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

Acoustique — Prescriptions relatives aux performances et à l'étalonnage des sources sonores de référence pour la détermination des niveaux de puissance acoustique

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This third edition cancels and replaces the second edition (ISO 6926:1999), which has been technically revised with the following changes:

— the clause on measurement uncertainty has been updated with stricter reference to ISO/IEC Guide 98-3 and moved backwards in the standard to be more in line with ISO 3745;

— the corrections for meteorological conditions have been brought in line with ISO 3745 and a new Annex A on the acoustic radiation impedance correction has been introduced;

— an alternative method using sound intensity for low frequency calibration in hemi-anechoic rooms not fully qualified for low frequencies has been introduced in a new Annex B.

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 acoustic 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 group or family of International Standards, the ISO 3740 group, which describes various methods for determining the sound power levels of machines and equipment. This group of International Standards specifies the acoustical requirements for measurements that are appropriate for different test environments.

Five International Standards in the ISO 3740 group include procedures in which a reference sound source is used: ISO 3741, ISO 3743-1, ISO 3744, ISO 3746 and ISO 3747. ISO 3740 gives guidelines for the use of all the International Standards in the group.

Note 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 can 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/TR 11690-3 and ISO 14257. Requirements other than those of this International Standard can 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 (stability) of the sound power output;

— spectral characteristics;

— directivity.

Temporal steadiness is defined in terms of the standard deviation of repeatability (see 5.2). The spectral characteristics can be verified in either a hemi-anechoic room or a reverberation test room from measurements of the frequency band sound power levels in accordance with this International Standard (see 5.4). The performance requirements on directivity index can only be verified in a hemi-anechoic room (see 5.5.)

This International Standard also specifies procedures for providing level calibration data and uncertainty on a sound source intended for use as a reference sound source in terms of its sound power level under reference meteorological conditions as defined in Clause 4 in octave and in one-third-octave bands, and with frequency weighting A.

This International Standard is titled as a calibration standard even though the method is conducted in a testing laboratory and the level calibration results are not directly traceable to national standards of measure in a strict metrological sense. Testing laboratories performing this method are not expected to meet all requirements normally associated with a calibration laboratory.

NOTE ISO/IEC 17025[15] specifies different requirements for the competence of testing laboratories and calibration laboratories respectively. Laboratories testing reference sound sources in accordance with this International Standard would typically comply with the requirements for testing laboratories but not necessarily with those for calibration laboratories.

This International Standard specifies methods to calibrate reference sound sources not only in a free field over a reflecting plane but also in reverberation test 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 200 Hz. At 160 Hz and below, some systematic differences can occur (see 11.2). For frequencies below 100 Hz, an alternative calibration method using sound intensity is given.

The sound source can either be placed directly on the floor or mounted on a stand to be used at a certain elevation above the floor. According to this International Standard, stand-mounted sources are calibrated in reverberation test rooms. Floor-mounted sources are either calibrated in hemi-anechoic or in reverberation test rooms. For floor-mounted sources in hemi-anechoic rooms, 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 can 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 documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3741:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms*

ISO 3744:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane*

ISO 3745:2012, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for anechoic rooms and hemi-anechoic rooms*

ISO 9613-1:1993, *Acoustics — Attenuation of sound during propagation outdoors — Part 1: Calculation of the absorption of sound by the atmosphere*

ISO 9614-3, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 3: Precision method for measurement by scanning*

IEC 60942:2003, *Electroacoustics — Sound calibrators*

IEC 61094-1, Measurement microphones — Part 1: Specifications for laboratory standard microphones

IEC 61094-4, Measurement microphones — Part 4: Specifications for working standard microphones

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

IEC 61260-1, Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

IEC 61672-3:2013, Electroacoustics — Sound level meters — Part 3: Periodic tests

IEC 62585, Electroacoustics — Methods to determine corrections to obtain the free-field response of a sound level meter

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

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

3.1
reference sound source
RSS
portable, generally electroacoustical or aerodynamic sound source or other noise-generating device, and associated control circuitry giving a broadband stable output complying with the requirements of this International Standard

3.2
free sound field over a reflecting plane
sound field in a homogeneous, isotropic medium in the half-space above an infinite, reflecting plane in the absence of other reflecting obstacles

3.3
hemi-anechoic room
test room in which a free sound field over a reflecting plane is obtained

3.4
reverberation test room
test room meeting the requirements of ISO 3741

3.5
measurement surface
hypothetical surface of area, S, on which the microphone positions are located at which the sound pressure levels are measured, enveloping the source under test and, in the case of a hemi-anechoic room, terminating on the reflecting plane on which the source is located

Note 1 to entry: The measurement surface area is expressed in metres squared.

3.6
surface sound pressure level
$\overline{L_p}$
energy-average of the time-averaged sound pressure levels at all the microphone positions, or traverses, on the measurement surface, with the background noise corrections, K_1, applied at each microphone position or traverse

Note 1 to entry: Surface sound pressure level is expressed in decibels.

Note 2 to entry: For definition and calculation of K_1, see ISO 3745.

3.7
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of the sound power of a source, P, to a reference value, P_0, expressed in decibels

$$L_W = 10 \lg \frac{P}{P_0} \text{dB}$$

where the reference value, P_0, is 1 pW

Note 1 to entry: If a specific frequency weighting as specified in IEC 61672–1, and/or specific frequency bands are applied, this should be indicated by appropriate subscripts; e.g. L_{WA} denotes the A-weighted sound power level.

Note 2 to entry: This definition is technically in accordance with ISO 80000-8:2007,[17] 8-23.

[SOURCE: ISO/TR 25417:2007, 2.9]

3.8
measurement radius
r
radius of a hemi-spherical measurement surface

3.9
directivity index
$D_{\mathrm{I}i}$
measure of the extent to which a source radiates sound in a particular direction, relative to the mean sound radiation over the measurement surface, where for fixed microphones, the direction is from the source to the position of the microphone, and for traverses, the direction is from the source to the position along the microphone path at which the highest sound pressure level is recorded

Note 1 to entry: The directivity index of direction, i, is calculated from measurements in a hemi-anechoic room by the following formula:

$$D_{\mathrm{I}i} = L_{pi} - \overline{L_p}$$

where

L_{pi} <for fixed microphones> is the sound pressure level for each one-third-octave band at the ith microphone position on the measurement surface, in decibels;

L_{pi} <for microphone traverses> is the maximum sound pressure level for each one-third-octave band that is recorded during the ith microphone traverse (see 8.2) on the measurement surface, in decibels;

$\overline{L_p}$ is the surface sound pressure level averaged over the same measurement surface, in decibels.

Note 2 to entry: With the above "operational" definition, the directivity index is a measure of the uniformity of sound radiation from the source over the particular measurement surface being employed and as it is installed in the test environment. Definitions for the "theoretical" directivity index appearing in textbooks and the literature usually represent the uniformity of sound radiation by comparing the source under test in its test environment to a point source of the same sound power radiating into a full sphere in a totally free field. When such definitions are applied to sources located in a free field above a reflecting plane, they include a constant "+3 dB" to account for the hemispherical radiation. Care should be taken when comparing or using different definitions of directivity index.

3.10
frequency range of interest
frequency range of one-third-octave bands with nominal mid-band frequencies from 100 Hz to 10 000 Hz

Note 1 to entry: The frequency range of interest in one-third-octave bands may be extended up to as much as 20 000 Hz or down to as low as 50 Hz, provided 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
direct method
method in reverberation test rooms where the sound power level is calculated using the equivalent sound absorption area determined from measurements of the reverberation time

3.13
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 to entry: 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 to entry: It is expressed in seconds.

3.14
repeatability condition
condition where independent test results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time

4 Reference meteorological conditions

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

air temperature: 23,0 °C;

static pressure: 1,013 25 × 10^5 Pa;

relative humidity: 50 %.

5 Performance requirements

5.1 General

A manufacturer may only state that its RSS is in compliance with this International Standard if all of the requirements laid out in this Clause are met.

5.2 Temporal steadiness (stability) of sound power output

The sound power level of the reference sound source shall be stable over time such that the measured standard deviations under repeatability conditions, σ_r (see 8.3.3 and 9.3.2), do not exceed those given in Table 1.

Table 1 — Maximum value of the standard deviation of the sound power level under repeatability conditions for a reference sound source in accordance with this International Standard

One-third-octave midband frequency Hz	**Standard deviation under repeatability conditions,** σ_r 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.

A reference sound source meeting the requirements of this International Standard shall include information on the range of variation of the source of electrical or mechanical power (e.g. the line 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.

NOTE 2 The sound power level of a reference sound source depends on the static pressure and the air temperature. For the RSS to be used at different temperatures or altitudes, it is expected that information concerning appropriate corrections, and their uncertainties, for the influence of air temperature and static pressure on sound power emitted by the RSS, is included. For an aerodynamic fan RSS, the rotational speed and variations due to changing meteorological conditions during the qualification test are found according to 8.4 and 9.4.

5.3 Total broadband sound power level

There are no specific requirements placed on the total broadband sound power level produced by the RSS. However, if the total broadband sound power level is reported, either as an unweighted or frequency-weighted quantity, the corresponding frequency range shall also be reported.

5.4 Spectral characteristics

The RSS shall produce broadband steady sound over the frequency range in which it is intended for use, but at least for one-third-octave midband frequencies between 100 Hz and 10 000 Hz. Over this frequency range, all of the one-third-octave-band sound power levels, when measured in conformity with the requirements of Clause 8 and Clause 9, as applicable, 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 higher or lower one-third-octave bands (the higher band only in the case of the 100 Hz band, and the lower band only in the case of the 10 000 Hz band). 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. However, if a RSS does not comply with the requirements of this International Standard over at least the frequency range from 100 Hz to 10 000 Hz, it shall not be labelled or declared as being in compliance with the frequency range of this International Standard.

5.5 Directivity

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 8.

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

5.6 Recalibration

5.6.1 Whenever any mechanical damage has been inflicted on the reference sound source, it shall be recalibrated. For aerodynamic sound sources, measure the rotational speed (RPM) of the fanwheel. If the present RPM after a few minutes stabilization deviates less than 1% from that found during the last calibration, then the RSS is not electrically damaged.

5.6.2 The user manual for the reference sound source should provide the recommended maximum time interval between successive calibrations such that changes in the sound power levels of the specified model of the reference sound source is not expected to exceed 2,83 times the values in Table 1 (presumably from qualified historical tracking by the manufacturer). If this time interval is provided, it shall be considered a requirement of this International Standard. If it is not provided in the user manual, the maximum time interval shall be two years.

NOTE If the difference between two consecutive calibrations is less than 2,83 times the standard deviation, there is, e.g. see ISO 5725-2 [7], a probability of 95 % that the temporal stability of the RSS complies with the values given in Table 1.

5.6.3 In order to determine whether or not recalibration of a reference sound source is necessary before the maximum time interval has expired, one-third-octave-band sound pressure levels shall be measured regularly at one or more fixed reference points with the source operating at a specific location in a specified test environment as a check of its temporal stability. The user manual for the reference sound source should specify the time interval between such regular measurements. If this time interval is provided, it shall be considered a requirement of this International Standard. If it is not provided in the user manual, the time interval shall be a maximum of six months. 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 between successive checks exceed 2,83 times the values in Table 1, the reference sound source shall be recalibrated.

NOTE If the above check indicates the need for recalibration, confidence may be diminished in any data that may have been taken with the reference sound source during the intervening time interval. In view of this, the laboratory may decide on a much shorter time interval, or select a variable time interval based on the number of tests it performs.

5.6.4 For laboratories using a reference sound source in a generally fixed location, in a controlled environment without transporting it, calibration intervals may be extended beyond the maximum time interval in 5.6.2 if changes in the surface time average band sound pressure levels measured at a maximum of one-year intervals over positions 1 to 10 of ISO 3744:2010, Table B.1, using a fixed measurement radius of at least 1 m, in an environment that has been qualified for broadband sound power level determination in accordance with ISO 3745:2012, Annex A do not exceed 2,83 times the values in Table 1. Alternatively, an equivalent test may be carried out with the RSS in one specified location in a reverberation room following the procedures specified for measurements of sound pressure levels from a RSS in ISO 3741. For this measurement, the reference sound source shall each time be measured at the same temperature,

pressure, and humidity within the tolerances specified in ISO 3741. The change in sound pressure levels is hereby defined as the difference between the latest measurement and a reference measurement using exactly the same test procedure that was carried out in connection with the arrival of the reference sound source directly after the latest accredited calibration in full compliance with this International Standard. Each check shall be documented.

However, the maximum permissible extension using this procedure is 10 years. After this period, the reference sound source shall be subject to a new calibration by an authorized laboratory in full compliance with this International Standard.

6 Instrumentation

6.1 General

For measurements conducted with a sound level meter, the instrument for measuring sound pressure levels, including microphone(s) as well as cable(s), windscreen(s), recording devices and other accessories, if used, shall meet the requirements of IEC 61672-1 for a class 1 sound level meter.

For measurements conducted using computerized data acquisition systems the complete measurement system, including hardware and software components, shall be validated in accordance with the periodic test requirements of IEC 61672-3. The validation shall be conducted for the requirements specified in IEC 61672-3:2013, Clauses 8, 9, 10, 11, 14, 15, 16, 17, 18, and 20 at conditions that are representative of those present in the environment where the measurements are conducted.

Proportional octave band filters for sound level meters or computerized data acquisition systems shall meet the requirements of IEC 61260-1, class 1.

6.2 Microphone in a hemi-anechoic room

Use either a microphone with a nominally flat frequency response at normal incidence mounted with the axis of the microphone (that runs perpendicular through the plane of the diaphragm) pointing towards the centre of the measurement hemisphere, or a microphone with a nominally flat frequency response at grazing incidence mounted with the axis of the microphone perpendicular to the line pointing towards the centre of the measurement hemisphere. Microphones used as part of a sound level meter shall meet the requirements of IEC 61672-1 for a class 1 sound level meter. Microphones used with computerized data acquisition systems shall be of type LS or WS and shall have free field (F), pressure (P), or diffuse field (D) response as defined by IEC 61094-1 and IEC 61094-4 respectively. Microphones shall be validated in accordance with the periodic testing requirements of IEC 61672- 3:2013 for a class 1 sound level meter and be individually frequency-corrected according to 6.4.

6.3 Microphone in a reverberation test room

Microphones used as a part of a sound level meter shall be of random incidence type (or corrected to random incidence) and shall be calibrated in accordance with IEC 61183 and shall meet the requirements of IEC 61672-1 for a class 1 sound level meter. Microphones used with computerized data acquisition systems shall be of type WS and shall have diffuse field (D) response as defined by IEC 61094-4. Microphones shall be validated in accordance with the periodic testing requirements of IEC 61672-3 for a class 1 sound level meter and be individually frequency-corrected according to 6.4.

6.4 Microphone frequency response correction

Microphones for use in hemi-anechoic rooms shall be provided with frequency response corrections obtained in accordance with IEC 62585. Microphones for use in reverberation rooms shall be provided with frequency response corrections obtained in accordance with IEC 61183.

The microphone response shall be corrected (usually using one-third-octave-band corrections obtained from an accredited microphone calibration performed in an accredited or otherwise nationally authorized laboratory) with a precision of 0,1 dB to give a nominally flat frequency response, in a

hemi-anechoic room at normal incidence or grazing incidence and in a reverberation room at random incidence over the frequency range of interest.

If the frequency range is extended above the 10 000 Hz one-third-octave band, there may be a small difference in frequency response accuracy between the two microphone types. The data on measurement uncertainty given in Table 2 are based on measurements using microphones with a nominally flat frequency response at grazing incidence.

6.5 Verification

Compliance of the sound pressure level measuring instrument, the filters, microphone and the sound calibrator with the requirements specified herein shall be verified by the existence of a valid certificate of compliance with the measurement parameters specified in the test method.

All certificates of compliance shall state that compliance testing was conducted by a laboratory being accredited or otherwise nationally authorized to perform the relevant tests and calibrations and ensuring metrological traceability to the appropriate measurement standards.

Unless national regulations dictate otherwise, it is recommended that

— the sound calibrator should be calibrated at intervals not exceeding one year,

— the compliance of the instrumentation system with the requirements stated in 6.1 should be verified at intervals not exceeding two years, and

— the compliance of an analog filter set should be verified with the requirements of IEC 61260-1 at intervals not exceeding two years. Digital filter sets should be verified with a certificate of compliance with the requirements of IEC 61260-1 and should be updated any time the algorithms associated with the filters are changed.

Periodic calibration shall be conducted by a laboratory being accredited or otherwise nationally authorized to perform the relevant tests and calibrations and ensuring metrological traceability to the appropriate measurement standards.

6.6 Microphone calibration check

At the beginning and at the end of every measurement session, the entire sound pressure level measuring system shall be checked at one or more frequencies by means of a sound calibrator meeting the requirements for a class 1 calibrator as specified in IEC 60942. Without any further adjustment, the difference between the readings of two consecutive checks shall not exceed 0,2 dB. If this value is exceeded, the results of all measurements obtained after the previous satisfactory check shall be discarded.

7 Installation and operation of the reference sound source during calibration

7.1 General

The RSS under test 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 might be necessary to use auxiliary equipment to measure the relevant operating parameters (e.g. a stroboscope to determine rotational speed).

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

7.2 Requirements in hemi-anechoic rooms

In a hemi-anechoic room, place the RSS to be calibrated on the reflecting plane, oriented as in normal usage and at least 1,0 m from the nearest wall.

Reference sound sources in positions more than 0,5 m from the reflecting plane cannot be calibrated in hemi-anechoic rooms.

7.3 Requirements in reverberation rooms

In a reverberation test room, place the RSS 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. Alternatively, the RSS can be calibrated in specified positions above the floor and close to the walls.

8 Calibration procedure in hemi-anechoic rooms

8.1 Test environment

The test environment shall be a hemi-anechoic room meeting the broadband qualification requirements of ISO 3745:2012, Annex A, over the frequency range of interest.

8.2 Microphone positions

8.2.1 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 8.2.2, 8.2.3, 8.2.4 or 8.2.5. Take care that the mechanical arrangement for fixing or traversing the microphone does not affect the measurements.

8.2.2 Meridional paths

Follow the procedures of ISO 3745:2012, 9.3.5 and Annex G. For sources with rotational symmetry, use three traverses at 120° increments around the vertical axis of the measurement surface. For other sources, use at least eight traverses.

NOTE 1 When using constant vertical speed, the angular velocity becomes infinite on the top of the hemisphere. In practice, this problem is solved by stopping the averaging a little before the top is reached.

NOTE 2 Other speed arrangements than those given in ISO 3745:2012, 9.3.5, may be used provided that the requirements of ISO 3745:2012, 9.4.3.3 are met.

8.2.3 Spiral path

Follow the procedures of ISO 3745:2012, 9.3.6 and Annex H. Use three traverses of the procedure chosen at 120° increments around the vertical axis of the measurement surface.

8.2.4 Fixed point array

For a hemispherical measurement surface, select positions according to ISO 3745:2012, 9.3.3, and Annex E. For sources with rotational symmetry in the horizontal plane, use the 20 fixed microphone positions numbered 1 to 20. For other sources, add the 20 positions numbered 21 to 40.

8.2.5 Coaxial circular paths

Follow the procedures of ISO 3745:2012, 9.3.4, but use the set of 20 circular traverses for a hemispherical measurement surface. 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 to within 15 mm. As an alternative to the equal-area traverses at equidistant heights specified in ISO 3745:2012 equal angle traverses may be used provided the number of heights is the same and that corrections for the unequal areas associated with each traverse are made following the procedure of ISO 3745:2012, 9.4.3.2

8.3 Measurements

8.3.1 General

At each microphone position or along each microphone traverse, measure the one-third-octave-band sound pressure levels in accordance with ISO 3745. For fixed microphone positions, the measurement time interval shall be at least 30 s at each microphone position. For traversing microphones, the measurement time interval shall be at least 200 s for each quarter circle traverse of the meridional paths and at least 600 s for each traverse of the spiral paths. For the coaxial circular paths, the measurement time interval shall correspond to an integral number of microphone or source rotations and shall not be less than 60 s.

Measure the RSS rotational speed and line voltage before, and at the end of the sound measurements. Average and record the result along with the observed variations. State the mains frequency and measured line voltage applied during this test.

8.3.2 Directivity index

This measurement is mandatory when a new RSS is calibrated for the first time unless it is dedicated for use in reverberation test rooms complying with ISO 3741 only. Otherwise, it is optional for regular recalibrations unless the RSS has suffered mechanical damage, or, for other reasons, is suspected to have changed its directional properties.

In order to determine the directivity index (see 3.9) when traversing microphones are used, either of the following additional measurements shall be taken. The sound pressure level using time-weighting S shall be continuously measured during the traverse, for each one-third-octave band, and the maximum value shall be recorded and used to compute the directivity index for that traverse. Alternatively, the time-averaged sound pressure level shall be sampled at least 20 times at regular intervals during each traverse and for each one-third-octave band and the maximum value recorded and used to compute the directivity index for that traverse. The actual position along the traverse at which the maximum value occurs need not be monitored or recorded. The corresponding procedure can be used if the RSS is rotating and the microphone is fixed.

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

8.3.3 Temporal steadiness

This measurement is optional unless the purpose of the test is to test the RSS for type approval.

In order to check the temporal steadiness (stability) of the sound power output (see 5.2), one of the following methods shall be used:

a) three repeated measurements of the sound power level of the reference sound source in conformance with the hemi-anechoic room method of this International Standard shall be taken in succession;

b) five repeated measurements of the time-averaged sound pressure level of the reference sound source shall be taken at one fixed microphone or over one of the traverses in conformance with the hemi-anechoic room method of this International Standard with a pause of at least 5 min between measurements.

The standard deviations shall be computed according to Formula (1) and compared with the limits in Table 1.

The standard deviation under repeatability conditions, σ_r, is obtained from Formula (1):

$$\sigma_r = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}\left(L_{X,j} - \overline{L_X}\right)^2} \tag{1}$$

where

N is the number of repeated measurements (N = 3 for sound power levels and N = 5 for sound pressure levels);

$L_{X,j}$ is the sound power level or the sound pressure level determined for the jth repetition of the prescribed test;

$\overline{L_X}$ is the energy-averaged sound power level or the energy-averaged sound pressure level calculated for all N repetitions.

8.4 Calculations

Calculate one-third-octave-band sound power levels, L_W, under reference meteorological conditions in accordance with ISO 3745 using Formula (2):

$$L_W = \overline{L_P} + 10\lg\left(\frac{S}{S_0}\right)\text{dB} + C_1 + C_2 + C_3 \tag{2}$$

where

$\overline{L_P}$ is the surface time-averaged sound pressure level for the noise source under test, in decibels;

S is the area of the measurement surface, in square metres;

S_0 = 1 m^2;

C_1 is the reference quantity correction, in decibels, to account for the different reference quantities used to calculate sound pressure level and sound power level, and is a function of the characteristic acoustic impedance of the air under the meteorological conditions at the time and place of the measurements:

$$C_1 = -10\lg\left(\frac{p_s}{p_{s,0}}\right)\text{dB} + 5\lg\left(\frac{\theta}{\theta_0}\right)\text{dB}$$

p_0 is the reference sound pressure, 2 × 10^{-5} Pa;

P_0 is the reference sound power, 10^{-12} W;

p_s is the static pressure at the time and place of the test, in pascals;

$p_{s,0}$ is the reference static pressure, 1,013 25 × 10^5 Pa;

θ is the air temperature at the time and place of the test, in degrees Kelvin;

θ_0 = 314 K, is the temperature (when static pressure is equal to $p_{s,0}$) where sound intensity and sound pressure have identical decibel values when measured in a plane wave;

C_2 is the acoustic radiation impedance correction, in decibels, to change the actual sound power relevant for the meteorological conditions at the time and place of the measurement into the sound power under reference meteorological conditions, the value shall be obtained from the manufacturer, but in the absence of such information, follow the guidance given in Annex A.

To minimize the error, the formula for C_2 used by the calibration laboratory to calculate L_W for the reference meteorological conditions should be the same as the one used by the user to calculate L_W for the actual meteorological conditions.

C_3 is the correction for air absorption, in decibels, at specific frequencies:

$$C_3 = A_0\left(1{,}005\ 3 - 0{,}001\ 2 \cdot A_0\right)^{1{,}6}\ \text{dB}$$

in which

A_0 is the numerical value of $a(f) \cdot r$, expressed in decibels;

$a(f)$ is the attenuation coefficient for specific temperature, humidity and static pressure as a function of frequency in accordance with ISO 9613-1:1993, Formulae (3) to (5), expressed in decibels per metre;

r is the measurement radius, expressed in metres.

9 Calibration procedure in reverberation test rooms

9.1 Test environment

The test environment shall meet the broadband requirements of ISO 3741 with the additional requirement that the smallest dimension of the reverberation test room shall be greater than 4,0 m.

9.2 Microphone positions

Normally, use a minimum of six fixed microphone positions or one or more traversing microphone paths in accordance with ISO 3741. If the frequency range is extended beyond the 10 000 Hz one-third-octave band, use only fixed microphone positions with random orientation in the room.

9.3 Measurements

9.3.1 General

Apply the direct method in accordance with ISO 3741.

For each of the four source positions specified in 7.3 measures the one-third-octave-band time-averaged sound pressure levels with a measurement time interval of at least 64 s for each fixed microphone position or microphone traverse. In accordance with ISO 3741, the measurement time interval shall include at least two full traverses.

Measure the reverberation time, T, by using at least three loudspeaker source positions and six microphone positions or, alternatively, a traversing microphone with a path length of at least 10 m. For each loudspeaker position, measure at least five decays at each microphone or 30 decays with the traversing microphone. Depending on the equipment available, use 10 dB or 15 dB decay and calculate T_{10} or T_{15} from averaging of T or from ensemble averaging.

Measure the RSS rotational speed and voltage before and at the end of the sound measurements. Average and record the result along with the observed variations. State the mains frequency and measured line voltage applied during this test.

9.3.2 Temporal steadiness

This measurement is optional unless the purpose of the test is to test the RSS for type approval.

In order to check the temporal steadiness (stability) of the sound power output (see 5.2), one of the following methods shall be used:

a) three repeated measurements of the sound power level of the reference sound source in conformance with the reverberation test room method of this International Standard shall be taken in succession;

b) five repeated measurements of the time-averaged sound pressure level of the reference sound source shall be taken at one fixed microphone in conformance with the reverberation test method of this International Standard with a pause of at least 5 min between measurements.

The standard deviations under repeatability conditions, σ_r, shall be computed according to Formula (1) and compared with the limits in Table 1.

9.4 Calculations

Calculate one-third-octave-band sound power levels in accordance with the direct method of ISO 3741 but using the value of C_2 as specified in 8.4 and Annex A.

For each one-third-octave band, calculate the sound power level from the energy-averaged sound pressure level from the four source positions, in accordance with the procedure for multiple source positions in ISO 3741.

Octave-band and A-weighted sound power levels shall be calculated from the one-third-octave-band data in accordance with ISO 3741:2010, Annex F.

10 Alternative calibration procedure at low frequencies

Calibration of the RSS in conformance with the provisions of Clause 8 and Clause 9 requires that the test environment shall be a hemi-anechoic room or reverberation test room meeting or exceeding the qualification requirements of ISO 3745 or ISO 3741, respectively, over the entire frequency range of interest. For an extension downwards of the frequency range of interest, laboratories that would otherwise be able to perform the required calibration, but are not qualified for measurements in the 63 Hz octave band (or 50 Hz, 63 Hz, and 80 Hz one-third-octave frequency bands), may use the alternative procedure of Annex B.

11 Measurement uncertainty

11.1 General

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 testing laboratory and others with experimental techniques.

ISO/IEC Guide 98-3 shall be used to determine the measurement uncertainty. For general information on a modelling approach for the estimation of measurement uncertainty see ISO 3745:2012, Clause 10 and Annex I or ISO 3741:2010, Clause 10 and Annex G. A hybrid approach that consists in using jointly the modelling approach and the interlaboratory approach may also be used. In this case, the interlaboratory approach is used for components of the uncertainty budget which contribution cannot be quantified using the mathematical model of the modelling approach because of lack of technical knowledge. In these cases, the laboratory shall at least attempt to identify all the components of uncertainty and make

a reasonable estimation, and shall ensure that the form of reporting of the result does not give a wrong impression of the uncertainty.

11.2 Typical values of the reproducibility standard deviation

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 using the same measurement method, 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 probably not exceed those listed in Table 2.

The values given in Table 2 are standard deviations of reproducibility, σ_R, as defined in ISO 5725-1. The values of Table 2 take into account the cumulative effects of measurement uncertainty in applying the procedures of this International Standard, but exclude variations in the sound power output caused by changes in operating conditions (e.g. rotational speed, line voltage) or mounting conditions.

Unless sufficient knowledge is available to fully apply ISO/IEC Guide 98-3, reproducibility data as given in Table 2 might be used to estimate the measurement uncertainty. The given data need to be multiplied by a coverage factor to derive the expanded measurement uncertainty for a desired degree of confidence. As an example, 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 ±1,96 σ_R (= the expanded measurement uncertainty) of the measured value..

NOTE 1 The calibration of a particular reference sound source does not apply to another reference sound source of the same design and manufacture.

Table 2 — Estimated values of the standard deviations of reproducibility of sound power levels of reference sound sources determined according to this International Standard

Octave midband frequency Hz	**One-third-octave midband frequency** Hz	**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 test rooms** σ_R dB
		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 include variations in the source output and refer to the meteorological conditions at the time and place of the measurements (C_2 = 0 dB, see 8.4). They are substantiated by experiments.

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

NOTE 2 The uncertainties in Table 2 do not include systematic differences between the sound power levels determined in the two different test environments. These differences are insignificant above 160 Hz. However, at 160 Hz and below, these differences might be significant. For 200 m^3 reverberation test rooms these differences are typically 1,5 dB or less.[20] These differences might increase for smaller reverberation test rooms, especially below 100 Hz.

NOTE 3 The measurement uncertainty, in terms of the reproducibility, stated in this International Standard is based on measurements in seven different reverberation test rooms with volumes in the range 197 m^3 to 238 m^3 using microphones of the type WS2 (so called half-inch microphones).

12 Information to be recorded

The information to be recorded shall be as specified in ISO 3745:2012, Clause 11, or in ISO 3741:2010, Clause 11, as applicable. Measured and calculated values shall be recorded at least to the nearest 0,1 dB.

Record the RSS rotational speed and voltage, including variation found, during test. Record the mains frequency and measured line voltage applied during this test.

13 Information to be reported

General information to be reported shall be as specified in ISO 3745:2012, Clause 12, or in ISO 3741:2010, Clause 12.

Report the following information:

a) whether or not the calibration has been carried out in full conformity with the procedures of this International Standard. Any deviations shall be reported;

b) whether the calibration has been carried out in a hemi-anechoic room or in a reverberation test room. If a hemi-anechoic room has been used, the microphone arrangement shall be indicated. If elevated source positions have been used in the reverberation test room, the stand or support used shall be described in detail (dimensions, material);

c) the volume of the reverberation test room or the lower limiting frequency of the hemi-anechoic room, whichever is relevant;

d) the sound power levels in frequency bands rounded to the nearest 0,1 dB with the statement that the sound power levels are in decibels (reference: 1 pW) under the reference meteorological conditions as specified in Clause 4. Report the RSS rotational speed and line voltage, including variation, found during test. Optionally, the sound power levels under the actual meteorological conditions may also be reported. It shall be clearly indicated that the reported sound power levels apply only to the specific operating conditions of the RSS used during the tests (e.g. for an aerodynamic RSS, the rotational speed). A deviation correction chart for the rotational speed of an aerodynamic RSS may be included;

e) the expanded measurement uncertainty for a coverage probability of 95 %;

f) the temperature, relative humidity and static pressure at the time of calibration, the value and the formula of the constant C_2 (see 8.4) and other adjustments, if any, to specified environmental conditions (see Clause 4) and the method to determine those other adjustments;

g) the essential characteristics of the source of electrical or mechanical power and the relevant operating parameters conditions of the reference sound source, particularly, the rotational speed for an aerodynamic RSS (see 7.1). If the calibration is part of the tests necessary to verify all the requirements specified in this International Standard, the following additional information shall be reported: whether or not the spectral uniformity, the temporal steadiness, the sound power output, the spectral characteristics and the directivity index comply with Clause 5.

Annex A
(informative)

Guidance on the determination of C_2

A.1 General

The calculation of C_2 depends on the character of the sound radiated by the source. Accurate values may only be obtained after extensive investigations, normally only carried out by the manufacturer of the reference sound source. In the absence of such values, the following information (see Reference [23]) may be useful.

A.2 C_2 for some type sources

a) For sources with monopole radiation character, e.g. for structures vibrating with low frequencies, $f < f_k$, where the knee frequency, f_k, is given by Formula (A.1):

$$f_k = \frac{c}{2\pi} \cdot \frac{1}{d_0} \tag{A.1}$$

where

c is the speed of sound, in metres per second;

d_0 is half the characteristic source dimension of the source (see ISO 3745), in metres;

NOTE In this context, the knee frequency is defined as the frequency at which the radiation efficiency has dropped 3 dB relative its maximum value at high frequencies.

$$C_2 = -10\lg\left(\frac{p_s}{p_{s,0}}\right)\text{dB} + 15\lg\left(\frac{\theta}{\theta_1}\right)\text{dB} \tag{A.2}$$

b) For structures vibrating as monopoles with higher frequencies, $f \geq f_k$:

$$C_2 = -10\lg\left(\frac{p_s}{p_{s,0}}\right)\text{dB} + 5\lg\left(\frac{\theta}{\theta_1}\right)\text{dB} \tag{A.3}$$

c) For aerodynamic sources of dipole character, $f \geq f_k$:

$$C_2 = -10\lg\left(\frac{p_s}{p_{s,0}}\right)\text{dB} + 25\lg\left(\frac{\theta}{\theta_1}\right)\text{dB} \tag{A.4}$$

d) For sources with unknown radiation:

$$C_2 = -10\lg\left(\frac{p_s}{p_{s,0}}\right)\text{dB} + 7{,}5\lg\left(\frac{\theta}{\theta_1}\right)\text{dB} \tag{A.5}$$

where

p_s is the static pressure at the time and place of the test, in pascals;

$p_{s,0}$ is the reference static pressure, 1,013 25 × 10^5 Pa;

θ is the air temperature at the time and place of the test, in degrees Kelvin;

θ_1 = 296 K.

Annex B
(normative)

Alternative calibration procedure at low frequencies

B.1 Procedure

To expand the frequency range of interest downwards, in a hemi-anechoic room, according to Clause 10, the RSS calibration procedures found in Clause 8 shall be carried out over the 50 Hz to 10 000 Hz one-third-octave-band frequency range using sound pressure level measurements. These requirements are then duplicated in the 50 Hz through 315 Hz one-third-octave bands using sound intensity level measurements. Sound intensity level measurements shall be made in accordance with ISO 9614-3 using a 50 mm spacer. The measurement positions and the measurement path of the intensity probe shall be as indicated in 8.2.

For all measurements, the sound intensity level shall be measured in the outward radial direction. The sound power levels determined from the sound pressure level and sound intensity level measurements shall be compared. If these sound power levels differ by no more than the tolerance of Table B.1, then the sound power levels determined from the sound intensity measurements shall be deemed valid and shall be the calibrated levels reported for the 50 Hz, 63 Hz and 80 Hz one-third-octave bands.

Table B.1 — Tolerance for sound power level difference

One-third-octave band Hz	Tolerance dB
50 to 80	±4,0
100 to 315	±1,0

B.2 Data to be reported

The reported RSS sound power levels and directivity index shall be those determined by sound pressure measurements made in accordance with Clause 5 for the 100 Hz to 10 000 Hz one-third-octave bands and 125 Hz to 8 000 Hz octave bands.

For the 50 Hz, 63 Hz and 80 Hz one-third-octave bands and the 63 Hz octave band, the reported sound power level and directivity index shall be determined from the sound intensity level measurements. The calibration report shall be marked to indicate the levels that were determined from sound intensity level measurements.

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