DRAFT INTERNATIONAL STANDARD ISO/DIS 3741

ISO/TC **43**/SC **1** | Secretariat: **DS**

Voting begins on:
2006-02-23

Voting terminates on:
2006-07-23

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

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

[Revision of third edition (ISO 3741:1999) and ISO 3741:1999/Cor1:2001]

ICS 17.140.01

ISO/CEN PARALLEL ENQUIRY

The CEN Secretary-General has advised the ISO Secretary-General that this ISO/DIS covers a subject of interest to European standardization. **In accordance with the ISO-lead mode of collaboration as defined in the Vienna Agreement, consultation on this ISO/DIS has the same effect for CEN members as would a CEN enquiry on a draft European Standard.** Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month FDIS vote in ISO and formal vote in CEN.

In accordance with the provisions of Council Resolution 15/1993 this document is circulated in the English language only.

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Pour accélérer la distribution, le présent document est distribué tel qu'il est parvenu du secrétariat du comité. Le travail de rédaction et de composition de texte sera effectué au Secrétariat central de l'ISO au stade de publication.

Contents

Page

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.

Introduction

0.1 This International Standard is one of the series ISO 3740 to ISO 3747, 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 will depend 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[1)]. The series of standards of which this International Standard is a part gives 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 on mounting, loading and operating conditions under which the sound power levels or sound energy levels are to be obtained.

0.2 The methods given in this International Standard require the source 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 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:

— the space/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/time averaged mean-square pressure throughout the room;

— 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 and set-up 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.

0.3 The methods given 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 and data with frequency weighting ‘A’ can be computed.

0.4 This International Standard describes methods giving a precision grade of accuracy (grade 1) 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, ISO 3743-2 or ISO 3747.

0.5 This International Standard cancels and replaces ISO 3741:1999.

1) Under revision

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 requirements for which are stated, from that noise source (machinery or equipment) located in the 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 midband 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. For higher frequencies, the use of methods given in ISO 9295 is recommended.

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 may 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 might not be possible to achieve accuracy grade 1 in the results.

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 limited bands of frequency and for calculations from those measurements with frequency weighting A applied. The uncertainty conforms with that of the precision grade of accuracy (grade 1) defined in ISO 12001.

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, *Acoustics – Measurement of the reverberation time of rooms with reference to other acoustical parameters*

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

ISO 7574-1, *Acoustics – Statistical methods for determining and verifying stated noise emission values of machinery and equipment – Part 1: General considerations and definitions*

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

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*

Guide to the expression of uncertainty in measurement (GUM). International Organization for Standardization, Geneva, Switzerland. ISBN 92-67-10188-9, First Edition 1993, corrected and reprinted 1995

3 Terms and definitions

For the purposes of this International Standard, the following definitions apply:

3.1
sound pressure
p
fluctuating pressure superimposed on the static pressure by the presence of sound, 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

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

The reference value, p_0, is 20 µPa (2×10^{-5} Pa).

3.3
time-averaged sound pressure level
$L_{p,T}$
level of the time-averaged square of the sound pressure over the measurement time interval $T = t_2 - t_1$, expressed in decibels

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

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}.

3.4
single-event sound pressure level
L_E
level of the time-integrated square of the sound pressure of an isolated single sound event (burst of sound or transient sound) of specified duration T (or specified measurement time interval $T = t_2 - t_1$ covering the single event) normalized to reference time interval T_0 = 1 s, expressed in decibels

$$L_E = 10 \lg \left[\frac{1}{T_0} \int_{t_1}^{t_2} \frac{p^2(t)}{p_0^2} \mathrm{d}t \right] \mathrm{dB} = L_{p,T} + 10 \lg \frac{T}{T_0} \mathrm{dB} \tag{3}$$

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, expressed in seconds

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_{rev}
time that would be required for the sound pressure level to decrease by 60 dB after a sound source in space has stopped instantaneously, expressed in seconds

NOTE The reverberation time is frequency dependent.

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 use in this International Standard, sound absorption coefficients are calculated in accordance with ISO 354.

3.10
equivalent sound absorption area
A
product of the area and sound absorption coefficient of a surface, expressed in square metres

3.11
reference sound source
sound source meeting the requirements of ISO 6926

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

NOTE For special purposes, the range may be extended or reduced, provided that the test environment and instrumentation otherwise meet all requirements of this International Standard. The range may be extended downwards in frequency as far as the 50 Hz one-third-octave band (see Annex E), but may not be extended upwards beyond the 10 000 Hz band. For reduced frequency ranges, the report shall clearly state the reduced range and shall indicate that the reported results are in conformance with this International Standard over the reduced frequency range.

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

NOTE Background noise may include 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, expressed in decibels

NOTE 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 midband frequency.

3.15
sound power
W
rate per unit time at which airborne sound energy is radiated by a source, expressed in watts

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 W, to a reference value, W_0, expressed in decibels

$$L_W = 10 \lg \frac{W}{W_0} \text{ dB} \tag{4}$$

The reference value, W_0, is 1 pW (10^{-12} W).

NOTE The frequency weighting, or the midband frequency of the frequency band used, is indicated in the symbol. For example, the A-weighted sound power level is L_{WA}.

3.17
sound energy
J
energy of a single burst of sound or transient sound emitted by a source, expressed in joules

3.18
sound energy level
L_J
ten times the logarithm to the base 10 of the ratio of the sound energy of a source, J, to a reference value, J_0, expressed in decibels

$$L_J = 10 \lg \frac{J}{J_0} \text{ dB} \quad (5)$$

The reference value, J_0, is 1 pJ (10^{-12} J).

NOTE The frequency weighting, or the midband frequency of the frequency band used, is indicated in the symbol. For example, the A-weighted sound energy level is L_{JA}.

4 Reference meteorological conditions

Reference meteorological conditions for the purpose of calculating the sound power level and sound energy level, corresponding to a reference characteristic impedance of ρc = 411,5 Nsm^{-3} (where ρ is the density of air and c is the speed of sound) are:

- air temperature: 23,0 °C;
- barometric pressure: 1,01325 × 10^5 Pa;
- 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 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 minimum volume of the room shall be as specified 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 of Annex C. A room qualification procedure for the measurement of discrete-frequency components is given in Annex D. Information is given in Annex E to assist in testing at frequencies below 100 Hz.

Table 1 — 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 and higher	70

5.3 Sound absorption of test room

The 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 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 1 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 of the noise source under test, but not closer than 1,5 metres. The remaining surfaces shall have absorptive properties such that the reverberation time, T_{rev} (for measurement see 8.7) in each one-third-octave band, without the source under test in place, is numerically greater than the ratio of V and S:

$$T_{rev} > V/S \qquad (6)$$

where

T_{rev} is the reverberation time, in seconds;

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

S is the numerical value in square metres of the total surface area of the test room.

If the requirements for the reverberation time given by Equation (6) are not met, the adequacy of the room for broadband measurements shall be established by the procedure described in Annex C.

5.4 Criterion for background noise

5.4.1 General

The 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 sound pressure level of the noise source under test by at least

— 6 dB for one-third-octave bands of midband frequency 200 Hz and below and 6300 Hz and above,

— 10 dB for one-third-octave bands of midband frequency from 250 Hz to 5000 Hz.

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

NOTE 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 should be measured with the traversing mechanism operating.

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.

Table 2 —Absolute maximum background noise levels in test room

One-third-octave midband 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
12 500	10
16 000	10
20 000	10

5.4.3 Relative background noise criteria for frequency band measurements

The requirements of 5.4.1 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 according to 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.

5.4.4 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 or not this quantity meets the background noise criteria of this International Standard:

a) the A-weighted sound power level or sound energy level is computed according to the procedures in this International 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 midband frequency 200 Hz and below and 6300 Hz and above, and for which $\Delta L_p < 10$ dB for one-third-octave bands of midband frequency from 250 Hz to 5000 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.

5.4.5 Failure to meet background noise criteria

If neither the 6 dB/10 dB criterion in 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 conformance” with ISO 3741.

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 concerned depends on ambient conditions. In such cases, those conditions, together with the measurement procedure, 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		
$-5 \leq \theta < 10$	± 1 °C, ± 3 %	± 1 °C, ± 5 %	± 3 °C, ± 10 %
$10 \leq \theta < 20$	± 1 °C, ± 3 %	± 3 °C, ± 5 %	± 3 °C, ± 10 %
$20 \leq \theta \leq 50$	± 2 °C, ± 3 %	± 5 °C, ± 5 %	± 5 °C, ± 10 %

6 Instrumentation and measurement equipment

6.1 General

The instrumentation system, including the microphones and cables, shall meet the requirements for a Class 1 instrument given in IEC 61672-1:2002, and the filters shall meet the requirements for a Class 1 instrument given in IEC 61260:1995. The reference sound source 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 Class 1 requirements given in IEC 60942:2003 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 at each end of the series of measurements shall be less than or equal to 0,5 dB. If the difference exceeds 0,5 dB, 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, and 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.

NOTE Unless national regulations dictate otherwise, it is recommended that the sound calibrator should be calibrated at intervals not exceeding 2 years, the reference sound source should be calibrated at intervals not exceeding 3 years, and the compliance of the instrumentation system with the requirements of IEC 61672-1 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 under test and are defined as part of the source, the sound power level or sound energy level of which 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 International Standard gives general specifications relating to noise source definition, installation and operation, but these are superseded by the instructions and specifications of a noise test code, if any exists for the particular type of source.

7.2 Auxiliary equipment

If practicable, all auxiliary equipment necessary for the operation of the noise source under test, but which is not an integral part of the source itself, including any electrical conduits, piping, air ducts, etc, connected to the source under test, shall be located outside the reverberation test room. If this is not possible, 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 quietened.

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 usage. 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 according to 8.4.2.4, the distance between different positions shall be equal to or larger than the half wavelength of sound corresponding to the lowest midband frequency of measurement. In the case of a test room having a rectangular floor shape, the sound source shall be placed asymmetrically on the floor.

Table-top 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 table top, and the source and table shall be regarded as an integral whole for the purpose of the test.