INTERNATIONAL STANDARD

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

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit à partir de la pression acoustique — Méthodes de laboratoire en salles réverbérantes

Reference number
ISO 3741:1999(E)

Contents

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 3.

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.

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

This third edition of ISO 3741 cancels and replaces ISO 3741:1988 and ISO 3742:1988, which have been technically revised and amalgamated.

Annexes A, E and F form a normative part of this International Standard. Annexes B, C and D are for information only.

0 Introduction

0.1 This International Standard is one of the ISO 3740 series, which specifies various methods for determining the sound power levels of machines, equipment, and their sub-assemblies. When selecting one of the methods of the ISO 3740 series, it is necessary to select the most appropriate for the conditions and purpose of the test. General guidelines to assist in the selection are provided in ISO 12001 and ISO 3740. The ISO 3740 series gives only general principles regarding the operating and mounting conditions of the machine or equipment under test. Reference should be made to the noise test code for a specific type of machine or equipment, if available, for specifications on mounting and operating conditions.

0.2 This International Standard specifies laboratory methods for determining the sound power radiated by sources as a function of frequency, using a reverberation test room having specified acoustical characteristics. If a room having these characteristics is not available, other documents of the series of basic standards with different environmental requirements are offered (see Table 1 and ISO 3744 or ISO 9614).

In this International Standard, the computation of sound power from sound pressure measurements is based on the premise that, for a source emitting a given sound power in the reverberation test room, the mean-square sound pressure averaged in space and time, $\overline{p^2}$, is directly proportional to the sound power and otherwise depends only on the acoustical and geometric properties of the room and on the physical constants of air.

If a source emits narrow-band or discrete-frequency sound, a precise determination of the radiated sound power level requires greater effort. The reasons are as follows:

a) 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;

b) the sound power radiated by the sources is more strongly influenced by the normal modes of the room and by the position of the source within the room.

If narrow bands of noise or discrete tones are emitted by a source, a determination of its sound power level in a reverberation room requires either the optimization and qualification of the room and test set-up (see annex A) or the use of a greater number of source locations and microphone positions (or greater path length for a moving microphone). These numbers can be reduced by adding low frequency absorbers to decrease the reverberation time. It is also helpful if one or more diffusers are rotating in the test room during the measurements. Guidelines for the design of suitable rotating diffusers are given in annex B.

Table 1 — Overview of International Standards for determination of sound power levels of noise sources under reverberation conditions giving different grades of accuracy

<table>
<tr><th>Parameter</th><th>ISO 3741
Precision method
Grade 1</th><th>ISO 3743-1
Engineering method
Grade 2</th><th>ISO 3743-2
Engineering method
Grade 2</th></tr>
<tr><th>Test environment</th><th>Reverberation room</th><th>Hard-walled room</th><th>Special reverberation test room</th></tr>
<tr><td>Criteria for suitability of test environment</td><td>Room volume, V, and reverberation time, T_{rev}, to be qualified</td><td>$V \geqslant 40$ m^3 and
$V > 40\ V_Q$
Sound absorption coefficient $\bar{\alpha} < 0,20$
Special qualification</td><td>Specified requirements</td></tr>
<tr><td>Volume of sound source V_Q</td><td>Preferably less than 2 % of test room volume</td><td colspan="2">Preferably less than 2,5 % of test room volume</td></tr>
<tr><td>Character of noise</td><td>Steady, broad-band, narrow-band, discrete frequencies</td><td colspan="2">Any, but no isolated bursts</td></tr>
<tr><td>Limitation for background noise</td><td>$\Delta L \geqslant 10$ dB</td><td>$\Delta L \geqslant 6$ dB</td><td>$\Delta L \geqslant 4$ dB</td></tr>
<tr><td>Number N_M of measuring positions</td><td>$N_M \geqslant 6$
or a continuous microphone traverse, if appropriate</td><td>$N_M \geqslant 3$
or a continuous microphone traverse, if appropriate</td><td>$N_M \geqslant 3$
or a continuous microphone traverse, if appropriate</td></tr>
<tr><td>Instrumentation:
a) Sound level meter at least complying with
b) Integrating sound level meter at least complying with
c) Frequency band filter set at least complying with
d) calibrator at least complying with</td><td colspan="3">
a) type 1 according to IEC 61672
b) type 1 according to IEC 61672
c) class 1 according to IEC 61260
d) class 1 according to IEC 60942</td></tr>
<tr><td rowspan="2">Sound power levels to be obtained</td><td>In one-third-octave or octave bands</td><td>In octave bands</td><td rowspan="2">A-weighted and in octave bands</td></tr>
<tr><td colspan="2">A-weighted (to be calculated)</td></tr>
<tr><td rowspan="2">Precision of method for determining L_{WA} expressed as standard deviation of reproducibility σ_R</td><td>$\sigma_R \leqslant 0,5$ dB</td><td>$\sigma_R \leqslant 1,5$ dB</td><td>$\sigma_R \leqslant 2,0$ dB</td></tr>
<tr><td colspan="3">(for sources which emit noise with a relatively "flat" spectrum)</td></tr>
</table>

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

1 Scope

1.1 This International Standard specifies a direct method and a comparison method for determining the sound power level that would be produced by a source operating in an environment at standard meteorological conditions corresponding to a characteristic impedance of ρc = 400 N·s/m^3 (where ρ is the density of air and c is the speed of sound). It specifies test room requirements, source location and general rules for operating conditions, instrumentation and techniques for obtaining an estimate of mean-square sound pressure levels from which the sound power levels of the source in octave or one-third-octave bands are calculated with a grade 1 accuracy. The quantities to be measured are time-averaged sound pressure levels in frequency bands. The quantities to be determined are sound power levels, A-weighted and in frequency bands. Other quantities, which are optional, are sound power levels with other frequency weightings calculated from the measurements in frequency bands. This standard does not provide the means to determine directivity and temporal variation of sound from a source.

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 in an extended frequency range in respect to lower frequencies are given in annex C. 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 The method specified in this International Standard is suitable for steady noise with broad-band, narrow-band and discrete-frequency components as described in ISO 12001. The noise may be emitted from a device, machine, component or sub-assembly.

This International Standard is applicable to noise sources with volumes which are preferably not greater than 2 % of the volume of the reverberation room used for the test. For sources with volumes greater than 2 % of the room volume, the standard deviations given by Table 2 could be exceeded.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 354, *Acoustics — Measurement of sound absorption in a reverberation room.*

ISO 4871, *Acoustics — Declaration and verification of noise emission values of machinery and equipment.*

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

ISO 7574-1:1985, *Acoustics — Statistical methods for determining and verifying stated noise emission values of machinery and equipment — Part 1: General considerations and definitions.*

ISO 7574-4:1985, *Acoustics — Statistical methods for determining and verifying stated noise emission values of machinery and equipment — Part 4: Methods for stated values for batches of machines.*

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

IEC 60942, *Sound calibrators.*

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

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

IEC 61672, *Electroacoustics — Sound level meters.*

3 Terms and definitions

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

3.1
reverberation room
a test room meeting the requirements of this International Standard

3.2
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

3.3
sound pressure
p
fluctuating pressure superimposed on the static pressure by the presence of sound

NOTE 1 It is expressed in pascals.

NOTE 2 The magnitude of the sound pressure can be expressed in several ways, but for this International Standard only the square root of the mean-square sound pressure over designated time and space is relevant.

3.4
mean-square sound pressure
$\overline{p^2}$
sound pressure averaged in space and time on a mean-square basis

NOTE In practice, space/time-averaging over a finite path length or a fixed number of microphone positions as well as deviations from the ideally reverberant sound field lead only to an estimate of $\overline{p^2}$.

3.5
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the sound pressure to the square of the reference sound pressure

NOTE Sound pressure levels are expressed in decibels. The reference sound pressure is 20 µPa (2×10^{-5} Pa).

3.5.1
time-averaged sound pressure level
$L_{p\mathrm{eq},T}$
level of the time-averaged square of the sound pressure, expressed in decibels:

$$L_{p\mathrm{eq},T} = 10 \lg \left[\frac{1}{T} \int_0^T \frac{p^2(t)}{p_0^2} \mathrm{d}t \right] \mathrm{dB} \quad (1)$$

NOTE 1 Time-averaged sound pressure levels are expressed in decibels.

NOTE 2 In general, the subscripts "eq" and "T" are omitted since time-averaged sound pressure levels are necessarily determined over a certain measurement time interval.

3.5.2
measurement time interval
portion or a multiple of an operational period or operational cycle for which the time-averaged sound pressure level is determined

NOTE See 8.1.3.

3.6
sound power
W
rate per unit time at which airborne sound energy is radiated by a source

NOTE It is expressed in watts.

3.7
sound power level
L_W

ten times the logarithm to the base 10 of the ratio of the sound power radiated by the sound source under test to the reference sound power

NOTE 1 It is expressed in decibels. The reference sound power is 1 pW (10^{-12} W).

NOTE 2 For example, the A-weighted sound power level is $L_{W\mathrm{A}}$.

3.8
background noise
noise from all sources other than the source under test

3.9
reference sound source
stable and steady source emitting constant broad-band noise with an adequate sound power level, performing and calibrated in accordance with ISO 6926

3.10
reverberation time
T_{rev}
time or extrapolated time that would be required for the sound pressure level to decrease 60 dB if a sound source in a space were stopped instantaneously

NOTE 1 It is expressed in seconds (s).

NOTE 2 In this International Standard, T_{rev} is calculated in accordance with ISO 354 except that the reverberation time is extrapolated from the decay of the first 10 dB or 15 dB, denoted T_{10} and T_{15} respectively.

3.11
frequency range of interest

frequency range covered by the one-third-octave bands with mid-frequencies from 100 Hz to 10 000 Hz

NOTE This is the general case. For special purposes, the frequency range may be extended as low as 50 Hz provided certain criteria are met (see annex C).

3.12
sound absorption coefficient

α

at a given frequency and for specified conditions, the fraction of incident sound power not reflected from a surface calculated in accordance with ISO 354

3.13
equivalent absorption area

A

product of the surface area and its absorption coefficient

NOTE It is expressed in square metres (m^2).

4 Measurement uncertainty

Measurements made in conformity with this International Standard tend to result in standard deviations of reproducibility which are equal to or less than those given in Table 2. A single value of the sound power level of a noise source determined according to the procedures of this International Standard is likely to differ from the true value by an amount within the range of the measurement uncertainty. The uncertainty in determinations of the sound power level arises from several factors which affect the results, some associated with environmental conditions in the measurement laboratory and others with experimental techniques. If a particular noise source were to be transported to each of a number of different laboratories, and if, at each laboratory, the sound power level of that source were to be determined in accordance with this International Standard, the results would show a scatter. The standard deviation of the measured levels could be calculated (see examples in ISO 7574-4:1985, annex B) and would vary with frequency. With few exceptions, these standard deviations would not exceed those listed in Table 2. The values given in Table 2 are standard deviations of reproducibility, σ_R, as defined in ISO 7574-1. The values of Table 2 take into account the cumulative effects of measurement uncertainty in applying the procedures of this International Standard, but exclude variations in the sound power output caused by changes in operating conditions (e.g. rotational speed, line voltage) or mounting conditions.

The measurement uncertainty depends on the standard deviation of reproducibility tabulated in Table 2 and on the degree of confidence that is desired. As examples, for a normal distribution of sound power levels, there is a 90 % confidence that the true value of the sound power level of a source lies within the range $\pm$ 1,645 σ_R of the measured value and a 95 % confidence that it lies within the range $\pm$ 1,96 σ_R of the measured value. For further examples, reference should be made to ISO 7574-4 and ISO 9296.

NOTE 1 The relationship between the standard deviation of reproducibility and the confidence level given in the ISO 7574 series and ISO 9296 is valid for standard deviations which are less than or equal to 2 dB. For larger standard deviations the confidence level associated with a given range will be lower. In general, however, the true value can be expected to fall within the range $\pm$ 3 σ_R of the measured value.

NOTE 2 The largest sources of uncertainty, other than possible deviations from the theoretical model (direct method) and errors in the calibration of the reference sound source (comparison method) in the test methods specified in this International Standard are associated with inadequate sampling of the sound field and with variations in the acoustic coupling from the noise source to the sound field (for different test rooms and for different positions within a test room). In any laboratory, it may be possible to reduce measurement uncertainty by one or more of the following procedures:

a) use of multiple source locations;

b) improvement of spatial sampling of the sound field by increasing the number of microphone positions or the length of the microphone traverse;

c) addition of low-frequency sound absorbers to improve modal overlap;

d) use of moving diffuser elements.

Table 2 — Estimated upper values of the standard deviations of reproducibility of sound power levels determined in accordance with this International Standard

Band width	Midband frequencies Hz	Upper values of standard deviation of reproducibility dB
One-third-octave	100[a] to 160	3,0
	200 to 315	2,0
	400 to 5 000	1,5
	6 300 to 10 000	3,0
Octave	125[a]	2,5
	250	1,5
	500 to 4 000	1,0
	8 000	2,0
A-weighted per annex E		0,5[b]

[a] Recommendations for frequencies below 100 Hz are given in annex C.

[b] Applicable to a source which emits noise with a relatively "flat" spectrum in the frequency range 100 Hz to 10 000 Hz.

In addition, a large reverberation room may be used to reduce uncertainties at low frequencies although the precision of high-frequency sound power level determinations may be degraded. Conversely, a small room may lead to reduced high-frequency uncertainties but increased low-frequency uncertainties. Thus, if improved precision is needed, and if two reverberation rooms are available, it may be desirable to carry out the low-frequency sound power level determinations in the larger room and high-frequency determinations in the smaller room.

NOTE 3 If several laboratories use similar facilities and instrumentation, the results of sound power determinations on a given source in those laboratories may be in better agreement than would be inferred by the standard deviations of Table 2.

NOTE 4 For a particular family of sound sources, of similar size with similar sound power spectra and similar operating conditions, the standard deviations of reproducibility may be smaller than the values given in Table 2. Hence, a noise test code for a particular type of machinery or equipment making reference to this International Standard may state standard deviations smaller than those listed in Table 2, only if substantiation is available from the results of suitable interlaboratory tests.

NOTE 5 The standard deviations of reproducibility, as tabulated in Table 2, include the uncertainty associated with repeated measurements on the same noise source under the same conditions (for standard deviation of repeatability, see ISO 7574-1). This uncertainty is usually much smaller than the uncertainty associated with interlaboratory variability. However, if it is difficult to maintain stable operating or mounting conditions for a particular source, the standard deviation of repeatability may not be small compared with the values given in Table 2. In such cases, the fact that it was difficult to obtain repeatable sound power level data on the source should be recorded and stated in the test report.

NOTE 6 The procedures of this International Standard and the standard deviations given in Table 2 are applicable to measurements on an individual machine. Characterization of the sound power levels of batches of machines of the same family or type involves the use of random sampling techniques in which confidence intervals are specified, and the results are expressed in terms of statistical upper limits. In applying these techniques, the total standard deviation has to be known or estimated, including the standard deviation of production, as defined in ISO 7574-1, which is a measure of the variation in sound power output between individual machines within the batch. Statistical methods for the characterization of batches of machines are described in ISO 7574-4.

5 Acoustic environment

5.1 General

Guidelines for the design of reverberation rooms to be used for determining sound power in accordance with this International Standard are given in annex D. The 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 (see annex D).

5.2 Volume and shape of test room

The minimum volume of the test room shall be as specified in Table 3. For reverberation rooms with volumes less than the values shown in Table 3 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 E.

Table 3 — Minimum volume of the 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 test room m^3
100	200
125	150
160	100
200 and higher	70

5.3 Requirements for absorption of test room

The absorption of the test room primarily affects the minimum distance to be maintained between the noise source 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 D).

The surfaces of the test room closest to the source shall be designed to be reflective with an absorption coefficient less than 0,06. The remaining surfaces shall have absorptive properties such that the reverberation time, T_{rev} (for measurement see 8.4.1) in each one-third-octave band, without the source under test in place, is numerically greater than the ratio of V and S:

$$T_{rev} > V/S \qquad (2)$$

where

T_{rev} is the reverberation time expressed in seconds (s);

V is the volume of the reverberation room expressed in cubic metres (m^3);

S is the total surface area of the test room expressed in square metres (m^2).

If the requirements for the reverberation time given by equation (2) are not met, the adequacy of the room for broad band measurements shall be established by the procedure described in annex E.

5.4 Requirements for background noise level

Averaged over the microphone positions or traverse, the level of background noise in all bands within the frequency range of interest shall be at least 10 dB below the sound pressure level due to the source under test.

For low noise equipment, $\Delta L > 10$ dB may not be achievable in all bands. Any bands in which the A-weighted (see annex F) sound power level of the source under test is more than 15 dB below the highest A-weighted band sound power level may be excluded from the frequency range of interest.

If the comparison method of 8.4.2 is used, the background noise shall be at least 15 dB below the sound pressure level due to the reference sound source in all bands within the frequency range of interest.

5.5 Requirements for temperature, humidity and pressure

In the region where the microphones are located, the variations of temperature and relative humidity shall be within the limits shown in Table 4.

Measurements of atmospheric pressure shall be made to within ± 1,5 kPa.

The limits of Table 4 are generally sufficient (see reference [9]). 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 4 — Allowable limits in the variation of temperature and relative humidity during measurements in the reverberation room

<table>
<tr><th rowspan="3">Ranges of temperature
θ
°C</th><th colspan="3">Ranges of relative humidity
%</th></tr>
<tr><th>< 30 %</th><th>30 % to 50 %</th><th>> 50 %</th></tr>
<tr><th colspan="3">Allowable limits for temperature and relative humidity</th></tr>
<tr><td>$-5 \leqslant \theta < 10$</td><td rowspan="2">± 1 °C
± 3 %</td><td>± 1 °C
± 5 %</td><td rowspan="2">± 3 °C
± 10 %</td></tr>
<tr><td>$10 \leqslant \theta < 20$</td><td>± 3 °C
± 5 %</td></tr>
<tr><td>$20 \leqslant \theta < 50$</td><td>± 2 °C
± 3 %</td><td>± 5 °C
± 5 %</td><td>± 5 °C
± 10 %</td></tr>
</table>

6 Instrumentation

6.1 General

The instrumentation system, including the microphone, shall fulfil the requirements for a type 1 instrument specified in IEC 61672. The filters used shall meet the requirements of a class 1 instrument specified in IEC 61260. The microphones shall be calibrated for random incidence as specified in IEC 61183.

6.2 Calibration

Before each series of measurements, a sound calibrator with an accuracy of class 1 as specified in IEC 60942 shall be applied to the microphone to verify the calibration of the entire measuring system at one or more frequencies in the frequency range of interest.

The calibrator shall be calibrated at least once a year and the compliance of the instrumentation system with the requirements of IEC 61672 shall be verified at least every 2 years in a laboratory making calibrations traceable to appropriate standards.

The date of the last verification of the compliance with the relevant IEC standards shall be recorded.