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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Acoustics — Determination of sound power levels of noise sources — Precision methods for broad-band sources in reverberation rooms

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit — Méthodes de laboratoire en salles réverbérantes pour les sources à large bande

Reference number
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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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

This second edition cancels and replaces the first edition (ISO 3741 : 1975), of which it constitutes a minor revision.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Acoustics — Determination of sound power levels of noise sources — Precision methods for broad-band sources in reverberation rooms

0.1 Related International Standards

This International Standard is one of a series specifying various methods for determining the sound power levels of machines and equipment. These basic documents specify only the acoustical requirements for measurements appropriate for different test environments as shown in table 1.

When applying these basic documents, it is necessary to decide which one is most appropriate for the conditions and purposes of the test. The operating and mounting conditions of the machine or equipment to be tested are given as general principles stated in each of the basic documents. Guidelines for making these decisions are provided in ISO 3740. If no noise test code is specified for a particular machine, the mounting and operating conditions shall be fully described in the test report.

0.2 Synopsis of ISO 3741

0.2.1 Applicability

0.2.1.1 Test environment

Reverberation room with specified volume and absorption or qualified in accordance with a test procedure given in annex A. Guidelines for the design of reverberation rooms are given in annex D. The minimum test room volume depends on the lowest frequency band of interest (V_{min} = 200 m^3 corresponds to 100 Hz for the lowest allowable one-third octave band).

0.2.1.2 Size of noise source

Volume of the source preferably less than 1 % of volume of the test room.

0.2.1.3 Character of noise radiated by the source

Steady (as defined in ISO 2204), broad-band.

0.2.2 Precision

Measurements made in conformity with this International Standard will, with very few exceptions, result in standard deviations equal to or less than 1,5 dB from 400 to 5 000 Hz, 2 dB from 200 to 315 Hz, increasing to 3 dB below 200 Hz and above 5 000 Hz (see 1.3 and table 2).

0.2.3 Quantities to be measured

Sound pressure levels in frequency bands on a specified path or at several discrete microphone positions.

0.2.4 Quantities to be determined

Sound pressure levels in frequency bands; A-weighted sound power levels (optional).

0.2.5 Quantities which cannot be obtained

Directivity characteristics of the source; temporal pattern of radiated noise for sources emitting non-steady noise.

0.3 Introduction

This International Standard specifies in detail two laboratory methods for determining the sound power radiated by a device, machine, component, or sub-assembly as a function of frequency, using a reverberation test room having specified acoustical characteristics. While other methods could be used to measure the noise emitted by machinery and equipment, the methods specified in this International Standard are particularly advantageous for rating the sound output of sources which produce steady noise and for which directivity information is not required. If the source emits non-steady noise or if directivity information is desired, one of the other methods specified in ISO 3740 shall be selected.

Among the reasons for obtaining data as described in this International Standard are the following:

a) rating apparatus according to its sound power output;

b) establishing sound control measures;

c) predicting the sound pressure levels produced by a device or machine in a given enclosure or environment.

In this International Standard, the computation of sound power from sound pressure measurements is based on the premise that the mean-square sound pressure averaged in space and time, $\overline{p^2}$, is

a) directly proportional to the sound power output of the source,

b) inversely proportional to the equivalent absorption area of the room, and

c) otherwise depends only on the physical constants of air density and velocity of sound.

Table 1 — International Standards specifying various methods for determining the sound power levels of machines and equipment

International Standard No.*	Classification of method**	Test environment	Volume of source	Character of noise	Sound power levels obtainable	Optional information available
3741	Precision (grade 1)	Reverberation room meeting specified requirements	Preferably less than 1 % of test room volume	Steady, broad-band	In one-third octave or octave bands	A-weighted sound power level
3742				Steady, discrete-frequency or narrow-band		
3743	Engineering (grade 2)	Special reverberation test room		Steady, broad-band, narrow-band, or discrete-frequency	A-weighted and in octave bands	Other weighted sound power levels
3744	Engineering (grade 2)	Outdoors or in large room	Greatest dimension less than 15 m	Any	A-weighted and in one-third octave or octave bands	Directivity information and sound pressure levels as a function of time; other weighted sound power levels
3745	Precision (grade 1)	Anechoic or semi-anechoic room	Preferably less than 0,5 % of test room volume	Any		
3746	Survey (grade 3)	No special test environment	No restrictions: limited only by available test environment	Any	A-weighted	Sound pressure levels as a function of time; other weighted sound power levels
3747	Survey (grade 3)	No special test environment; source under test not movable	No restrictions	Steady, broad-band, narrow-band, or discrete-frequency	A-weighted	Sound power levels in octave bands

* See clause 2.

** See ISO 2204.

1 Scope and field of application

1.1 General

This International Standard specifies a direct method and a comparison method for determining the sound power level produced by a source. It specifies test room requirements, source location and operating conditions, instrumentation and techniques for obtaining an estimate of mean-square sound pressure from which the sound power level of the source in octave or one-third octave bands is calculated.

1.2 Field of application

1.2.1 Types of noise

This International Standard applies primarily to sources which produce steady broad-band noise as defined in ISO 2204.

NOTE — If discrete frequencies or narrow bands of noise are present in the spectrum of a source, the mean-square sound pressure tends to be highly dependent on the positions of the source and the microphone within the room. The average value over a limited microphone path or array may differ significantly from the value averaged over all points in the room. Procedures for determining the sound power radiated by a source when discrete tones are present in the spectrum are described in ISO 3742.

1.2.2 Size of source

This International Standard applies only to small noise sources, i.e. sources with volumes which are preferably not greater than 1 % of the volume of the reverberation room used for the test.

1.3 Measurement uncertainty

Measurements made in conformity with this International Standard tend to result in standard deviations which are equal to or less than those given in table 2. The standard deviations given in table 2 take into account the cumulative effects of all causes of measurement uncertainty.

Table 2 — Uncertainty in determining sound power levels of broad-band noise sources in reverberation rooms

Octave-band centre frequencies	One-third octave-band centre frequencies	Standard deviation
Hz	Hz	dB
125	100 to 160	3
250	200 to 315	2
500 to 4 000	400 to 5 000	1,5
8 000	6 300 to 10 000	3

NOTES

1 The standard deviations given in table 2 are measures of the uncertainties associated with the test methods defined in this International Standard. If a stable source of steady broad-band noise were transported to each of a large number of laboratories, and if, at each laboratory, the sound power level of that source were measured in accordance with the provisions of this International Standard, the standard deviation, as a function of frequency, of these many sound power level calculations could be calculated. If a similar inter-laboratory series of measurements were carried out on each of a large number of different specimens of the same type of stable sources of steady broad-band, it would be possible to calculate overall standard deviations that would correspond to the random selection of a noise source and the random selection of a laboratory. It is these standard deviations which have been estimated and given in table 2.

2 If two laboratories use similar facilities and instrumentation, the results of sound power level determinations on a given source in these laboratories may be in better agreement than would be inferred from the standard deviations in table 2.

3 For a particular family of noise sources, of similar size and with similar sound spectra, the standard deviations of sound power level determinations in different laboratories may be significantly smaller than the values given in table 2. Thus, a test code for a particular type of machinery may state standard deviations smaller than those given in table 2 if the results of inter-laboratory tests are available to substantiate the smaller values.

4 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;

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

d) use of moving diffuser elements.

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.

2 References

ISO 266, *Acoustics — Preferred frequencies for measurements.*

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

ISO 2204, *Acoustics — Guide to International Standards on the measurement of airborne acoustical noise and evaluation of its effects on human beings.*

ISO 3740, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards and for the preparation of noise test codes.*

ISO 3742, *Acoustics — Determination of sound power levels of noise sources — Precision methods for discrete-frequency and narrow-band sources in reverberation rooms.*

ISO 3743, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for special reverberation test rooms.*

ISO 3744, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane.*

ISO 3745, *Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms.*

ISO 3746, *Acoustics — Determination of sound power levels of noise sources — Survey method.*

ISO 3747, *Acoustics — Determination of sound power levels of noise sources — Survey method using a reference sound source.*

ISO 6926, *Acoustics — Determination of sound power levels of noise sources — Characterization and calibration of reference sound sources.* [1)]

IEC Publication 50(08), *International Electrotechnical Vocabulary — Electro-acoustics.*

IEC Publication 225, *Octave, half-octave and third-octave band filters intended for the analysis of sound and vibrations.*

IEC Publication 651, *Sound level meters.*

3 Definitions

For the purposes of this International Standard, the following 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 mean-square sound pressure, $\overline{p^2}$: The sound pressure averaged in space and time on a mean-square basis. 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 $\overline{p^2}$, called p^2_{av} in this International Standard.

3.4 sound pressure level, L_p, in decibels: Ten times the logarithm to the base 10 of the ratio of the mean-square sound pressure of a sound to the square of the reference sound pressure. The width of a restricted frequency band shall be indicated: for example, octave-band pressure level, one-third octave-band pressure level, etc. The reference sound pressure is 20 μPa.

3.5 sound power level, L_W, in decibels: Ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power. The width of a restricted frequency band shall be indicated; for example, octave-band power level, one-third octave-band power level, etc. The reference sound power is 1 pW ($= 10^{-12}$ W).

3.6 frequency range of interest: For general purposes, the frequency range of interest includes the octave bands with centre frequencies between 125 and 8 000 Hz or the one-third octave bands with centre frequencies between 100 Hz and 10 000 Hz. Any band may be excluded in which the level is more than 40 dB below the highest band pressure level.

For special purposes, other frequency ranges of interest may be defined depending upon the characteristics of the noise source, provided that the test room is satisfactory for use over the appropriate frequency range.

3.7 direct method: That method in which the sound power level is calculated from the measured sound pressure levels produced by the source in a reverberation room and from the volume and reverberation time of the room.

3.8 comparison method: That method in which the sound power level is calculated by comparing the measured sound pressure levels produced by the source in a reverberation room with the sound pressure levels produced in the same room by a reference sound source (RSS) of known sound power output.

4 Acoustical environment

4.1 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 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).

4.2 Volume of test room

The minimum volume of the test room shall be as specified in table 3. If frequencies above 3 000 Hz are included in the frequency range of interest, the volume of the test room shall not exceed 300 m³. The ratio of the maximum dimension of the test room to its minimum dimension shall not exceed 3:1.

1) At present at the stage of draft.

Table 3 — Minimum volume of the test room as a function of the lowest frequency band of interest

Lowest frequency band of interest	Minimum volume of the test room m^3
125 Hz octave or 100 Hz one-third octave	200
125 Hz one-third octave	150
160 Hz one-third octave	100
250 Hz octave or 200 Hz one-third octave and higher	70

4.3 Criterion for absorption of test room

4.3.1 General

The equivalent absorption area 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. For these reasons, the absorption area shall be neither too large nor extremely small (see annex D).

The reverberation time, in seconds, shall be greater than

$$V/S$$

where

V is the room volume, in cubic metres;

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

4.3.2 Minimum distance

The minimum distance between the noise source and the nearest microphone position, $d_{\min}$, shall not be less than

$$d_{\min} = C_1\sqrt{V/T}$$

where

$C_1 = 0{,}08$;

V is the room volume, in cubic metres;

T is the reverberation time, in seconds.

NOTE — In order to minimize the near-field bias error, it is strongly recommended that the value of C_1 be 0,16.

4.3.3 Surface treatment

The surfaces of the test room closest to the source shall be designed to be reflective with an absorption coefficient less than 0,06. Except for these surfaces, none of the other surfaces shall have absorptive properties significantly deviating from each other. These other surfaces shall be designed so that for each one-third octave band within the frequency range of interest, the mean value of the absorption coefficient of each surface is between 0,5 and 1,5 times the mean value of the absorption coefficients of all surfaces.

4.4 Criterion for adequacy of test room

If the test room does not have an absorption as required by 4.3, the adequacy of the room shall be established by the procedure described in annex A.

4.5 Criterion for background noise level

The background noise level including any noise due to motion of the microphone shall be at least 6 dB, and preferably more than 12 dB, below the sound pressure level to be measured in each frequency band within the frequency range of interest.

4.6 Criteria for temperature and humidity

The air absorption in the reverberation room varies with temperature and humidity, particularly at frequencies above 1 000 Hz. The temperature θ, in degrees Celsius, and the relative humidity (r.h.), expressed as a percentage, shall be controlled during the sound pressure level measurements. The product

$$\text{r.h.} \times (\theta + 5\ °\text{C})$$

shall not differ by more than ± 10 % from the value of the product which prevailed during the measurements of clause 7.

5 Instrumentation

5.1 General

Instrumentation shall be designed to determine the mean-square value of the sound pressure in octave and/or one-third octave bands averaged over time and space.

Several alternative procedures for space-averaging are given in clause 7; those involving automatic sampling require instrumentation with longer integration (averaging) times.

There are two alternative approaches to time-averaging the output voltage of the octave (or one-third octave) band filters:

a) Integration of the squared voltage over a fixed time interval, τ_D, by analogue or digital means.

b) Continuous analogue averaging of the squared voltage, using an RC-smoothing network with a time constant τ_A. This provides only an approximation of the true time average, and it places restrictions on the "settling" time and observation time (see 7.2.2).

5.2 Indicating device

5.2.1 General

An estimate of $\overline{p^2}$ is obtained by determining the mean-square pressure corresponding to the mean-square value of the voltage at the output of the filter set, $e_o(t)$. This mean-square pressure is denoted by p^2_{av}, and is determined for a given microphone path traverse (or array) and time (see 7.2.1).

5.2.2 Integration over a fixed time interval

If this method is used (see 5.1), the normalized variance of the estimates of the level of the mean-square voltage shall be less than 0,25 dB for a steady sine-wave input over the frequency range of interest; the average value of a series of ten estimates of the level of the mean-square voltage shall not differ from the value obtained by continuous integration by more than ± 0,25 dB.

The integration time, τ_D [see 5.1 a)], shall be identical to the observation period used (for minimum values of observation periods, see 7.2.2; for relation between integrating time and microphone traversing or scanning period, if applicable, see 7.1.1).

5.2.3 Continuous averaging

The time constant, τ_A [see 5.1 b)], shall be at least 0,7 s and long enough to meet the criterion of 7.1.1.

5.3 Microphone and its associated cable

A condenser microphone, or the equivalent in accuracy, stability and frequency response, shall be used. The microphone shall have a flat frequency response for randomly incident sound over the frequency range of interest.

NOTES

1 This requirement is met by a microphone of a standardized sound level meter fulfilling at least the requirements for a type 1 instrument in accordance with IEC Publication 651 and calibrated for free-field measurements only if it has a linear random response.

2 If several microphones are used, it is desirable to avoid the axis of each microphone being oriented in the same direction in space.

The microphone and its asociated cable shall be chosen so that their sensitivity does not change by more than 0,5 dB in the temperature range encountered during the measurements. If the microphone is moved, care shall be exercised to avoid introducing acoustical or electrical noise (e.g. from gears, flexing cables, or sliding contacts) that could interfere with the measurements.

5.4 Frequency response of the instrumentation system

The frequency response of the instrumentation for randomly incident sound shall be determined in accordance with the procedure in IEC Publication 651 with the tolerances given in table 4.

5.5 Filter characteristics

An octave-band or one-third octave-band filter set meeting the requirements of IEC Publication 225 shall be used. The centre frequencies of the bands shall correspond to those of ISO 266.

Table 4 — Relative tolerances for the instrumentation system
(adapted from IEC Publication 651)

Frequency Hz	Tolerance limits dB
50	± 1,5
63	± 1,5
80	± 1,5
100	± 1
125	± 1
160	± 1
200	± 1
250	± 1
315	± 1
400	± 1
500	± 1
630	± 1
800	± 1
1 000	± 1
1 250	± 1
1 600	± 1
2 000	± 1
2 500	± 1
3 150	± 1
4 000	± 1
5 000	+ 1,5 − 2
6 300	+ 1,5 − 2
8 000	+ 1,5 − 3
10 000	+ 2 − 4
12 500	+ 3 − 6
16 000	+ 3 − ∞
20 000	+ 3 − ∞

5.6 Calibration

During each series of measurements, a sound calibrator with an accuracy of ± 0,2 dB shall be applied to the microphone to check the calibration of the complete instrumentation system at one or more frequencies within the frequency range of interest. The calibrator shall be checked annually to check that its output has not changed. In addition, an electrical calibration of the instrumentation system over the entire frequency range of interest shall be carried out periodically.

6 Installation and operation of source

6.1 General

If the source is mounted near one or more reflecting planes, the radiation impedance can differ appreciably from that of free