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Acoustics — Requirements for the performance and calibration of reference sound sources used for the determination of sound power levels

Acoustique — Exigences relatives aux performances et à l'étalonnage des sources sonores de référence utilisées dans la détermination des niveaux de puissance sonore

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Foreword

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

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

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

International Standard ISO 6926 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 6926:1990), which has been technically revised.

Introduction

Reference sound sources are used extensively in "comparison methods" for determining the noise emissions of physically stationary sound sources. A reference sound source, of known sound power output, is used to establish the numerical relationship between the sound power level of a source, in a given location in a given acoustical environment and the space- and time-averaged sound pressure level at a set of microphone positions. Once that relationship is established, it is straightforward to measure the average sound pressure level produced by an "unknown source" and to determine the sound power level produced by that source.

This International Standard defines the important physical and performance characteristics of reference sound sources and specifies procedures for their calibration, primarily to determine the sound power level of other sound sources.

This International Standard supplements a series of International Standards, the ISO 3740 series, that describes various methods for determining the sound power levels of machines and equipment. This series specifies the acoustical requirements for measurements that are appropriate for different test environments.

Five International Standards in the ISO 3740 series include procedures in which a reference sound source is used: ISO 3741, ISO 3743, ISO 3744, ISO 3746 and ISO 3747. ISO 3740 gives guidelines for the use of all the International Standards in the series.

It should be noted that the sound power output of reference sound sources will vary, in particular at low frequencies, with the distance from the source to nearby reflecting planes. Sound power data of reference sound sources are thus valid only for the position used during the calibration.

In addition to being useful for determining sound power levels by the comparison method, reference sound sources may be used for qualification tests on an acoustic environment and to estimate the influence of an acoustic environment on the sound pressure levels produced by one or more sound sources located in that environment. Examples of International Standards referring to reference sound sources with these applications are ISO 11690-3 and ISO 14257. Requirements other than those of this International Standard may be applicable in these cases.

Acoustics — Requirements for the performance and calibration of reference sound sources used for the determination of sound power levels

1 Scope

This International Standard specifies the acoustical performance requirements for reference sound sources:

— temporal steadiness and repeatability of the sound power output,

— spectral characteristics,

— directivity index.

The stability of the sound power output and the directivity index, for those sources where directivity is needed, are normally only determined in connection with pattern evaluation of the reference sound source. Because of the directivity measurements (for an exception see 5.5), pattern evaluations can only be performed in a hemi-anechoic environment. For regular verification measurements, only the frequency band sound power levels are normally determined. In this case measurements may be made in either hemi-anechoic or reverberant conditions.

This International Standard also specifies procedures for calibrating a sound source intended for use as a reference sound source in terms of its sound power level under the reference condition that the characteristic impedance of air (ρc) is equal to 400 Ns/m^3 in octave and in one-third-octave bands, and with frequency weighting A. Different procedures are specified for pattern evaluation and verification.

NOTE Reference sound sources may also be used for measurements in one-half-octave bands, e.g. for ISO 9295. However, under these circumstances the stability and reproducibility limits stated in this International Standard will not apply.

This International Standard specifies methods to calibrate reference sound sources not only in a free field over a reflecting plane but also in reverberation rooms at different distances from the boundary surfaces. For the position of the reference sound source on one reflecting plane, the two different test environments mentioned above are considered equivalent for frequency bands above or equal to 100 Hz. Below 100 Hz the measurement uncertainties are significantly different (see Table 1).

This International Standard is applicable to a sound source which is intended for use as a reference sound source. The sound source may either be placed directly on the floor or mounted on a stand to be used at a certain elevation above the floor. For floor-mounted sources, this International Standard is valid only for sources whose maximum vertical dimension is less than 0,5 m and whose maximum horizontal dimension is less than 0,8 m. According to this International Standard only floor-mounted reference sound sources may be used when carrying out measurements on a measurement surface. For reference sound sources to be used or calibrated under reverberant conditions, no such restrictions on maximum dimensions apply.

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 3741:1999, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for reverberation rooms*.

ISO 3744, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane*.

ISO 3745:1977, *Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms*.

ISO 5725-1, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions*.

ISO 9613-1, *Acoustics — Attenuation of sound during propagation outdoors — Part 1: Calculation of the absorption of sound by the atmosphere*.

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

3 Terms and definitions

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

3.1
free field over a reflecting plane
sound field in a homogeneous, isotropic medium in the half-space above an infinite, rigid plane surface over which the source is located

3.2
hemi-anechoic room
test room with a reflecting plane (hard floor) meeting the requirements of ISO 3745

3.3
surface sound pressure level
$L_{p\mathrm{f}}$
energy-average (see ISO 3744) of the time-averaged sound pressure levels at all the microphone positions on the measurement surface

NOTE It is expressed in decibels.

3.4
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 (10^{-12} W)

NOTE It is expressed in decibels.

3.5
measurement surface
hypothetical surface enveloping the source on which the sound pressure levels are measured

NOTE For the purposes of this International Standard, the measurement surface is either a hemisphere terminating on the reflecting plane or a sphere.

3.6
far field
that portion of the radiation field of a sound source in which the sound pressure level decreases by 3 dB for each doubling of the area of the measurement surface

NOTE This attenuation rate is equivalent to a decrease of 6 dB for each doubling of the distance from a point source. In the far field the mean-square sound pressure is proportional to the total acoustic power radiated by the source.

3.7
near field
that portion of the radiation field of a sound source which lies between the source and the far field

3.8
directivity index
$D_{\mathrm{I}i}$
measure of the extent to which a source radiates sound predominantly in one direction

NOTE 1 The directivity index of direction i is calculated from measurements in a hemi-anechoic or anechoic room by the equation

$$D_{\mathrm{I}i} = L_{pi} - L_{p\mathrm{f}} \quad (1)$$

where

L_{pi} is the sound pressure level, in decibels, as measured on the measurement surface of the source in the particular direction in which $D_{\mathrm{I}i}$ is desired;

$L_{p\mathrm{f}}$ is the surface sound pressure level, at the same distance averaged over the measurement surface.

The measurement surface is a hemisphere when the reference sound source is intended to be located directly on the floor and a sphere if it is intended to be used in positions elevated above the floor.

NOTE 2 This definition is different from that in ISO 3745 because the reference is a source in a free field above a reflecting plane instead of a source in a free field.

3.9
reverberation room
test room meeting the requirements of ISO 3741

3.10
frequency range of interest
this is normally the octave bands with midband frequencies from 125 Hz to 8 000 Hz or the one-third-octave bands with midband frequencies from 100 Hz to 10 000 Hz

NOTE The frequency range may be extended up to as much as 20 000 Hz or down to as low as 50 Hz, provided that the requirements of this International Standard are still met.

3.11
comparison method
method in which the sound power level is calculated by comparing the measured sound pressure levels produced by the source under test in an environment with the sound pressure levels produced by a reference sound source of known sound power output in the same environment

3.12
reverberation time
T
time that is required for the sound pressure level to decrease by 60 dB after the sound source has stopped

NOTE 1 If the reverberation time is evaluated from the decay of the first 10 dB or 15 dB, it is denoted T_{10} or T_{15} respectively.

NOTE 2 It is expressed in seconds.

3.13
reference sound source
RSS
portable, generally electroacoustical or aerodynamic sound source or other noise-generating device, and associated control circuitry giving a broad-band stable output complying with the requirements (see clause 5)

3.14
repeatability
as defined in ISO 5725-1 when applying one of the measurement procedures of this International Standard

4 Measurement uncertainty

A single value of the sound power level of a reference sound source determined according to the procedures of this International Standard is likely to differ from the true value by an amount within the measurement uncertainty. The uncertainty in determination 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.

Table 1 — Estimated upper values of the standard deviations of reproducibility of sound power levels of reference sound sources determined according to this International Standard

Octave midband frequency	One-third-octave midband frequency	Standard deviation of reproducibility[a] with source on the floor in hemi-anechoic rooms σ_R dB		Standard deviation of reproducibility[a] with source in reverberation rooms σ_R dB
Hz	Hz	Meridional or spiral paths	20 discrete positions or coaxial circular paths	
63	50 to 80	2,0	2,0	2,5
125	100 to 160	0,8	0,8	1,0
250 to 2 000	200 to 3 150	0,3	0,5	0,3
4 000 to 8 000	4 000 to 10 000	0,3	1,0	0,3
16 000	12 500 to 20 000	0,3	1,0	0,4
	A-weighted	0,3[b]	0,5	0,2[b]

[a] The values exclude variations in the source output and are substantiated by experiments.

[b] The A-weighted values have been calculated from one-third-octave-band data.

If a particular 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 the provisions of this International Standard, the results would show a scatter. The standard deviations of the measured values could be calculated (for examples, see ISO 7574-4:1985, annex B) and would vary with frequency. These standard deviations would not exceed those listed in Table 1.

The values given in Table 1 are standard deviations of reproducibility, σ_R, as defined in ISO 5725-1. The values of Table 1 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. rotation speed, line voltage) or mounting conditions.

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

NOTE 1 The uncertainties in Table 1 apply only to the particular source that is being calibrated. The calibration of a particular reference sound source does not apply to another reference sound source of the same design and manufacture unless statistical data are available to specify additional uncertainty introduced by product variability.

NOTE 2 The uncertainties in Table 1 do not include systematic differences between the sound power levels determined in the two different test environments. These differences are insignificant above 100 Hz. However, at 100 Hz and below, these differences may be significant. For 200 m^3 reverberation rooms these differences are typically 1,5 dB or less.

5 Performance requirements

5.1 General

The manufacturer shall state whether or not the RSS is in full compliance with this International Standard.

5.2 Temporal steadiness and repeatability of sound power output

The reference sound source shall be designed and constructed so that the sound power level, under repeatability conditions, in each one-third-octave band is constant in time as given in Table 2.

Table 2 — Maximum value of the standard deviation of the sound power level under repeatability conditions for a reference sound source according to this International Standard

Frequency range Hz	Standard deviation dB
50 to 80	0,8
100 to 160	0,4
200 to 20 000	0,2

NOTE 1 For special purposes a reference sound source may have a more limited frequency range.

The manufacturer of the reference sound source shall state the range of variation of the source of electrical or mechanical power (e.g. the supply voltage) within which the sound power level in any one-third-octave band within the frequency range of interest shall not vary by more than ± 0,3 dB. The manufacturer shall provide procedures to adjust the sound power levels produced by the reference sound source for the influence of larger variations in the source of electrical voltage or mechanical power.

NOTE 2 The sound power level of a reference sound source depends on the atmospheric pressure and the air temperature. For use at different temperatures or altitudes, the manufacturer should supply information concerning appropriate corrections, and their uncertainties, for the influence of air temperature and atmospheric pressure on sound power level.

5.3 Total broad-band sound power level

There are no specific requirements placed on the total broad-band sound power level produced by a reference sound source. However, if the total broad-band sound power level is reported, the corresponding frequency range shall also be reported.

5.4 Spectral characteristics

The reference sound source shall produce broad-band steady sound over the frequency range in which it is intended for use, at least for one-third-octave-midband frequencies between 100 Hz and 10 000 Hz. Over this frequency range, all the one-third-octave-band sound power levels, when measured in conformity with the requirements of clauses 7 and 8, shall be within a range of 12 dB. Under these same measuring conditions, and over this same frequency range, the sound power level in each one-third-octave band shall not deviate by more

than 3 dB from the sound power level in the adjacent one-third-octave bands. If the frequency range is extended beyond 100 Hz to 10 000 Hz then the requirements for the extended range are 16 dB and 4 dB respectively.

It may be desirable for special sound sources to meet these criteria over a more limited frequency range or for a different spectrum shape. If a reference sound source does not comply with the requirements of this International Standard over the frequency range from 100 Hz to 10 000 Hz, the manufacturer shall state that the frequency response of the reference sound source does not comply with this International Standard.

5.5 Directivity index

The highest value of the directivity index of the source in any one-third-octave band with midband frequency between 100 Hz and 10 000 Hz, shall not exceed +6 dB when measured in a hemi-anechoic room complying with clause 7. If a moving microphone is used, the maximum sound pressure level, measured with time-weighting S, for each one-third-octave band during any traverse shall be recorded and used to compute the directivity index. For fixed microphone positions, the maximum sound pressure level for each frequency band of any of the 20 positions shall be used.

If the RSS is to be used exclusively in reverberation rooms complying with ISO 3741, the above requirements do not apply but in that case the RSS shall be labelled "For use as a reference sound source in qualified reverberation rooms only".

If the RSS is designed to be used on a stand above the floor, the above requirements apply for a free field and the directivity measurements are to be carried out in an anechoic room according to ISO 3745.

5.6 Recalibration

The manufacturer shall recommend the maximum time interval between successive calibrations. During this interval, changes in the sound power levels of the reference sound source shall not exceed the limits given in Table 2. Whenever any mechanical damage has been inflicted on the reference sound source, it shall be recalibrated.

In order to determine whether or not recalibration of a reference sound source is necessary during the recommended maximum time interval, one-third-octave-band sound pressure levels should be measured occasionally at one or more fixed reference points (e.g. at time intervals and locations recommended by the manufacturer) with the source operating at a specific location in a specified test environment. If, after using manufacturer-specified procedures to adjust the measured sound pressure levels to constant environmental conditions when necessary, changes in any one-third-octave-band sound pressure level exceed 2,83 times the values in Table 2, recalibration of the reference sound source may be necessary (see ISO 5725-1).

6 Installation and operation of the reference sound source during calibration

6.1 General

The source shall be operated in accordance with the manufacturer's instructions. The essential characteristics of the source of mechanical or electrical power (e.g. line voltage and frequency) and the relevant operating parameters of the reference sound source (e.g. rotational speed of an aerodynamic source) shall be recorded.

NOTE It may be necessary to use auxiliary equipment to measure the relevant operating parameters (e.g. a stroboscope to determine rotational speed).

The reference sound source shall be in a stable operating condition before any measurements (either of acoustic properties or of operating parameters) are made.

6.2 Position of the reference source

6.2.1 RSS to be located on the reflecting plane and away from the walls

In a hemi-anechoic room, place the source to be calibrated on the reflecting plane, oriented as in normal usage.

In a reverberation room, place the source on the floor unsymmetrically in relation to the walls and at least 1,5 m from the nearest wall. Use four such positions at least 2 m from each other.

6.2.2 RSS to be located above the floor or close to wall(s)

If the reference sound source is to be calibrated in positions other than those of 6.2.1, these calibrations shall take place in a reverberation room.

Reference sound sources in positions more than 0,5 m from the reflecting plane or close to wall(s) cannot be calibrated in hemi-anechoic rooms.

7 Calibration procedure in hemi-anechoic rooms

7.1 Test environment

The test environment shall be a hemi-anechoic room meeting the qualification requirements of annex A of ISO 3745:1977 over the frequency range of interest. The floor shall extend at least 1 m in each horizontal direction beyond the projection of the measurement surface onto the floor.

7.2 Microphone

For the normal frequency range of interest, use either a microphone with a nominally flat frequency response at normal incidence mounted with the plane of the diaphragm towards the centre of the measurement hemisphere or a microphone with a nominally flat frequency response at grazing incidence mounted with the plane of the diaphragm at 90° towards the centre of the measurement hemisphere. The microphone response shall be corrected to give a flat frequency response within 0,1 dB at normal incidence or grazing incidence over the frequency range of interest. If the frequency range is extended above the 10 000 Hz one-third-octave band, use only a microphone with a nominally flat frequency response at grazing incidence.

7.3 Microphone positions

7.3.1 General

Use a hemispherical measurement surface with a radius of 2 m. Centre it over the geometrical centre of the projection of the top surface of the RSS on the reflecting plane. Use one of the sets of microphone positions given in 7.3.2, 7.3.3, 7.3.4 or 7.3.5. Make sure that the mechanical arrangement for fixing or moving the microphone does not affect the measurements.

7.3.2 Meridional paths

For sources with rotational symmetry, use three traverses (see Figure 4 in annex F of ISO 3745:1977) at 120° increments around the vertical axis of the measurement surface. For other sources, use at least eight traverses. If the traverses are made at a constant angular speed, use a sine potentiometer (or its electrical, mechanical or mathematical equivalent) to obtain proper weighting for the surface area associated with the time required for the microphone to traverse a given arc length. If the traverse is conducted such that the microphone moves at a constant vertical speed (i.e. the angular speed is inversely proportional to the sine of the angle between the angular position of the microphone and the vertical axis of the measurement surface), apply no area weighting.

NOTE When using a sine potentiometer, the angular velocity becomes infinite on the top of the hemisphere. In practice this problem is solved by stopping the integration a little before the top is reached.

7.3.3 Spiral path

Use a traverse along one meridional path as in 7.3.2, and simultaneously traverse the microphone slowly through an integral number of at least five circular paths, thus forming a spiral path around the vertical axis of the measurement surface. Alternatively, generate a spiral path by slowly rotating the reference sound source at a constant rotational speed through at least five complete turns while traversing the microphone along a meridional path. Use area weighting as in 7.3.2, if required. Use three traverses, for each of the above procedures, at 120° increments around the vertical axis of the measurement surface.

7.3.4 Fixed point array

Use 20 fixed microphone positions distributed over the surface of a 2,0 m radius (R) hemisphere at evenly spaced heights from the floor, one microphone position being located at each height. The 20 heights shall be 0,025R, 0,075R,….., 0,975R. For each height, the azimuth position shall be moved by 60° from the previous position to create a spiral sampling pattern. If the source is not rotationally symmetrical in the horizontal plane, a second set of measurements shifted 180° from the first set shall be made and averaged with the first set of measurements.

7.3.5 Coaxial circular paths

Use 20 circular traverses on the surface of 2,0 m hemisphere and around a vertical axis passing through the centre of the RSS. The circular traverses shall be located at the 20 heights given in 7.3.4 and represent equal areas of the hemispherical surface. The circular paths may be achieved by uniformly rotating either the microphone or the RSS slowly through 360°. The period of circular scan rotation shall be at least 60 s. If a turntable is used to rotate the RSS, its surface shall be flush with the reflecting plane.

7.4 Measurements

Measure one-third-octave-band sound pressure levels in accordance with ISO 3745 with an integration time of at least 200 s for each quarter circle traverse of the meridional path and 600 s for the spiral path. For discrete microphone positions, integrate for 30 s in each microphone position. For the coaxial circular paths, the integration time shall correspond to an integral number of microphone or source rotations.

NOTE Octave-band and A-weighted sound pressure levels may be measured directly or calculated, on a mean-square sound pressure basis, from the one-third-octave-band data.

7.5 Air absorption

If the measurements are extended to frequencies higher than 10 000 Hz, correct for air absorption in accordance with ISO 9613-1.

7.6 Calculations

Calculate one-third-octave-band surface sound pressure levels and sound power levels in accordance with ISO 3745 using the following formula:

$$L_W = L_{pf} + 10\lg\left(\frac{S_1}{S_0}\right)\text{dB} + C \qquad (2)$$

where

L_{pf} is the surface sound pressure level over the measurement surface, in decibels (ref. 20 μPa);

S_1 is the area of the measurement surface;

S_0 = 1 m^2;