energy level is computed in accordance with the procedures in this International Standard using the data from every frequency band within the frequency range of interest;

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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 International 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 International 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 International 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 International Standard.

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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

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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		
$-5 \leqslant \theta < 10$	± 1 °C, ± 3 %	± 1 °C, ± 5 %	± 3 °C, ± 10 %
$10 \leqslant \theta < 20$	± 1 °C, ± 3 %	± 3 °C, ± 5 %	± 3 °C, ± 10 %
$20 \leqslant \theta \leqslant 50$	± 2 °C, ± 3 %	± 5 °C, ± 5 %	± 5 °C, ± 10 %

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