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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.

Contents

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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 m^3. 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

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

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, $e_0(t)$. 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	Tolerance limits
Hz	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 space, and the sound power radiated by the source may depend strongly on its position and orientation. It is possible to measure the radiated sound power either for a particular source position and orientation, or as the average value for several positions and orientations.

6.2 Source location

The source to be tested shall be placed in the reverberation room in one or more locations that are typical of normal usage. If a particular position is not specified, the source shall be placed at least 1,5 m from any wall of the room.

6.3 Source mounting

In many cases, the sound power emitted will depend on the support or mounting conditions of the source, which shall be carefully described in the test report. Whenever a typical condition of mounting or use exists for the equipment under test, that condition shall be used for the test, if feasible.

No major surfaces of the source shall be oriented parallel to a nearby surface of the reverberation room unless it is so oriented in its typical mounting condition.

Sources normally mounted through a window, wall or ceiling shall be mounted through a wall or the ceiling of the reverberation room and located at least 1,5 m from any other wall or surface, except that sources normally mounted near a corner shall be located at the normal distance from such a corner.

Equipment normally installed on a table or stand shall be so mounted during the test.

6.4 Auxiliary equipment

Care shall be taken to ensure that any electrical conduits, piping or air ducts connected to the equipment do not radiate significant amounts of sound energy into the test room. If possible, all auxiliary equipment necessary for the operation of the equipment to be tested shall be located outside the reverberation room.

6.5 Operation of source during measurements

During the acoustical measurements, the source shall be operated in a specified manner typical of normal use. One or more of the following operational conditions may be appropriate:

a) device under normal load;

b) device under full load [if different from a)];

c) device under no load (idling);

d) device under the operating condition corresponding to maximum sound generation.

The sound power levels of sources may be determined for any desired set of operating conditions (i.e. temperature, humidity, equipment speed, etc.). These test conditions shall be selected beforehand and shall be held constant during the test. The source shall be in a stable operating condition before any noise measurements are made.

7 Measurement of mean-square sound pressure

7.1 Microphone positions

7.1.1 General

The microphone shall be traversed at constant speed over a path **at least** 3 m in length while the signal is being averaged on a mean-square basis. The path may be a line, an arc as obtained by swinging the microphone, a circle or some other geometrical configuration.

Alternatively, an array of **at least** three fixed microphones or microphone positions spaced at least a distance of $\lambda/2$ from each other, where λ is the wavelength of the sound wave corresponding to the lowest frequency of the frequency band of interest, may be used. The output of the microphones shall be scanned automatically and/or averaged on a mean-square basis.

7.1.2 Repetition rate

The repetition rate of the microphone traverse (or the scanning rate for an array of fixed microphones) shall meet the following criteria:

a) there shall be a whole number of microphone traverses or array scans during the observation period (see 7.2.2);

b) if integration over a fixed time interval, τ_D, is used [see 5.1 a)], there shall be a whole number of microphone traverses or array scans during the integrating time of the indicating device;

c) if continuous averaging is used [see 5.1 b)], the traverse or scanning period shall be less than twice the time constant of the indicating device.

7.1.3 Microphone traverse or array

The microphone traverse or array shall not lie in any plane within 10° of a room surface. No point on the traverse or array shall be closer than $\lambda/2$ or 1 m, whichever is the smaller, to any room surface of the reverberation room, where λ is the wavelength of sound corresponding to the centre frequency of the lowest frequency band of interest. All microphones shall be at least $\lambda/4$ or 0,5 m, whichever is the smaller, from the nearest surface of the rotating diffuser (if any).

The location of the microphone traverse or array shall be within that portion of the test room where the reverberant sound field dominates. The criterion to ensure that the microphone traverse or array is within the reverberant field is given in 4.3.2.

The microphone traverse or array shall avoid areas of air discharge (if any) or sound beaming from the equipment being tested.

7.2 Required data and conditions of measurement

7.2.1 Sound pressure level readings

Determinations of the mean-square sound pressure along the microphone path (or at the individual microphone positions) shall be made for each frequency band within the frequency range of interest, as follows:

a) the band pressure levels produced by background noise [including noise from the support equipment, the motion of the microphone and diffuser (if any), and internal electrical noise in the measuring instrumentation];

b) the band pressure levels during operation of the source being tested;

c) if applicable, the band pressure levels during operation of the reference sound source (see 8.3.2).

The microphone traverse or array shall be the same for each set of readings and shall comply with the requirements of 7.1. The sound diffuser(s) (if any) shall be operated identically for each set of readings. No observers or operators shall be present in the test room during the measurements, unless necessary for operating the device under test.

7.2.2 Period of observation

The readings shall be averaged over the following periods of observation:

a) for the frequency bands centred on or below 160 Hz, the period of observation shall be at least 30 s;

b) for the frequency bands centred on or above 200 Hz, the period of observation shall be at least 10 s.

NOTE — If the instrumentation uses continuous time-averaging (RC-smoothing), no observation should be made after any microphone or filter switching (including transfer of the microphone to a new position) until a "settling" time of five times the time constant of the instrumentation has elapsed. The observation time should have at least the same duration as the "settling time".

7.2.3 Correction for background sound pressure levels

The measured band pressure levels shall be corrected for the influence of background noise according to table 5. If the background noise level is less than 6 dB below the sound pressure level with either the reference sound source or the equipment operating, the accuracy of the measurements will be reduced and no data shall be reported.

Table 5 — Corrections for background sound pressure levels

Difference between sound pressure level measured with noise source operating and background sound pressure level alone	Correction to be subtracted from sound pressure level measured with noise source operating to obtain sound pressure level due to noise source alone
dB	dB
6	1,3
7	1
8	0,8
9	0,6
10	0,4

7.2.4 Calculation of mean band pressure levels

If a continuous path or automatic microphone scanning is used, the measured levels (after corrections for background noise in accordance with 7.2.3) in each frequency band of interest constitute the desired estimate of p^2_{av}. If individual microphone positions are used, the sound pressure levels, L_p, (after corrections for background noise in accordance with 7.2.3), in decibels (reference: 20 μPa), for each frequency band of interest shall be averaged by using the following equation:

$$L_p = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} (10^{0,1\,L_i}) \right]$$

where

L_i is the band pressure level resulting from the ith measurement, in decibels (reference: 20 μPa);

N is the total number of measurements in the band.

8 Calculation of sound power level

8.1 General

In this International Standard, two methods are described for determining the sound power level of a source: both methods require a determination of p^2_{av} in octave or one-third octave bands.

8.2 Direct method (Method 1)

8.2.1 Additional data required

In addition to the data required by 7.2.1, the reverberation time of the room, T, with the source present shall be determined in each octave band or one-third octave band within the frequency range of interest using the procedures described in ISO 354. However, for determination of sound power level at frequencies of 250 Hz and below, it is recommended that the reverberation time be determined by the early decay (over the first 10 dB of the recorded reverberation time) rather than from the slope between −5 dB and −35 dB.

NOTES

1 Use of the reverberation time as determined from the early decay will result in better agreement between free-field and reverberant-field determinations of sound power level.

2 The loudspeaker system used for the measurement of the reverberation time should be considered to be a part of the test room.

8.2.2 Calculation

The sound power level produced by the source, L_W, in decibels (reference: 1 pW), in each octave band or one-third octave band within the frequency range of interest shall be calculated from the following equation:

$$L_W = L_p - 10 \lg \frac{T}{T_0} + 10 \lg \frac{V}{V_0} + + 10 \lg \left(1 + \frac{S \lambda}{8V}\right) - 10 \lg \left(\frac{B}{1\,000}\right) - 14$$

where

L_p is the mean band pressure level (after corrections for background noise) determined according to 7.2.1 and 7.2.3, in decibels (reference: 20 µPa);

T is the reverberation time of the room, in seconds;

$T_0 = 1$ s;

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

$V_0 = 1$ m^3;

λ is the wavelength at the centre frequency of the octave or one-third octave band, in metres;

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

B is the barometric pressure, in millibars.

This equation accounts (approximately) for the effect of the interface pattern formed near the room surfaces.

8.3 Comparison method (Method 2)

8.3.1 General

The comparison method requires the use of a reference sound source with known sound power output which preferably is operated in the presence of the device to be tested. This method has the advantage that it is not necessary to measure the reverberation time of the test room.

8.3.2 Location of the reference sound source

The reference sound source shall be mounted on the floor of the reverberation room at least 1,5 m away from any other sound-reflecting surface such as a wall or the source being evaluated. The distance from the microphone traverse or array shall be such that the microphone(s) is (are) in the reverberant field as required by 7.1.3.

8.3.3 Required additional data

The sound pressure level corresponding to p^2_{av} during operation of the reference sound shall be determined following the procedures of clause 7.

8.3.4 Calculation

The sound power level produced by the source, L_W, in decibels (reference: 1 pW), in each octave band or one-third octave band within the frequency range of interest is obtained as follows:

a) subtract the band pressure level produced by the reference sound source, L_{pr} (after corrections for background noise in accordance with 7.2.3), from the known sound power level produced by the reference sound source L_{Wr};

b) add the difference to the band pressure level of the source under test, L_p (after corrections for background noise in accordance with 7.2.3), i.e.

$$L_W = L_p + (L_{Wr} - L_{pr})$$

where

L_p is the mean band pressure level of the source under test, in decibels (reference: 20 µPa);

L_{Wr} is the band power level of the reference sound source, in decibels (reference: 1 pW);

L_{pr} is the mean band pressure level of the reference sound source, in decibels (reference: 20 µPa).

9 Information to be recorded

The information specified in 9.1 to 9.4, when applicable, shall be compiled and recorded for measurements that are made in accordance with the requirements of this International Standard.

9.1 Noise source under test

The following information shall be recorded:

a) description of the noise source under test;

b) operating conditions;

c) mounting conditions;

d) location of noise source in test room.

9.2 Acoustical environment

The following information shall be recorded:

a) description of test room, including dimensions, surface treatment of the walls, ceiling and floor; sketch showing the location of source and room contents;

b) qualification of reverberation room (see annex A);

c) air temperature, in degrees Celsius, relative humidity, expressed as a percentage, and barometric pressure, in millibars.

9.3 Instrumentation

The following information shall be recorded:

a) equipment used for the measurements, including name, type, serial number and manufacturer;

b) bandwidth of the frequency analyser;

c) frequency response of the instrumentation system;

d) method used to calibrate the microphone(s), and the date and place of calibration;

e) calibration of reference sound source (for Method 2 only).

9.4 Acoustical data

The following information shall be recorded:

a) the locations and orientation of the microphone path or array (a sketch should be included if necessary);

b) the corrections, in decibels, if any, applied in each frequency band for the frequency response of the microphone, frequency response of the filter in the pass band, background noise, etc.;

c) the sound power levels, in decibels (reference: 1 pW), tabulated or plotted to the nearest one-half decibel.

NOTES

1 Calculation of the weighted sound power level is optional. If the A-weighted sound power level is calculated, the computational procedure of annex C is to be used.

2 The preferred format for plotting sound power level data is given in ISO 3740. One octave corresponds to 15 mm, 10 dB to 20 mm.

10 Information to be reported

The following information shall be reported:

a) the date and time when the measurements were performed;

b) the sound power levels for all frequency bands of interest, and all operating conditions of the source;

c) the location of the noise source under test with respect to the walls, floor and ceiling of the reverberation room;

d) of the additional information listed in clause 9, only those items need be reported which are required for the proper application of the sound power data;

e) the statement that the sound power levels have been obtained in full accordance with the direct method or the comparison method of this International Standard and these sound power levels are given in decibels (reference: 1 pW).

Annex A

Test room qualification procedure for the measurement of broad-band sound

(This annex forms an integral part of the standard.)

A.1 Introduction

If the criterion for room absorption (4.3) cannot be satisfied, the procedure described in this annex shall be used to determine whether or not broad-band sounds can be measured with the precision specified in table 2. It provides a measure of the uncertainties in the coupling between the sound source and the reverberant field as well as uncertainties in the space/time-averaging procedure. The precision of the broad-band sound measurements for each octave or one-third octave band is expressed in terms of the standard deviation of the measurements.

A.2 Instrumentation and equipment

The instrumentation and microphone traverse or array shall be the same as those used during the actual testing of a source. The test procedure given in this annex requires the use of a reference sound source having the characteristics specified in B.1.1 to B.1.5 (see annex B).

The instrumentation shall conform to the requirements laid down in clause 5.

The microphone traverse or array shall conform to the requirements laid down in 7.1.

A.3 Test procedure

Six or more reverberant-field measurements shall be taken of the one-third octave or octave-band sound pressure levels in the room, each with the reference sound source placed at a different location within the room, under the following conditions:

a) The source location shall be selected within a floor area not closer than $\lambda/2$ to a wall and not closer to the microphone than permitted by 4.3.2. The distance between any two source locations shall be greater than $\lambda/4$, where λ is the wavelength of the lowest frequency for which the room is to be qualified. No source location shall lie on a room centreline. The source locations shall be in the general vicinity of the location intended for the source being evaluated.

b) With the reference sound source at each of the above locations, measurements of the one-third octave or octave-band sound pressure levels shall be recorded at least to the nearest 0,5 dB.

c) The microphone traverse or array, sound diffusers (if any), instrumentation and observation time shall be identical to those used for carrying out actual tests with equipment in the source area being qualified.

A.4 Calculation

For each frequency band for which the test room is to be qualified, the standard deviation, s, in decibels, shall be calculated using the following formula:

$$s = (N - 1)^{-1/2} \left[\sum_{i=1}^{N} (L_i - L_m)^2 \right]^{1/2}$$

where

L_i is the band pressure level measured according to the space-averaging technique described in clause 7, in decibels (reference: 20 µPa);

L_m is the arithmetic mean of band pressure levels, in decibels (reference: 20 µPa);

N is the number of source positions.

A.5 Qualification

For each frequency band, the test room qualifies for the measurement of broad-band sound if the calculated standard deviation does not exceed the limits given in table 6.

Table 6 — Maximum allowable standard deviation of L_i

Octave-band centre frequencies	One-third octave-band centre frequencies	Maximum allowable standard deviation
Hz	Hz	dB
125	100 to 160	1,5
250 and 500	200 to 630	1
1 000 and 2 000	800 to 2 500	0,5
4 000 and 8 000	3 150 to 10 000	1

Annex B

Characteristics and calibration of reference sound source

(This annex forms an integral part of the standard.)

B.1 Characteristics of reference sound source

The reference sound source shall have the characteristics specified in B.1.1 to B.1.5 over the frequency range of interest.

B.1.1 The sound radiated shall be broad-band in character without discrete-tone components, i.e. the sound pressure level in any one-tenth octave band shall be at least 5 dB below the corresponding octave band level.

B.1.2 The reference sound source shall be suitably mounted to prevent transmission of vibration to the structure on which it rests.

B.1.3 The directivity index of the source, in any one-third octave band, shall not exceed 6 dB relative to uniform hemispherical radiation over the frequency range from 100 to 10 000 Hz.

B.1.4 The reference sound source should be physically small (maximum dimension preferably less than 0,5 m).

B.1.5 The power level in each frequency band shall remain constant, within the tolerances of table 7, during the useful life of the source.

B.2 Calibration of reference sound source

The sound power produced by the reference sound source shall be determined in octave and one-third octave bands with an accuracy as specified in table 7. During calibration, the source shall be operated on the floor in the same manner as it will be during its intended use.

Table 7 — Calibration accuracy for reference sound source

One-third octave-band centre frequencies	Tolerance
Hz	dB
100 to 160	± 1
200 to 4 000	± 0,5
5 000 to 10 000	± 1

NOTE — The tolerances specified in table 7 can only be obtained by more elaborate measurement procedures than those described in this International Standard (see ISO 3745 and ISO 6926).