BRITISH STANDARD

BS EN ISO 3745:2003

Incorporating Corrigenda Nos.1 and 2

Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for anechoic and hemi-anechoic rooms

The European Standard EN ISO 3745:2003 has the status of a British Standard

ICS 17.140.01

British Standards

National foreword

This British Standard is the official English language version of EN ISO 3745:2003, including Corrigenda March 2004 and January 2006. It is identical with ISO 3745:2003. It supersedes BS 4196-5:1981 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee EH/1, Acoustics, to Subcommittee EH/1/4, Machinery noise, which has the responsibility to:

— aid enquirers to understand the text:

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

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Summary of pages

This document comprises a front cover, an inside front cover, the EN ISO title page, the EN ISO foreword page, the ISO title page, pages ii to iv, pages 1 to 45, and a back cover.

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 3745

December 2003

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Including Corrigenda March 2004 and January 2006

English version

Acoustics - Determination of sound power levels of noise sources using sound pressure - Precision methods for anechoic and hemi-anechoic rooms (ISO 3745:2003)

Acoustique - Détermination des niveaux de puissance acoustique emis par les sources de bruit à partir de la pression acoustique - Méthodes de laboratoire pour les salles anéchoiques et semi-anéchoïques (ISO 3745:2003)

Akustik - Bestimmung der Schallleistungspegel von Geräuschquellen aus Schalldruckmessungen - Verfahren der Genauigkeitsklasse 1 für reflexionsarme Räume und Halbräume (ISO 3745:2003)

This European Standard was approved by CEN on 3 November 2003.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This document (EN ISO 3745:2003) has been prepared by Technical Committee ISO/TC 43 "Acoustics" in collaboration with Technical Committee CEN/TC 211 "Acoustics", the secretariat of which is held by DS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2004, and conflicting national standards shall be withdrawn at the latest by June 2004.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZB, which is an integral part of this document.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of ISO 3745:2003 has been approved by CEN as EN ISO 3745:2003 without any modifications.

NOTE Normative references to International Standards are listed in Annex ZA (normative).

INTERNATIONAL STANDARD

ISO 3745

Second edition
2003-12-01

Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for anechoic and hemi-anechoic rooms

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit à partir de la pression acoustique — Méthodes de laboratoire pour les salles anéchoïques et semi-anéchoïques

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. 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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3745 was prepared by Technical Committee ISO/TC 43, *Acoustics,* Subcommittee SC 1, *Noise.*

This second edition cancels and replaces the first edition (ISO 3745:1977), which has been technically revised.

Introduction

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

0.2 This International Standard specifies a laboratory method for determining the sound power radiated by sources using an anechoic test room or a hemi-anechoic test room having specified acoustical characteristics. The method specified in this International Standard is only applicable to indoor measurements in specialized test rooms.

0.3 This International Standard specifies a laboratory method for the determination of not only sound power levels but also sound energy levels of sound sources. For a single burst of sound energy or transient sound, the sound power level cannot be defined and so it is necessary to adopt the sound energy level in order to specify the emitted sound with such a time history. The application of sound energy levels will be considered in the future revision of other standards of the ISO 3740 series.

0.4 In this International Standard, the sound power level or sound energy level for reference meteorological conditions is determined. This is required especially for grade 1 measurements.

Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for anechoic and hemi-anechoic rooms

1 Scope

This International Standard specifies methods for measuring the sound pressure levels on a measurement surface enveloping a noise source in anechoic and hemi-anechoic rooms, in order to determine the sound power level or sound energy level produced by the noise source. It gives requirements for the test environment and instrumentation, as well as techniques for obtaining the surface sound pressure level from which the sound power level or sound energy level is calculated, leading to results which have a grade 1 accuracy.

The methods specified in this International Standard are suitable for measurements of all types of noise.

The noise source can be a device, machine, component or sub-assembly. The maximum size of the source under test depends on the radius of the hypothetical sphere (or hemisphere) used as the enveloping measurement surface.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

IEC 60942:2003, *Electroacoustics — Sound calibrators*

IEC 61260:1995, *Electroacoustics — Octave-band and fractional-octave-band filters*

IEC 61672-1:2002, *Electroacoustics — Sound level meters — Part 1: Specifications*

GUM:1993[1]), *Guide to the expression of uncertainty in measurement.* BIPM/I EC/I FCC/I SO/I UPAC/IU PAP/ OIML (ISBN 92-67-10188-9)

1) Corrected and reprinted in 1995.

3 Terms and definitions

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

3.1
instantaneous sound pressure
$p(t)$
value at a particular instant in time of the fluctuating pressure that is superimposed on the atmospheric static pressure due to the presence of a sound wave, and existing at a given point in space, in a stated frequency band

NOTE It is expressed in pascals.

3.2
sound pressure
p
in space, the root mean square pressure determined over a specified time interval of the instantaneous sound pressure

NOTE It is expressed in pascals.

3.3
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the time-mean-square of the instantaneous sound pressure to the square of the reference sound pressure p_0 [p_0 = 20 µPa (2 x 10^{-5} Pa)]

$$L_p = 10 \lg \frac{p^2}{p_0^2} \text{ dB} \quad (1)$$

NOTE 1 Sound pressure levels are expressed in decibels.

NOTE 2 The frequency weighting or the width of the frequency band used and the time weighting should be indicated.

EXAMPLE The A-weighted sound pressure level with time weighting S is L_{pAS}

3.3.1
time-averaged sound pressure level
$L_{peq,T}$
sound pressure level of a steady or fluctuating sound over the measurement time interval T: ten times the logarithm to the base 10 of the ratio of the time-mean-square of the instantaneous sound pressure, during a stated time interval, to the square of the reference sound pressure

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

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

3.3.2
measurement time interval
time interval for which the time-averaged sound pressure level is determined

3.4
measurement surface
hypothetical surface of area *S,* enveloping the source, on which the measurement positions are located

NOTE In the case of a hemi-anechoic room, the measurement surface terminates on the reflecting plane.

3.5
surface sound pressure level
$\overline{L_{pf}}$
energy-average of the time-averaged sound pressure levels at all the microphone positions on the measurement surface, with the background noise correction $K1$ (3.18) applied

$$\overline{L_{pf}} = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1 L_{pi}} \right] \text{ dB} \tag{3}$$

where

$\overline{L_{pf}}$ is the surface sound pressure level, in decibels;

L_{pi} is the sound pressure level corrected for background noise resulting from the *i*th microphone position, in decibels;

N is the number of microphone positions.

NOTE It is expressed in decibels.

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

NOTE It is expressed in watts.

3.7
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of the sound power radiated by the sound source under test to the reference sound power *Wo* [*Wo* = 1 pW (10^{-12} W)]

$$L_W = 10 \lg \frac{W}{W_0} \text{ dB} \tag{4}$$

NOTE 1 It is expressed in decibels.

NOTE 2 The frequency weighting or the width of the frequency band used should be indicated.

3.8
single-event sound pressure level
L_{pE}
sound pressure level of a single burst of sound or transient sound, given by the formula

$$L_{pE} = 10 \lg \left[\int_{t_1}^{t_2} \frac{p^2(t)}{p_0^2 T_0} \mathrm{d}t \right] \text{ dB} \tag{5}$$

where

$p(t)$ is the instantaneous sound pressure;

p_o = 20 µPa

$t_2 - t_1$ is a stated time interval long enough to encompass all significant sound of a stated event;

T_0 = 1 s

NOTE 1 It is expressed in decibels.

NOTE 2 Other standards refer to this quantity as "sound exposure level".

3.9
sound energy
E
sound energy of a single burst of sound or transient sound radiated by the sound source

$$E = \int_0^T W(t)\,\mathrm{d}t \qquad (6)$$

NOTE It is expressed in joules.

3.10
sound energy level
L_J
ten times the logarithm to the base 10 of the ratio of the sound energy, E (in joules), radiated by the sound source under test to the reference sound energy, E_0 [E_0 = 1 pJ (10^{-12}J)]

$$L_J = 10 \lg \frac{E}{E_0} \text{ dB} \qquad (7)$$

NOTE 1 It is expressed in decibels.

NOTE 2 The frequency weighting or the width of the frequency band used should be indicated.

3.11
free field
sound field in a homogeneous, isotropic medium, free of boundaries

NOTE In practice, it is a field in which reflections at the boundaries are negligible over the frequency range of interest.

3.12
anechoic room
room in which a free field is obtained

3.13
free field over a reflecting plane
hemi-free field
sound field in a homogeneous, isotropic medium in the half-space above an infinite, rigid plane surface

3.14
hemi-anechoic room
room in which a free field over a reflecting plane is obtained

3.15
frequency range of interest
one-third-octave bands having centre frequencies from 100 Hz to 10 000 Hz

NOTE For special purposes, the range may be extended or reduced at either end, provided the test room and instrument accuracy are satisfactory for use over the extended or reduced frequency range.

3.16
measurement radius
r
radius of a spherical or hemi-spherical measurement surface

3.17
background noise
noise from all sources other than the source under test

NOTE Background noise may include contributions from airborne sound, structure-borne vibration, and electrical noise in instrumentation.

3.18
background noise correction
K_{1i}
correction term to account for the influence of background noise on the measurements at each microphone position

NOTE K_{1i} is frequency dependent and is expressed in decibels.

3.19
directivity index
D_I
measure of the extent to which a source radiates sound predominantly in one direction

NOTE It is expressed in decibels.

4 Measurement uncertainty

If a particular noise source were to be transported to each of a number of different laboratories, and if, at each laboratory, the sound power level of that source were to be determined in accordance with this International Standard, the results would show a scatter. The standard deviation of the measured levels could be calculated (see examples in ISO 7574-4:1985, B.2.1) and would vary with frequency. With few exceptions, these standard deviations would not exceed those listed in Table 1. The values given in Table 1 are standard deviations of reproducibility, a_R, as defined in ISO 7574-1. 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. rotational speed, line voltage) or mounting conditions.

The expanded measurement uncertainty of determinations of sound power level or sound energy level, for a coverage probability of 95 % (coverage factor k = 2) as defined in the GUM, shall be taken to be two times the standard deviation of reproducibility, unless more specific knowledge is available (e.g. in the laboratory undertaking the measurements or in a noise test code for the particular family of noise sources).

Table 1 — Estimated upper values of the standard deviations of reproducibility of sound power levels and sound energy levels determined in accordance with this International Standard

One-third-octave midband frequency Hz	Upper values of standard deviation of reproducibility, σ_R dB	
	Anechoic room	Hemi-anechoic room
50 to 80[a]	2,0	2,0
100 to 630	1,0	1,5
800 to 5 000	0,5	1,0
6 300 to 10 000	1,0	1,5
12 500 to 20 000[b]	2,0	2,0
A-weighted	0,5	0,5

[a] If the sound field is qualified according to Clause 5.

[b] If the instrumentation allows and if correction is made for absorption of sound by the atmosphere.

NOTE 1 The standard deviations listed in Table 1 are associated with the test conditions and procedures defined in this International Standard and not with the noise source itself. They arise in part from variations between measurement laboratories, the geometry of the test room, the acoustical properties of the reflecting plane, absorption at the test room boundaries, background noise, and the type and calibration of instrumentation. They are also due to variations in experimental techniques, including the size of the measurement surface, number and location of microphone positions, sound source location and integration times. The standard deviations are also affected by uncertainties associated with measurements taken in the near field of the source; such uncertainties depend upon the nature of the sound source, but generally increase for smaller measurement distances and lower frequencies (below 250 Hz).

NOTE 2 For some sound sources, the standard deviations of reproducibility may be smaller than the values given in Table 1. Hence, a noise test code for a particular type of machinery or equipment making reference to this International Standard may state standard deviations smaller than those listed in Table 1, if substantiation is available from the results of suitable interlaboratory tests.

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

NOTE 3 The standard deviations of reproducibility given in Table 1 are obtained from interlaboratory tests. This method of presenting information relating to measurement uncertainty is not in accordance with the requirements of the GUM. At the time when this International Standard was being prepared, insufficient information was available on which to draw up a statement which was in accordance with the GUM. However, an indication of the kind of information which would need to be included in such a statement is given in Annex J.

5 Test room requirements

5.1 General

The test rooms that are applicable for measurements according to this International Standard are either

a) a room which provides a free field or a free field over a reflecting plane and satisfies Annex A over the frequency range of interest, or

b) for the purposes of determination of sound power levels of specific noise sources, a room which provides a free field or a free field over a reflecting plane and satisfies Annex B over the frequency range of interest.

The requirements of this International Standard shall be met, as a minimum, over the frequency range of interest. If the requirements can only be met over a more limited frequency range, this fact shall be clearly stated in the report and any claim of "conformance with ISO 3745" shall only be made over this stated, limited frequency range.

5.2 Criterion for adequacy of the test room

Annexes A and B describe procedures for determining the extent of deviations of the test room from the ideal free field condition or the ideal hemi-free field condition, and criteria are given to assess the adequacy of the test room. Qualification procedures for the test room shall be referred to Annex A or Annex B.

NOTE If it is necessary to make measurements in spaces in which deviations from the inverse square law exceed the values shown in Annexes A and B, see ISO 3744, ISO 3746, ISO 9614-1 or ISO 9614-2.

5.3 Criterion for background noise

At all microphone positions on the measurement surface and in each frequency band in the frequency range of interest, the level of background noise shall be at least 10 dB below the sound pressure level due to the source under test. A-weighted sound power determinations may be made which include some bands where this criterion is not satisfied, provided that the summed A-weighted background noise of these bands is 10 dB or more below the A-weighted sound pressure level summed from all bands.

5.4 Criterion for temperature

The air temperature during the measurements shall be within the range of 15 °C to 30 °C.

NOTE The range of temperature is limited in order to guarantee a bias smaller than 0,2 dB when using Equation (15) for noise sources having different noise generation mechanisms.

5.5 Humidity correction

Over an air temperature range from 15 °C to 30 °C, the maximum correction for humidity is approximately 0,04 dB and may be ignored.

6 Instrumentation

6.1 General

The acoustical instrumentation system, including the microphones and cables, shall meet the requirements for a class 1 instrument specified in IEC 61672-1:2002. The filters used shall meet the requirements for a class 1 instrument specified in IEC 61260:1995.

The orientation of the microphone shall be that for which it has been calibrated.

Either the manufacturer's instructions or the requirements from a specific test code should be followed for selecting the most appropriate orientation for the conditions of the test. In the absence of these, the microphone should be oriented along the normal to the measurement surface at the point on the surface closest to the microphone.

The instrument used to determine barometric pressure shall have an uncertainty equal to or better than 2 %. The instrument used to determine temperature shall have an uncertainty equal to or better than 1 °C. The instrument used to determine relative humidity shall have an uncertainty equal to or better than 10 %.

6.2 Calibration

During each series of measurements, a sound calibrator with an accuracy of class 1 as specified in IEC 60942:2003 shall be applied to the microphone to verify the calibration of the entire measuring system at one or more frequencies over the frequency range of interest.

The calibrator shall be calibrated and the compliance of the instrumentation system with the requirements of IEC 61672-1 shall be verified periodically in a manner that is traceable to appropriate standards.

7 Installation and operation of source under test

7.1 General

The manner in which the source under test is installed and operated may have a significant influence on the sound power emitted by the source. This clause specifies conditions that minimize variations in the sound power output due to the installation and operating conditions of the source under test. The instructions of a noise test code, if any exists, shall be followed in so far as installation and operation of the source under test is concerned.

7.2 Source location

In locating the source within the test room, it is important to allow sufficient space so that the measurement surface can envelop the source under test in accordance with the requirements of 8.2.

Detailed information on installation conditions and the configuration of the microphone array shall be based on the general requirements of this International Standard and specific noise test codes for such sources.

7.3 Source mounting

7.3.1 General

In many cases, the sound power emitted will depend upon the support or mounting conditions of the source under test. Whenever a typical condition of mounting exists for the equipment under test, that condition shall be used or simulated.

If the support or mounting conditions for the source under test are specified in a specific test code, those conditions shall be used. If such a specification does not exist, but if a principal or typical condition of support or mounting exists, then that shall be used for the test. In all these cases, care shall be taken to avoid changes in the sound output of the source caused by the mounting system employed for the test. Steps shall be taken to reduce any sound radiation from the structure on which the source under test may be mounted.

NOTE Many small sound sources, although themselves poor radiators of low frequency sound, can, as a result of an inappropriate method of mounting, radiate more low frequency sound when their vibrational energy is transmitted to surfaces large enough to be efficient radiators.

7.3.2 Hand-held noise sources

Hand-held noise sources shall be held or guided by hand. If the source under test requires a support for its operation, the support structure shall be small, considered to be a part of the source under test, and described in the machine test code.

7.3.3 Base-mounted and wall-mounted noise sources

Base-mounted and wall-mounted noise sources shall be placed on a reflecting (acoustically hard) plane (floor and wall). Table top equipment shall be placed on the floor, unless a table or stand is required for operation according to the test code for the equipment under test. Such equipment shall be placed in the centre of the top of the test table.

7.4 Auxiliary equipment

Care shall be taken to ensure that air ducts, electrical conduits and piping connected to the source under test but not part of the typical source configuration, do not radiate a significant amount of sound energy into the test room.

If practicable, any auxiliary equipment necessary for the operation of the source under test but which is not part of the source shall be located outside the test room.

7.5 Operation of source under test

During the measurements, the operating conditions specified in the relevant test code, if one exists for the particular type of machinery and equipment under test, shall be used. If there is no test code, the source shall be operated, if possible, in a manner which is typical of normal use. In such cases, one or more of the following operating conditions shall be selected:

— specified load and operating conditions;

— full load (if different from above);

— no load (idling);

— operating conditions corresponding to maximum sound generation representative of normal use;

— simulated load operating under carefully defined conditions;

— operating conditions with a characteristic work cycle.

The sound power level of the source may be determined for any desired set of operating conditions (e.g. loading, device speed, temperature). These test conditions shall be selected beforehand and shall be held constant during test. The source shall be in the desired operating condition before any noise measurements are made.

If the noise emission depends on secondary operating parameters, such as the type of material being processed or the type of tool being used, as far as is practicable, those parameters shall be selected that give to the smallest variations and that are typical of the operation. The noise test code for a specific family of machines shall specify the tool and the material for the test.

For special purposes, it is appropriate to define one or more operating conditions in such a way that the noise emission of sources of the same family is highly reproducible and that the operating conditions which are most common and typical for the family of sources are covered. These operating conditions shall be defined in specific test codes.

If simulated operating conditions are used, they shall be chosen to give sound power levels representative of normal usage of the source under test.

If appropriate, the results for several separate operating conditions, each lasting for defined periods of time, shall be combined by energy-averaging to yield the result for a composite overall operating procedure.

The operating conditions of the source during the acoustical measurements shall be fully described in the test report.

8 Measurement of sound pressure levels for the determination of sound power level

8.1 General

An anechoic room provides the preferred environment for measurements with the smallest uncertainty. However, reasonable accuracy can be obtained in a hemi-anechoic room provided the precautions specified in this International Standard are observed.

8.2 Measurement surface

8.2.1 Measurement sphere (for measurements in an anechoic room)

For measurements in an anechoic room, the spherical surface at which the sound pressure level is measured should preferably be centred on the acoustic centre of the sound source. As the location of the acoustic centre is frequently unknown, the assumed acoustic centre (e.g. the geometric centre of the source) shall be clearly stated in the test report. The radius of the test sphere shall be equal to or greater than all of the following:

a) twice the largest source dimension;

b) $\lambda/4$ of the lowest frequency of interest; and

c) 1 m.

No microphone position shall be used which lies outside the region qualified for measurements according to Annex A or Annex B.

NOTE For small, low-noise products to be measured over a limited frequency range (see 3.15), the radius of the test sphere may be made less than 1 m, but not less than 0,5 m. However, a radius less than 1 m could itself impose limits on the frequency range over which tests are performed.

8.2.2 Measurement hemisphere (for measurements in a hemi-anechoic room)

For measurements in a hemi-anechoic room, the hemispherical surface shall be centred on the projection on the floor of the acoustic centre selected according to 8.2.1. The radius of the test hemisphere shall be equal to or greater than all of the following:

— twice the largest source dimension or three times the distance of the acoustic centre of the source from the reflecting plane, whichever is the larger;

— $\lambda/4$ of the lowest frequency of interest; and

— 1 m.

No microphone position shall be used which lies outside the region qualified for measurements according to Annex A or Annex B.

NOTE For small, low-noise products to be measured over a limited frequency range (see 3.15), the radius of the test hemisphere may be made less than 1 m, but not less than 0,5 m. However, a radius less than 1 m could itself impose limits on the frequency range over which tests are performed.

8.3 Microphone positions

8.3.1 General

To obtain the surface sound pressure level of the test sphere (or hemisphere), one of the following four defined microphone arrangements, or a user-defined arrangement that meets the requirements of 8.3.6, shall be used.

a) An array of fixed microphone positions is used, the positions being distributed over the surface of the test sphere (or hemisphere). Either a single microphone may be moved from one position to the next sequentially or a number of fixed microphones may be used and their outputs sampled sequentially or simultaneously.

b) The single microphone is moved along multiple circular paths regularly spaced on the test sphere (or hemisphere). Alternatively, the microphone may be fixed while the source is rotated through 360° or multiples thereof.

c) The single microphone is moved along multiple meridional arcs regularly spaced on the test sphere (or hemisphere).

d) The single microphone is moved along a spiral path around the vertical axis of the test sphere (or hemisphere).

8.3.2 Fixed microphone positions

8.3.2.1 Test sphere (for measurements in an anechoic room)

The array of 20 microphone positions shown in Annex C shall be used. In general, the number of microphone positions is sufficient if the difference, in decibels, between the highest and lowest sound pressure levels measured in any frequency band of interest is numerically less than half the number of microphone positions. If this requirement is not satisfied using the 20-point array of Annex C, an additional 20-point array shall be defined by rotating either the source or the original array of Annex C by 180° about the *z*-axis. (The top and bottom positions on the *z*-axis of the new array are coincident with the top and bottom positions of the original array.) The 40 positions on the two arrays are associated with equal areas on the surface of the test sphere of Annex C.

If the requirement about the sufficiency of the number of microphone positions is not satisfied by the 40 positions on the two arrays, a detailed investigation is necessary of the sound pressure levels over a restricted area of the sphere where "beaming" from a highly directional source may be observed. This detailed investigation is necessary to determine the highest and lowest values of the sound pressure level in the frequency band of interest. If this procedure is followed, the microphone positions will usually not be associated with equal areas on the surface of the test sphere and proper allowance shall be made (see 8.7.2.3).

8.3.2.2 Test hemisphere (for measurements in a hemi-anechoic room)

The array of 20 microphone positions shown in Annex D shall be used. In general, the number of microphone positions is sufficient if the difference in decibels between the highest and lowest sound pressure levels measured at any position and in any frequency band of interest is numerically less than half the number of microphone positions. If this requirement is not satisfied using the 20-point array of Annex D, an additional 20-point array shall be defined by rotating either the source or the original array of Annex D by 180° about the *z*-axis. The 40 positions on the two arrays are associated with equal areas on the surface of the test hemisphere of Annex D.

If the requirement about the sufficiency of the number of microphone positions is not satisfied by the 40 positions on the two arrays, a detailed investigation is necessary of the sound pressure levels over a restricted area of the hemisphere where "beaming" from a highly directional source may be observed. This detailed investigation is necessary to determine the highest and lowest values of the sound pressure levels in the frequency band of interest. If this procedure is followed, the microphone positions will usually not be associated with equal areas on the surface of the test hemisphere and proper allowance shall be made (see 8.7.2.3).

8.3.3 Coaxial circular paths in parallel planes (for measurements in an anechoic or a hemi-anechoic room)

The sound pressure level is averaged in space and time by moving a single microphone successively along a number of circular paths. In case of a hemi-free field, the minimum number of paths is 5 as shown in Annex E, and, especially for sources emitting discrete-frequency tones, there shall be at least 20 paths with heights as specified in Table D.1. In the case of a free field, these numbers are increased to 10 and 40 respectively, with heights chosen symmetrically in the upper and lower halves of the measurement sphere.

The circular paths may be achieved by uniformly rotating either the microphone or the source under test slowly through 360°. If a turntable is used to rotate the source, its surface should preferably be flush with the reflecting plane. In any case, its surface shall not be more than 10 % of the height of the source from the reflecting plane.

8.3.4 Meridional arc traverses (for measurement in an anechoic or a hemi-anechoic room)

The third alternative method for obtaining the surface sound pressure level of a sphere or hemisphere uses a single microphone and traverses along a semicircular arc about a horizontal axis through the centre of the source (see Figure F.1). The vertical velocity (dz/dt) shall be held constant. That is, the angular velocity of the microphone support is increased to be proportional to 1/cos φ, where φ is the angle above the horizontal. The microphone output is squared and averaged by electronic means, giving suitable weighting to the surface area of the sphere or hemisphere. Alternatively, a constant angular velocity may be used but with electronic weighting according to cos φ (see Figure F.1).

At least eight such microphone traverses at equal increments of azimuth angle around the source shall be used. This may be accomplished by rotating the source.

8.3.5 Spiral path (for measurement in an anechoic or a hemi-anechoic room)

The fourth alternative method for obtaining the surface sound pressure level of a sphere or hemisphere uses a traverse along one meridional path in conformance with 8.3.4, and simultaneously traverses 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, a spiral path is generated by slowly rotating the sound source ata constant rotational speed through at least five complete turns while traversing the microphone along a meridional path. An example of spiral path is shown in Annex G. Angular weighting is described in 8.3.4.

8.3.6 Other microphone arrangements

Microphone arrangements and measurement surfaces which may provide improved accuracy are not excluded by the above requirements. However, to use an alternative microphone arrangement and measurement surface, it shall be demonstrated that the deviations between the one-third-octave band sound power levels over the frequency range of interest and those determined with one of the specified arrangements in 8.3.2 to 8.3.5 do not exceed ±0,5 dB in any band. The alternative measurement surface shall completely envelop the source.

NOTE The reason for defining an alternative arrangement should be to improve accuracy and not simply to reduce the number of microphone positions or otherwise compromise one of the specified arrays in 8.3.2 to 8.3.5. An example of an alternative measurement surface and microphone arrangement may be found in reference [12].

8.4 Conditions of measurement

Environmental conditions may have an adverse effect on the microphone used for the measurements. The effect of such conditions (e.g. strong electric or magnetic fields, wind impingement of air discharge, if any, from the equipment being tested), shall be avoided by proper selection or placement of the microphone.

The attenuation of the air above 10 000 Hz shall be compensated in conformance with ISO 9613-1.

8.5 Data to be obtained

The sound pressure level shall be measured over a typical period of operation of the source (see 7.5). Sound pressure level data shall be taken at each microphone position with A-weighting and/or for each frequency band of interest. The instrumentation used shall comply with the requirements of Clause 6.

The following data shall be averaged over a period of at least one or more complete source operations:

a) A-weighted sound pressure levels and/or band sound pressure levels during operation of the source under test;

b) A-weighted sound pressure levels and/or band sound pressure levels produced by the background noise.

For the frequency bands centred on or below 160 Hz, the measurement time interval shall be at least 30 s. For A-weighted sound pressure levels and for the frequency bands centred on or above 200 Hz, the measurement time interval shall be at least 10 s.

In addition, the meteorological conditions at the time of the test (barometric pressure, temperature and relative humidity of the air around the source) shall be measured.

8.6 Correction for background sound pressure levels

The background sound pressure levels shall be obtained using one of the methods specified in 8.3 with the source not in operation. If the levels of background noise L''_{pi} at each microphone position or over each microphone traverse and in each frequency band are between 20 dB and 10 dB below the measured sound pressure levels L'_{pi}, with the source operating, correct the values of L'_{pi} for the influence of background noise. The measured sound pressure levels shall be corrected for the influence of background noise by subtracting a value of K_{1i} which is calculated for each frequency band and microphone position according to the following equation:

$$K_{1i} = -10 \lg \left(1 - 10^{-0,1 \Delta L_i}\right) \text{ dB} \tag{8}$$

where

$$\Delta L_i = L'_{pi} - L''_{pi}$$

resulting in a corrected sound pressure level, L_{pi}, as follows:

$$L_{pi} = L'_{pi} - K_{1i}$$

If the background noise levels are more than 20 dB below the sound pressure levels with the source operating, no correction is made.

For sound sources having low sound pressure levels, it may be that the background noise level is less than 10 dB below the sound pressure level for a few of the frequency bands in the frequency range of interest with the source in operation. In that case, the maximum correction to be applied to these bands shall be 0,5 dB. If such data are reported, it shall be clearly reported in the text that they represent an upper limit for the sound power level of the source under test.

Moreover, if the total A-weighted sound power level is to be calculated, this overall level shall be calculated in two different ways:

a) using the data for every frequency band in the frequency range of interest;

b) without the frequency bands in which the background noise level is less than 10 dB below the sound pressure level with the source in operation.

If the difference between these two levels is less than 0,5 dB, the total level calculated using the data for all the bands shall be considered as conforming to this International Standard. If the difference is larger than 0,5 dB, the total level calculated using the data for all the bands represents an upper limit for the sound power level and it shall be clearly reported as such in the text of the report as well as in tables of results and graphs.

8.7 Calculation of surface sound pressure level

8.6.1 General

The sound power level L_W of a source is calculated from the surface sound pressure level averaged over the surface of the sphere (or hemisphere), $\overline{L_{pf}}$. This surface sound pressure level, $\overline{L_{pf}}$, is calculated from the space average of the mean-square sound pressure over the test sphere (or hemisphere). To obtain the surface sound pressure level, $\overline{L_{pf}}$, from the sound pressure level readings, the procedures given in 8.7.2 to 8.7.4 are appropriate.

8.6.2 Fixed microphone positions

8.7.2.1 General

When fixed microphone positions are used, one of the procedures given in 8.7.2.1 or 8.7.2.2 is appropriate.

8.7.2.2 Equal areas

When the microphone positions are associated with equal partial areas of the test sphere (or hemisphere), the following equation shall be used to obtain the surface sound pressure level, $\overline{L_{pf}}$:

$$\overline{L_{pf}} = 10 \lg \left(\frac{1}{N} \left[\sum_{i=1}^{N} 10^{0,1 L_{pi}} \right] \right) \text{dB} \qquad (9)$$

where

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

L_{pi} the sound pressure level corrected for background noise resulting from the ith microphone position, in decibels (ref. 20 µPa);

N is the number of microphone positions.

8.7.2.3 Unequal areas

When the microphone positions are associated with unequal partial areas of the measurement surface, the following equation shall be used to obtain the surface sound pressure level, $\overline{L_{pf}}$:

$$\overline{L_{pf}} = 10 \lg \left(\frac{1}{S} \left[\sum_{i=1}^{N} S_i \times 10^{0,1 L_{pi}} \right] \right) \text{dB} \qquad (10)$$

where

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

L_{pi} is the sound pressure level corrected for background noise level resulting from the ith microphone position, in decibels (ref. 20 µPa);

S_i is the partial area of the sphere (or hemisphere) associated with the ith microphone position;

S is the total area of the measurement sphere (or hemisphere);

N is the number of microphone positions.

8.6.3 Circular microphone traverses

When the microphone is caused to traverse along circular paths (see 8.3.3), the surface sound pressure level, $\overline{L_{pf}}$, is obtained from Equation (9), where L_{pi} is the average sound pressure level for the ith traverse.

8.6.4 Traverses along meridional arcs or spiral path

If the methods specified in 8.3.4 and 8.3.5 are used, the surface sound pressure level, $\overline{L_{pf}}$, is obtained by squaring and averaging the output of the microphone and giving suitable weighting to the surface areas of the sphere.

9 Measurement of single-event sound pressure levels for the determination of sound energy level

For the measurement of single-event sound pressure levels of a single burst of sound energy or transient sound, the procedures are the same as those specified in Clause 8 for the measurement of sound pressure levels but with the following amendmdents.

Only microphone arrangements employing fixed microphone positions shall be used. One single work cycle of the source shall be measured at a time. The work cycle shall be clearly described in the record or report. At each microphone position, the single-event sound pressure level L_{pE} shall be measured for at least five work cycles. The measurement time interval shall be long enough to encompass all significant sound of the stated single event, but not so long that significant portions of the non-event sound before and after the event (such as the ambient noise) would be included.

The measurement time interval shall be clearly defined and stated in the test report. It is strongly recommended that all microphones on the measurement surface be sampled simultaneously unless it can be shown that the noise during the work cycle is stationary and repeatable at each position. The measurement result is then given by

$$\overline{L_{pE}} = 10 \lg \left(\frac{1}{N} \left[\sum_{n=1}^{N} 10^{0,1 \overline{L_{pEn}}} \right] \right) \text{dB} \tag{11}$$

where

$\overline{L_{pEn}}$ is the single-event surface sound pressure level for one work cycle;

N is the number of work cycles used.

It is often convenient to allow the instrumentation to take an average over A^ work cycles at each microphone position. In this case, the result is given by

$$\overline{L_{pE}} = L_{pEN} - 10 \lg (N) \text{ dB} \tag{12}$$

where L_{pEN} is the single-event sound pressure level measured over N work cycles.

For evaluation of background noise corrections, L_{pE} of the background noise shall be measured at each microphone position using the same integration time as used for the source under test and applying the procedures of 8.6.

10 Calculation of sound power level and sound energy level

10.1 Sound power level

10.1.1 Sound power level in an anechoic room

In a free field, the sound power level L_W of a source under reference meteorological conditions, 23 °C and 1,01325 x 10^5 Pa, is calculated from the following equation:

$$L_W = \overline{L_{pf}} + 10 \lg \left(\frac{S_1}{S_0} \right) \text{dB} + C_1 + C_2 \quad (13)$$

where

$$C_1 = -10 \lg \left[\frac{B}{B_0} \sqrt{\left(\frac{313{,}15}{273{,}15 + \theta} \right)} \right] \text{dB} \quad (14)$$

$$C_2 = -15 \lg \left[\frac{B}{B_0} \left(\frac{296{,}15}{273{,}15 + \theta} \right) \right] \text{dB} \quad (15)$$

where

$\overline{L_{pf}}$ is the surface sound pressure level over the test sphere, in decibels (ref. 20 µPa);

S_i $= 4 \pi r^2$ is the area of the test sphere (of radius r);

S_0 $= 1$ m^2

B is the barometric pressure during the measurements, in pascals;

B_0 is the reference barometric pressure, 1,01325 x 10^5 Pa;

θ is the air temperature during measurement, in degrees Celsius.

Equation (15) is applicable in the temperature range 15 °C $\leq \theta \leq$ 30 °C.

10.1.2 Sound power level in a hemi-anechoic room

For a free field over a reflecting plane, the sound power level L_W of a source is calculated from the following equation:

$$L_W = \overline{L_{pf}} + 10 \lg \left(\frac{S_2}{S_0} \right) \text{dB} + C_1 + C_2 \quad (16)$$

where

S_2 $= 2 \pi r^2$ is the area of the test hemisphere (of radius r)

S_0 $= 1$ m^2

Other symbols are the same as those used in Equations (13) to (15).

10.1.3 Weighted sound power level and band sound power level

The values of the surface sound pressure level, $\overline{L_{pf}}$, used in Equations (13) and (16) may be obtained using a weighted network in the instrumentation system (e.g. A-weighting) or by means of a one-third-octave band filter. If a weighted sound power level is to be obtained, the calculations using Equation (13) [or Equation (16)] need be done only once. To obtain band power levels, the calculation procedure shall be repeated for each frequency band within the frequency range of interest. Weighted sound power level is also obtained from band power levels. Calculation procedures are shown in Annex H.

10.1.4 Sound power level under different meteorological conditions

The sound power level, L'_W that will be emitted by the same source under different meteorological conditions, B' and θ', is calculated from L_W as

$$L'_W = L_W + 15 \lg \left[\frac{B'}{B_0} \left(\frac{296{,}15}{273{,}15 + \theta'} \right) \right] \text{dB} \tag{17}$$

10.2 Sound energy level

10.2.1 Sound energy level in an anechoic room

In a free field, the sound energy level of a source, L_J is calculated from the following equation:

$$L_J = \overline{L_{pEf}} + 10 \lg \left(\frac{S_1}{S_0} \right) \text{dB} + C_1 + C_2 \tag{18}$$

where $\overline{L_{pEf}}$ is the surface single-event sound pressure level averaged over the measurement sphere.

Other symbols are the same as those used in Equations (13) to (15).

10.2.2 Sound energy level in a hemi-anechoic room

In a free field over a reflecting plane, the sound energy level of a source, *Lj,* is calculated from the following equation:

$$L_J = \overline{L_{pEf}} + 10 \lg \left(\frac{S_2}{S_0} \right) \text{dB} + C_1 + C_2 \tag{19}$$

where $\overline{L_{pEf}}$ is the surface single-event sound pressure level averaged over measurement hemisphere

In Equations (18) and (19), symbols except for $\overline{L_{pEf}}$ are the same as those used in Equations (13) to (16).

11 Information to be recorded

11.1 General

The following information, when applicable, shall be compiled and recorded for all measurements made according to the requirements of this International Standard.

Those items that do not change from test to test (e.g. dimensions of test room, serial numbers and frequency response of instrumentation system) may be kept on file and need not be newly recorded for each measurement.

11.2 Sound source under test

The following shall be specified:

a) description of the sound source under test (including dimensions);

b) operating conditions;

c) mounting conditions;

d) location of the sound source in the test room and its assumed acoustic centre;

e) description of source(s) in operation during measurements, if the test object has multiple noise sources.

11.3 Acoustic environment

The following shall be specified:

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

b) acoustical qualification of test room according to Annex A or Annex B:

— if Annex A is used, then it shall also be reported whether pure tone or broadband noise was used in qualification;

— if Annex B is used, then the source used for qualification shall be identified;

— if the test room was qualified over a reduced frequency range, the reduced frequency range shall be reported;

c) air temperature in degrees Celsius, relative humidity in percent, and barometric pressure in pascals.

11.4 Instrumentation

The following shall be specified:

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

b) frequency response of instrumentation system;

c) method used to calibrate the microphone(s) and the date and place of calibration.

11.5 Acoustic data

The following shall be specified:

a) the locations and orientation of the microphone path or array (a sketch shall be included, if necessary); the microphone locations shall be indicated with respect to the reflecting planes, walls of the room and the assumed acoustic centre of the source;

b) the surface sound pressure level, $\overline{L_{pf}}$, in decibels, calculated for the A-weighted sound power level (other weightings are optional) and the surface sound pressure level in each frequency band of interest, with reference to 20 μPa;

c) the sound power levels calculated for all frequency bands used and the A-weighted sound power level, in decibels with reference to 1 pW (= 10^{-12} W);

d) the sound energy level calculated for all frequency bands used and the A-weighted sound energy level, in decibels with reference to 1 pJ (= 10^{-12} J);

e) the date and place when/where the measurements were performed;

f) remarks on subjective impression of noise (audible discrete tones, spectral content, temporal characteristics, etc.);

g) if required, the directivity index and directivity factor (see Annex I).

12 Information to be reported

The report shall state whether or not the reported sound power level or sound energy level has been obtained in full conformity with the procedures of this International Standard. The report shall state that these sound power levels are in decibels (ref. 1 pW) or the sound energy levels are in decibels (ref. 1 pJ).

Annex A
(normative)

General procedures for qualification of anechoic and hemi-anechoic rooms

A.1 General

The performance of an anechoic or hemi-anechoic room is assessed by comparing the spatial decrease of sound pressure emitted from a test source with the decrease of sound pressure with distance from the source, according to the inverse square law that would occur in a true anechoic or hemi-anechoic field.

NOTE When the test room is to be used for purposes other than sound power determinations, some applications may require a more rigorous qualification procedure than specified here (i.e. continuous measurements along each traverse using a pure tone sound source).

A.2 Instrumentation and measurement equipment

A.2.1 General

The instrumentation system, including the microphones and cables, shall meet the requirements for a Class 1 instrument as specified in IEC 61672-1:2002. The filters used shall meet the requirements for a Class 1 instrument as specified in IEC 61260:1995.

A.2.2 Test sound source type

A.2.2.1 General

A sound source approximating a point source over the frequency range of interest shall be used for the qualification. The source shall meet the performance requirements of A.2.2.2, and shall be

a) compact with an identifiable centre (to provide a good reference for the origin of the microphone traverses specified in A.3.3),

b) relatively omnidirectional (to have energy incident on all the room surfaces in roughly equal proportions),

c) able to generate sufficient sound output over the frequency range of interest to yield sound pressure levels 10 dB above the background noise levels for all points on each microphone traverse, and

d) of high stability so that the radiated sound power does not change during measurements along the microphone traverse.

The design or selection of the test source is the responsibility of the laboratory or acoustical expert performing the qualification. One or more sources may be used to cover the overall frequency range of interest, but the requirements given above and in A.2.2.2 shall be met for each source over its applicable frequency range.

The sound power level of the test source (with the associated signal generation and amplification electronics) should not vary more than +0,5 dB in any one-third-octave band in the frequency range of interest during the measurements for each microphone traverse (see Note). This may be demonstrated by measuring the band sound power levels of the sound source, according to the methods of this International Standard, repeatedly over a period of time corresponding to a typical microphone traverse, and noting the deviations.

NOTE It is advisable to use a "reference microphone" located at an arbitrary but fixed position in the room in order to verify that the source output during the test complies with the above.

A.2.2.2 Test sound source directionality

The directionality of the test source shall be uniform to within the allowable deviations given in Table A.1 when determined according to the following procedure. However, a traverse line shall not be mounted in such a way that the microphone passes through the loudspeaker nodes.

Install the test source in its normal qualification position in the centre of the room, and operate it at an output level representative of the level to be used for the room qualification. Select a spherical coordinate system with the source at the centre, r = 0, and with the ϕ = 90° plane corresponding to the rigid floor for a hemi-anechoic room or to a plane parallel with the floor and ceiling in an anechoic room. The Θ =0° (or 90°, 180°, 270°) plane shall be parallel to the walls of the room if the room is rectangular. Select r = 1,5 m, Θ = 0°, and measure the one-third- octave band sound pressure levels at ϕ = 80°, 60°, 40° and 20°. For a source used in the qualification of an anechoic room, make additional measurements at ϕ = 100°, 120°, 140° and 160°. For each of the ϕ angles, measure at 6 = 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°, for a total of 32 measurements in a hemi-anechoic room, or 56 measurements in an anechoic room. For each one-third-octave band, compute the mean of these measurements, and the maximum and minimum deviations from the mean. If the deviations are within the allowable limits, the test source is suitable for conducting the qualification. (A position directly above the source at ϕ = 0° may be added for each of the eight angular positions for information and as a check on the stability of the sound source, but it is not required for determining the directionality of the source.)

Table A.1 — Allowable deviation in directionality of the test source

Type of test room	One-th i rd-octave band frequency Hz	Allowable deviations in directionality dB
Anechoic	≤ 630	± 1,5
	800 to 5 000	± 2,0
	6 300 to 10 000	± 2,5
	> 10 000	± 5,0
Hemi-anechoic	≤ 630	± 2,0
	800 to 5 000	± 2,5
	6 300 to 10 000	± 3,0
	> 10 000	± 5,0

For the directionality measurements, the source may be installed and evaluated in a different anechoic or hemi-anechoic room than the one being qualified (e.g. one known to have good anechoic properties over the frequency range of interest).

NOTE 1 Sources suitable for use in qualification for anechoic and hemi-anechoic room are described in the Bibliography.

NOTE 2 For qualification of a hemi-anechoic room, it is useful to have a small cavity in the centre of the floor. The purpose of the cavity is to install a source whose radiating surface is in the plane of the floor.

At frequencies below 800 Hz, sources meeting the requirements of ISO 140-3 may be suitable. A possible alternative is an electrodynamic loudspeaker in a sealed box having dimensions less than one-tenth of a wavelength.

For frequencies up to 10 kHz, a source that may be suitable is an acoustically shielded compression driver attached to a tapered cylindrical tube. The tube should have a length of 1,5 m and an outlet diameter of 6 mm. For use at lower frequencies, a shorter tube may be acceptable.

It is advisable to use a source that meets the requirements of A.2.2.2 at a radius of 0,5 m from the source. Sources tend to be more omnidirectional in the far field, and any difference in source directivity in the near and far field will make it more difficult to qualify the test room.

A.3 Installation of test sources and microphones

A.3.1 Anechoic rooms

The test sound source shall be located so that the assumed position of the acoustic centre coincides as closely as possible with a point identified as the geometric centre of the measurement sphere, preferably in the centre of the room.

A.3.2 Hemi-anechoic rooms

A.3.2.1 General

The test sound source shall be located so that the assumed position of the acoustic centre coincides as closely as possible with a point identified as the geometric centre of the measurement hemisphere, preferably in the centre of the floor of the room.

The test sound source should be located on the plane of the reflecting floor, so that the acoustic centre of the test source is situated as close as possible to the reflecting floor, but in any case it should not be more than 150 mm away. If possible, the acoustic centre of the test source should be within 0,1 of a wavelength from the reflecting floor. Therefore, it is recommended to install the test source in a cavity in the reflecting floor (seeA.2.2.2, Note 2).

A.3.2.2 Size of reflecting plane

The reflecting plane shall extend at least 0,75 m beyond the projection of the measurement surface on the plane.

A.3.2.3 Sound absorption coefficient

The sound absorption coefficient of the reflecting plane shall be less than 0,06 over the frequency range of interest.

NOTE The requirement is satisfied by a sealed concrete construction or a sealed lightweight construction with a surface density of 20 kg/m^2 or more.

A.3.3 Microphone traverse

Microphone traverses shall be made along at least five straight paths away from the geometric centre of the measurement sphere or hemisphere in different directions. Key microphone paths are the lines from the geometric centre of the measurement sphere or hemisphere to the room corners (where "corner" refers to the intersection between two walls and the ceiling, or two walls and the floor). The key paths to the corners shall comprise four of the five required traverses. In an anechoic room, the four selected traverses shall be located in the working area of the room, i.e. that part of the room normally used for measurements. When there is no clear working area in an anechoic room, the selected corners shall lie in an imaginary plane that passes through the centre of the room. In a hemi-anechoic room, paths very close to and parallel to the reflecting floor shall be avoided.

The test sound source should be placed in a chosen orientation and held in that orientation for all microphone traverses.

Where the acoustic centre of the test source is not clearly identifiable, a point representing the centre should be selected appropriately and used uniformly throughout the qualification procedure. This point is used for measurement only; the actual location of the acoustic centre is as calculated in A.4.3.1.

A.4 Test procedures

A.4.1 Generation of sound

Except for the requirements of pure tone qualification procedures, the test source described in A.2.2 shall be excited by random noise. Analysis shall be made in one-third-octave bands in sequential steps that cover the entire frequency range over which the room is being qualified. Below 125 Hz and above 4 000 Hz, the sequential steps shall correspond to the midband frequencies of contiguous one-third-octave bands, and between 125 Hz and 4 000 Hz, the steps shall correspond to the midband frequencies of contiguous octave bands (i.e. between 125 Hz and 4 000 Hz; not all one-third-octave bands need be used).

An alternative to qualification using random noise is qualification using pure tones. In addition, in the special case that the room is to be qualified for measurement of sources that predominantly radiate pure tones, room qualification using pure tones is the only acceptable method. The test source described in A.2.2 shall be operated at discrete frequencies that cover in sequential steps the entire frequency range over which the room is being qualified. The frequencies of the tones shall correspond to the midband frequencies of the one-third-octave bands specified above.

NOTE Use of a mix of pure tones spaced apart by more than one frequency band can be much more rapid than sequential traverses, each at a single pure tone.

If random noise is used, measurement times shall be long enough to achieve stable levels.

A.4.2 Measurement of sound pressure level

The microphone shall be moved along the paths described in A.3.3 for each test signal. The measurement of sound pressure level shall be carried out starting 0,5 m from the acoustic centre of the test source and ending at or beyond the measurement surface the user wishes to qualify. Sound pressure levels shall be measured along each microphone traverse using equally spaced measurement points. For a measurement surface to be qualified according to this International Standard, it shall enclose at least 10 measurement points along each of the five microphone traverses (a total of at least 50 points). In addition, the spacing between measurement points shall not exceed 0,1 m.

Alternatively, the microphone shall be moved slowly and continuously along the traverse and the sound pressure levels recorded.

Sound reflection from the microphone traverse system shall be carefully avoided.

NOTE Due to the long averaging time required to measure random noise, a continuous traverse is only recommended for use with pure tone signals.

A.4.3 Determination of deviations from the inverse square law

A.4.3.1 Equation for estimation of sound pressure levels based on the inverse square law

From the sound pressure levels measured at the positions specified in A.4.2, the estimation of sound pressure levels based on the inverse square law shall be determined for each direction of measurement from the following equation:

$$L_p(r) = 20 \lg\left[\frac{a}{r - r_0}\right] \text{dB} \tag{A.1}$$

where

$$a = \frac{\left(\sum_{i=1}^{N} r_i\right)^2 - N\sum_{i=1}^{N} r_i^2}{\sum_{i=1}^{N} r_i \sum_{i=1}^{N} q_i - N\sum_{i=1}^{N} r_i q_i}$$

and r_0 is the collinear offset of the acoustic centre along the axis of the microphone traverse. It is a measurement of the separation between the acoustic centre of the source and the centre of the measurement sphere or hemisphere.

It is given by the following equation:

$$r_0 = -\left[\frac{\sum_{i=1}^{N} r_i \sum_{i=1}^{N} r_i q_i - \sum_{i=1}^{N} r_i^2 \sum_{i=1}^{N} q_i}{\sum_{i=1}^{N} r_i \sum_{i=1}^{N} q_i - N \sum_{i=1}^{N} r_i q_i}\right]$$

where

$q_i = 10^{-0{,}05 L_{pi}}$

L_{pi} is the sound pressure level at the ith measurement position, in decibels;

r_i is the distance of the ith measurement position from the centre of the measurement sphere or hemisphere;

N is the number of measurement positions along each microphone traverse.

Other methods may be used to estimate the sound pressure level on the basis of the inverse square law provided they allow calculation of $L_p(r)$ as in Equation (A.1).

If a continuous traverse is used, an analog recording of level versus distance is obtained. To use the equations in this annex, sound pressure levels at a large number of points at regularly spaced intervals should be derived from the records. The selection of point spacing should be based on the criteria of A.4.2.

A.4.3.2 Deviations from the inverse square law

Using the estimation of sound pressure levels based on the inverse square law, deviations of the sound pressure levels at all measurement positions from the inverse square law are determined by the following equation:

$$\Delta L_{pi} = L_{pi} - L_p(r_i) \text{ dB} \qquad \text{(A.2)}$$

where

ΔL_{pi} is the deviation from the inverse square law, in decibels;

L_{pi} is the sound pressure level at the ith measurement position, in decibels;

$L_p(r_i)$ is the sound pressure level at distance r_i estimated by the inverse square law, in decibels.

A.5 Qualification procedure

The deviations of the measured sound pressure levels from those estimated using the inverse square law, obtained according to A.4.3.2, shall not exceed the values given in Table A.2.

Table A.2 — Maximum allowable deviation of measured sound pressure levels from theoretical levels using the inverse square law

Type of test room	One-third-octave band frequency Hz	Allowable deviations dB
Anechoic room	≤ 630	± 1,5
	800 to 5 000	± 1,0
	≥ 6 300	± 1,5
Hemi-anechoic room	≤ 630	± 2,5
	800 to 5 000	± 2,0
	≥6 300	± 3,0

NOTE A room to be qualified for pure tones will be more costly both to construct and to qualify than one to be qualified for one-third-octave band random noise.

The deviations in Table A.2 determine the largest space surrounding the noise source under test within which a measurement surface may be chosen. If the measurement surface thus determined lies outside the near field of the noise source to be tested, this measurement surface is suitable for the determination of sound power levels and sound energy levels according to this International Standard.

The deviations in Table A.2 also determine the frequency range over which measurements may be made according to this International Standard. If the range is not at least 100 Hz to 10 kHz (see 3.15), measurements taken in this test room will not be in *full* conformance with this International Standard. If the test room is qualified over a reduced frequency range, measurements may still be reported to be "in conformance" with this International Standard provided that

a) the one-third-octave bands comprising the reduced frequency range are contiguous,

b) the test report clearly states the reduced frequency range, and

c) the words "in full conformance with ISO 3745" are not used or implied.

Annex B
(normative)

Alternative qualification procedure for anechoic and hemi-anechoic rooms for the determination of sound power levels of specific noise sources

B.1 General

The purpose of the procedure in this annex is to provide an alternative qualification of the test room for sound power measurement of a specific sound source that may be under test according to this International Standard. This procedure is not an alternative to that specified in Annex A for qualifying the test room itself.

An environment providing a free field or a free field over a reflecting plane shall be used for measurements made in accordance with this International Standard.

The test room shall be large enough and free from reflecting objects, with the exception of the reflecting plane in a hemi-anechoic room.

The test room shall provide a measurement surface that lies

a) in a sound field that is free of undesired sound reflections from the room boundaries, and

b) outside the near field of the sound source under test.

Procedures are described in this annex to determine the undesired environmental influences, if any, and to check the free field or hemi-free field conditions. For measurements in hemi-anechoic rooms, the reflecting plane shall satisfy the requirements given in B.2.

B.2 Properties of a reflecting plane

B.2.1 General

In the case of hemi-anechoic rooms, measurements shall be made over a reflecting plane in a test room in which one of the surfaces is reflecting.

Particularly when the reflecting surface is not a ground plane, or is not an integral part of a test room surface, care shall be exercised to ensure that the plane does not radiate any appreciable sound due to vibration.

B.2.2 Size

The reflecting plane shall extend at least 0,75 m beyond the projection of the measurement surface on the plane.

B.2.3 Sound absorption coefficient

The sound absorption coefficient of the reflecting plane shall be less than 0,06 over the frequency range of interest.

NOTE The requirement is satisfied by a sealed concrete construction or a sealed lightweight construction with a surface density of 20 kg/m^2 or more.

B.3 Procedure using two measurement spheres or hemispheres with different radii (Two surface method)

B.3.1 Test sound source

In general, the machinery to be tested is used as the test sound source for qualification procedures.

The measurement surface is qualified only for the test sound source or sound sources that are very similar to it.

B.3.2 Procedures

Select two spherical (anechoic room) or hemispherical (hemi-anechoic room) surfaces that surround the sound source. The first surface shall be the measurement surface, in accordance with 8.2, for determination of the sound power level. The area of the first surface shall be designated as S_1. The second surface with area S_2 shall be geometrically similar to the first surface and located further away and symmetrical with respect to the sound source. On both surfaces, the background noise criteria specified in 5.3 shall be fulfilled.

The microphone locations on the second surface (S2) shall correspond to those on the first surface (S1). The ratio of the areas S_2/S_1 shall not be less than 2 and preferably should be greater than 4.

From measurements of the average sound pressure levels for both surfaces, the area-weighted level difference, δ, is calculated for each frequency band in the frequency range of interest, as follows:

$$\delta = L_{p1} - L_{p2} - 10 \lg \frac{S_2}{S_1} \text{ dB} \tag{B.1}$$

where

L_{p1} is the average sound pressure level on the first surface (S1), in decibels;

L_{p2} is the average sound pressure level on the second surface (S2), in decibels.

If the values of $|\delta|$ are equal to or less than 0,5 dB, the test room and the measurement surface (S1) are considered to be appropriate for the purposes of this International Standard.

Annex C
(normative)

Array of microphone positions in a free field

The location of 20 positions associated with equal areas on the surface of a sphere of radius *r* are shown in Table C.1, which gives the microphone positions with the origin at the acoustical centre of the source.

Table C.1 — Microphone positions

No.	*x*/*r*	*y*/*r*	*z*/*r*
1	− 1,00	0	0,05
2	0,49	− 0,86	0,15
3	0,48	0,84	0,25
4	− 0,47	0,81	0,35
5	− 0,45	− 0,77	0,45
6	0,84	0	0,55
7	0,38	0,66	0,65
8	− 0,66	0	0,75
9	0,26	− 0,46	0,85
10	0,31	0	0,95
11	1,00	0	− 0,05
12	− 0,49	0,86	− 0,15
13	− 0,48	− 0,84	− 0,25
14	0,47	− 0,81	− 0,35
15	0,45	0,77	− 0,45
16	− 0,84	0	− 0,55
17	− 0,38	− 0,66	− 0,65
18	0,66	0	− 0,75
19	− 0,26	0,46	− 0,85
20	− 0,31	0	− 0,95

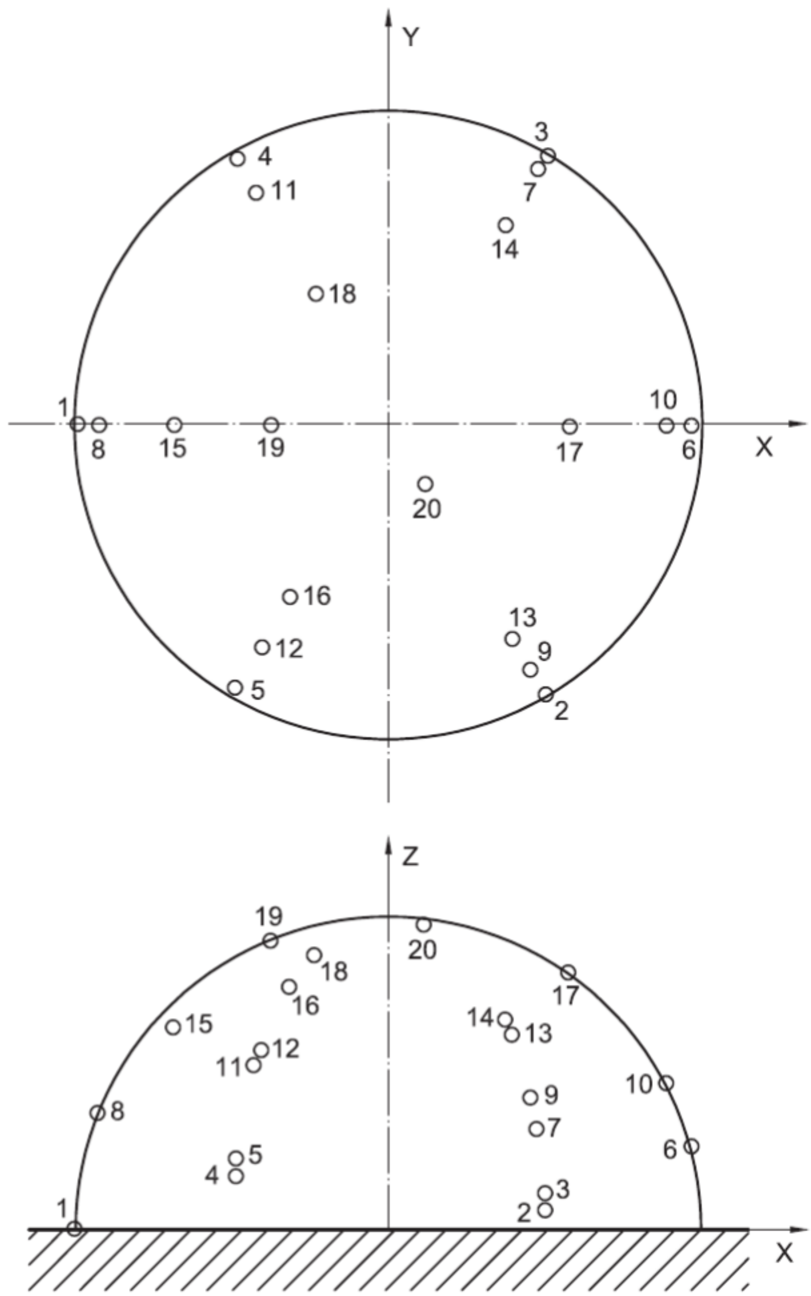
Annex D
(normative)

Array of microphone positions in a free field over a reflecting plane

The location of the 20 points with equal areas on the surface of the hemisphere of radius *r* are shown in Figure D.1. The coordinates of these locations (*x, y, z)* with the origin centred on the projection of the acoustic centre of the source on the reflecting plane are given in Table D.1.

Table D.1 — Microphone positions for free field over a reflecting plane

No.	*x*/*r*	*y*/*r*	*z*/*r*
1	– 1,00	0	0,025
2	0,50	– 0,86	0,075
3	0,50	0,86	0,125
4	– 0,49	0,85	0,175
5	-0,49	– 0,84	0,225
6	0,96	0	0,275
7	0,47	0,82	0,325
8	– 0,93	0	0,375
9	0,45	– 0,78	0,425
10	0,88	0	0,475
11	– 0,43	0,74	0,525
12	– 0,41	– 0,71	0,575
13	0,39	– 0,68	0,625
14	0,37	0,64	0,675
15	– 0,69	0	0,725
16	– 0,32	– 0,55	0,775
17	0,57	0	0,825
18	– 0,24	0,42	0,875
19	– 0,38	0	0,925
20	0,11	– 0,19	0,975



Key

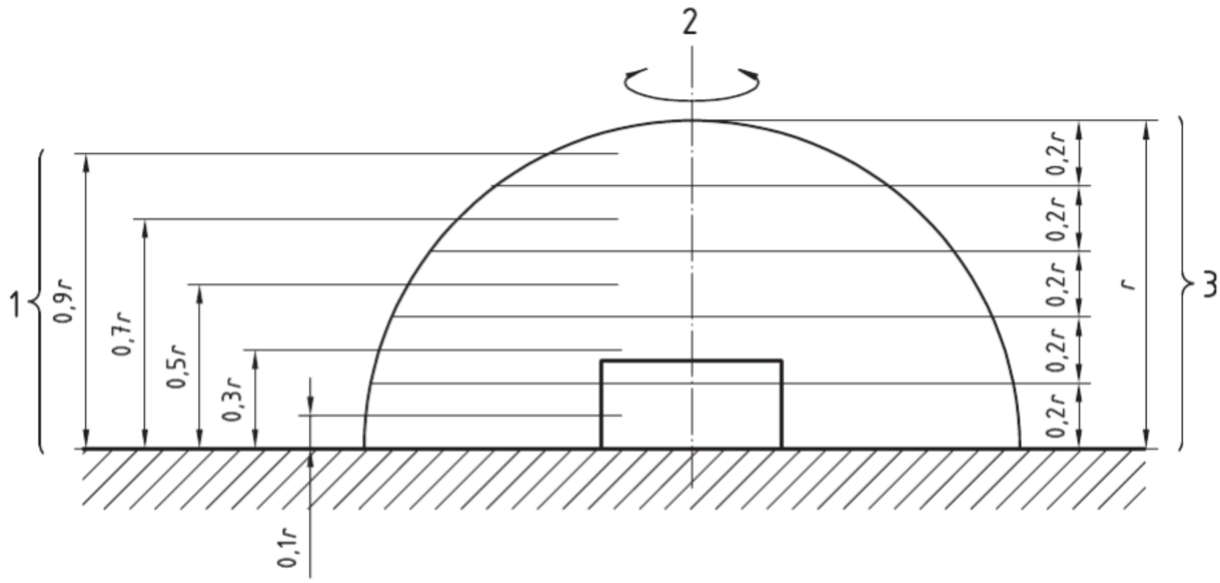
1 to 20 microphone positions

Figure D.1 — Microphone positions on the hemisphere

Annex E
(normative)

Coaxial circular paths of microphones in a hemi-free field

Paths are selected, see Figure E.1, so that the annular areas of the hemisphere associated with each are equal.



Key

1 elevations of microphone traverses

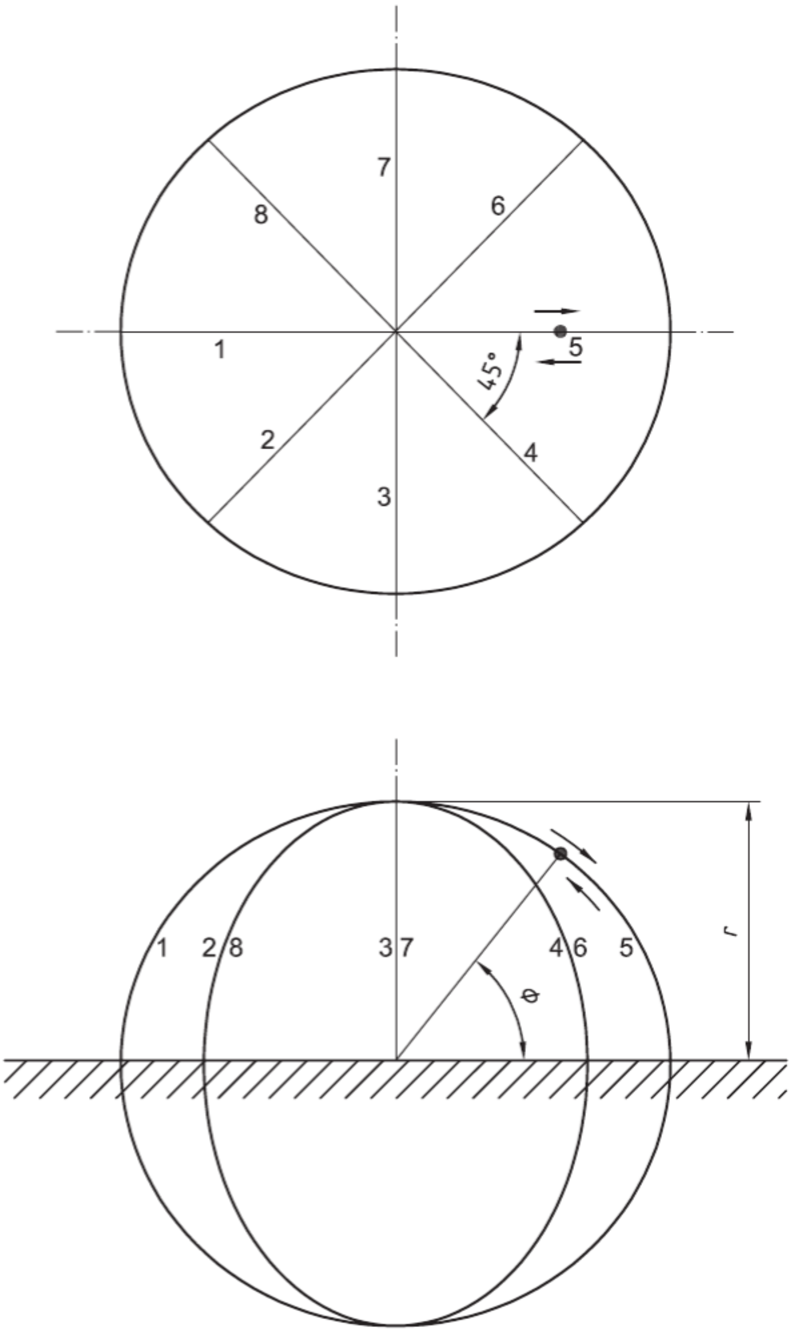
2 axis of rotation of microphone traversing mechanism

3 height of corresponding areas of hemisphere

Figure E.1 — Coaxial circular paths fora moving microphone

Annex F
(normative)

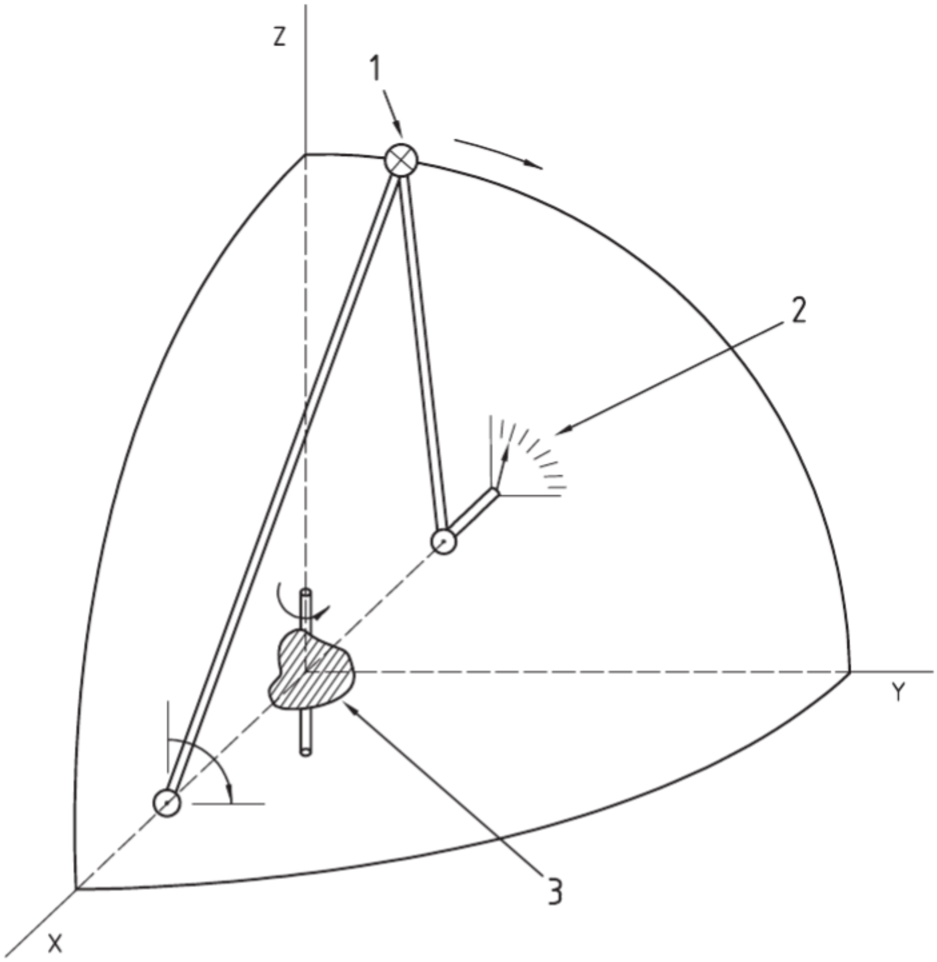
Meridional paths of microphones in a hemi-free field



Key

1 to 8 paths of microphone

Figure F.1 — Meridional paths fora moving microphone



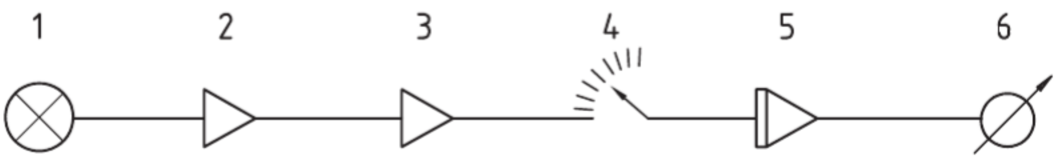
Key

1 travelling microphone

2 cosine function potentiometer for area weighting

3 noise source on revolving platform

Figure F.2 — Example of a mechanical system to realise a meridional path



Key

1 microphone

2 amplifier and spectrum analyser

3 square-law amplifier

4 cosine potentiometer

5 integrating circuit

6 meter

Figure F.3 — Example of an electronic control circuit

Annex G
(normative)

Spiral paths of microphones in a hemi-free field

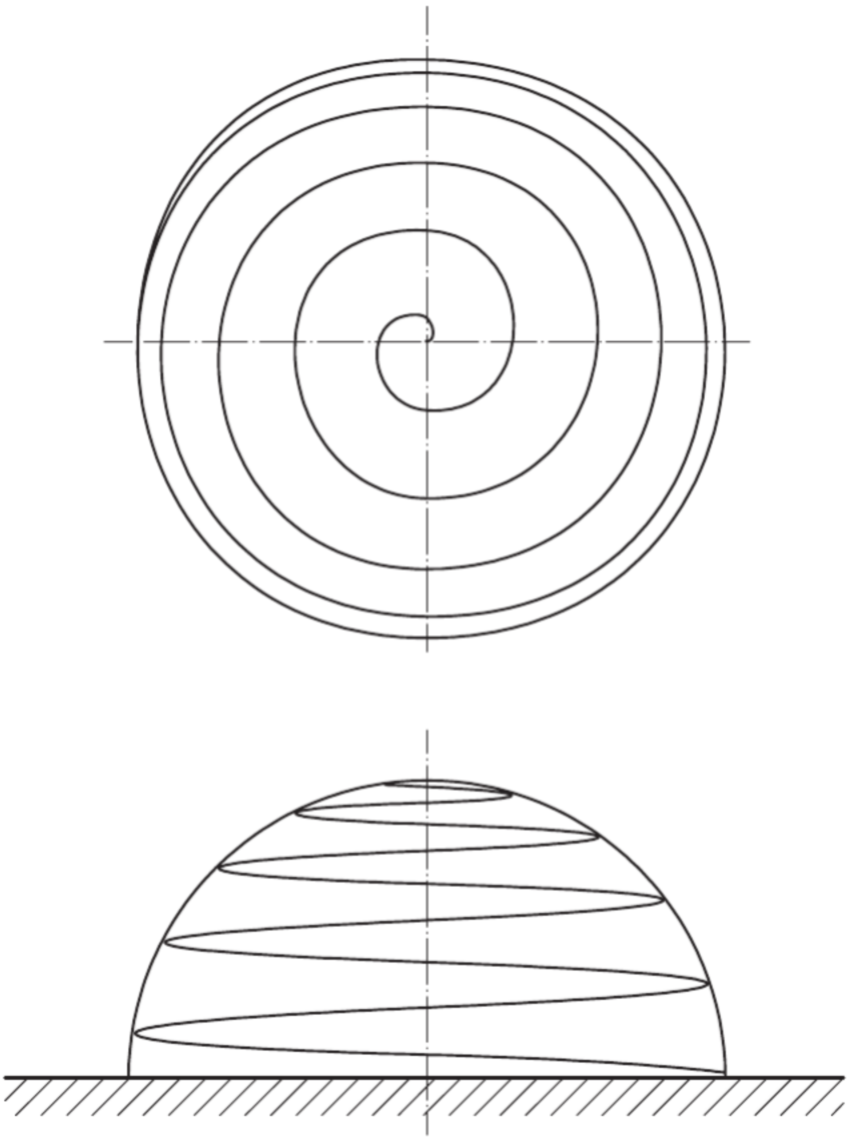


Figure G.1 —Spiral path fora moving microphone

Annex H
(normative)

Calculation of A-weighting sound power level from one-third-octave-band sound power levels

The A-weighted sound power level shall be calculated from the following equation using the levels that are included in the frequency range of interest of the measurements:

$$L_{WA} = 10 \lg \sum_{j=j_{\min}}^{j_{\max}} 10^{(L_{Wj} + C_j)/10} \text{ dB} \qquad \textbf{(H.1)}$$

where

L_{Wj} is the sound power level in the jth one-third-octave band (in dB);

j and C_j are given in Table H.1;

$j_{\min}$,$j_{\max}$ are the values of j corresponding to the lowest and highest frequency bands of measurement, respectively, from Table H.1.

Table H.1 —Values of *j* and C_j for one-third-octave band data

j	One-third-octave midband frequency Hz	C_j dB
1	50	– 30,2
2	63	– 26,2
3	80	– 22,5
4	100	– 19,1
5	125	– 16,1
6	160	– 13,4
7	200	– 10,9
8	250	– 8,6
9	315	– 6,6
10	400	– 4,8
11	500	– 3,2
12	630	– 1,9
13	800	– 0,8
14	1 000	0
15	1 250	+ 0,6
16	1 600	+ 1,0
17	2 000	+ 1,2
18	2 500	+ 1,3
19	3 150	+ 1,2
20	4 000	+ 1,0
21	5 000	+ 0,5
22	6 300	– 0,1
23	8 000	– 1,1
24	10 000	– 2,5
25	12 500	– 4,3
26	16 000	– 6,6
27	20 000	– 9,3

Annex I
(normative)

Calculation of directivity index and directivity factor

I.1 Directivity index

The directivity index D_I, in decibels, of the source shall be calculated from measurements using the following equation:

$$D_I = L_{pi} - \overline{L_{pf}} \qquad \text{(I.1)}$$

where

L_{pi} is the sound pressure level, in decibels, measured in the particular direction in which D_I is desired, at a distance r from the source;

$\overline{L_{pf}}$ is the surface sound pressure level, in decibels, over the test sphere of radius r.

I.2 Directivity factor

The directivity factor Q of the source, in a given direction, shall be determined from the following equation:

$$Q = 10^{D_I/10} \text{ dB} \qquad \text{(I.2)}$$

Annex J
(informative)

Measurement uncertainty

J.1 General

The information on measurement reproducibility given in this International Standard (see Clause 4) can be helpful towards the derivation of measurement uncertainties, but it is incomplete. In particular, it gives no indication of any systematic bias which might occur between sound power levels and sound energy levels determined using the methods of different standards, nor does it give an exhaustive analysis of the various components of measurement uncertainty and their magnitudes. The accepted format for expression of uncertainties generally associated with methods of measurement is that given in the GUM. This format incorporates an uncertainty budget, in which all the various sources of uncertainty are identified and quantified, from which the combined standard uncertainty can be obtained. The data necessary to enable such a format to be adopted in the case of this International Standard were not available at the time when it was being prepared. However, an indication is given below of the sources of uncertainty which are thought to be associated with the methods and equipment described. The general approach to calculation of uncertainties appropriate to this International Standard, conforming with the GUM, is illustrated for information. A method is also given by which an estimate may be made of measurement uncertainties using the data included on reproducibility.

J.2 Expression for the calculation of the sound power level

The general expression for the calculation of the sound power level, L_W, is given by the following equation:

$$L_W = \overline{L_{pf}} + 10\,\lg\left(\frac{S}{S_0}\right)\text{dB} + \delta_{\text{slm}} + \delta_{\text{rep}} + \delta_{\text{mic}} + \delta_{\text{boun}} + \delta_{\text{angle}} + \delta_{\text{imp}} + \delta_{\text{met}} \quad \text{(J.1)}$$

where

$\overline{L_{pf}}$ is the surface sound pressure level, in decibels;

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

S_0 = 1 m^2;

δ_{slm} is an input quantity to allow for any error in the measuring instrumentation;

δ_{rep} is an input quantity to allow for any error in the operating conditions of the noise source under test;

δ_{mic} is an input quantity to allow for any error in the finite number of microphone positions;

δ_{boun} is an input quantity to allow for any error in the influence of the test room boundaries;

δ_{angle} is an input quantity to allow for any difference of angle between the direction in which sound is emitted by the source and the normal to the measurement surface;

δ_{imp} is an input quantity to allow for any error in the impedance of the surroundings into which the source is emitting sound energy;

δ_{met} is an input quantity to allow for any error in the meteorological conditions.

NOTE 1 aSimilar expressions to that of Equation (J.1) apply with respect to sound power levels determined in frequency bands and with A-weighting applied, and to sound energy levels.

NOTE 2 The inputs included in Equation (J.1) to allow for errors are those thought to be applicable in the state of knowledge at the time when this International Standard was being prepared, but further research could reveal that there are others.

A probability distribution (normal, rectangular, etc.) is associated with each of the inputs to allow for errors. Its expectation (mean value) is the best estimate for the value of the input and its standard deviation is a measure of the dispersion of values, termed uncertainty. It is presumed, for the purposes of Equations (13), (16), (17), (18) and (19), that the mean values of all of the input quantities for errors given in Equation (J.1) are equal to zero. However, in any particular determination of a sound power level or sound energy level of a noise source under test, the uncertainties do not vanish and they contribute to the combined standard uncertainty associated with values of the sound power level or sound energy level.

J.3 Contributions to measurement uncertainty

The contributions to the combined uncertainty associated with the value of the surface sound pressure level depend on each of the input quantities to allow for errors, their respective probability distributions and sensitivity coefficients, c_i. The sensitivity coefficients are a measure of how the values of the surface sound pressure level are affected by changes in the values of the respective input quantities. In the model used in Equation J.1, all sensitivity coefficients have the value 1. The contributions of the respective input quantities to allow for errors to the overall uncertainty are then given by the products of the standard uncertainties and their associated sensitivity coefficients. Thus, the information needed from which to derive the overall uncertainty is that illustrated in Table J.1.

Table J.1 — Uncertainty budget for determinations of sound power level and sound energy level

Quantity	Estimate dB	Standard uncertainty u_i dB	Probability distribution	Sensitivity coefficient c_i	Uncertainty contribution $c_i u_i$ dB
Surface sound pressure level	$\overline{L_{pf}}$				
δ_{slm}	0				
δ_{rep}	0				
δ_{mic}	0				
δ_{boun}	0				
δ_{angle}	0				
δ_{imp}	0				
δ_{met}	0				

The standard uncertainty of the surface sound pressure level is the standard deviation of repeated determinations. The standard uncertainties from the various contributions for most noise sources remain to be established by research. In the case of a reference sound source conforming to ISO 6926, however, an uncertainty budget for determinations of the A-weighted sound power level can be given as an example, as shown in Table J.2. In this case, the estimates for the mean values of the errors from the microphone angle and the radiation impedance are small, but not quite zero.

Table J.2 — Uncertainty budget for determinations of the A-weighted sound power level of a reference sound source

Quantity	Estimate dB	Standard uncertainty u_i dB	Probability distribution	Sensitivity coefficient c_i	Uncertainty contribution $c_i u_i$ dB
Surface sound pressure level	$\overline{L_{pf}}$	0,14	Normal	1	0,14
δ_{slm}	0	0,25	Normal	1	0,25
δ_{rep}	0	0,10	Normal	1	0,10
δ_{mic}	0	0,14	Normal	1	0,14
δ_{boun}	0	0,10	Normal	1	0,10
δ_{angle}	0,05	0,02	Rectangular	1	0,02
δ_{imp}	0,007	0,004	Rectangular	1	0,004
δ_{met}	0	0,04	Normal	1	0,04

J.4 Expanded uncertainty of measurement

The combined standard uncertainty of the determination of the sound power level, $u(L_W)$ (and similarly for the sound energy level) is given by the following equation:

$$u(L_W) = \sqrt{\sum_{i=1}^{8} (c_i u_i)^2} \quad \text{(J.2)}$$

Thus, for the example of a reference sound source, the combined standard uncertainty of the sound power level is 0,352 dB.

The GUM requires an expanded uncertainty, *U,* to be specified, such that the interval $[L_W - U, L_W + U]$ covers, for example, 95 % of the values of L_W that might reasonably be attributed to L_W. To that purpose, a coverage factor, *k,* is used, such that $U = k\ u$. The coverage factor depends on the probability distribution associated with the measurand.

In the above example for a reference sound source, it may be assumed that the combination of the probability distributions associated with the eight inputs results in a normal distribution. In that case, *k* has a value of 2 forr a coverage probability of 95 % and the expanded uncertainty of measurement is 0,70 dB

J.5 Measurement uncertainty based upon reproducibility data

In the absence of data for uncertainty contributions, values for the standard deviation of reproducibility as given in Clause 4 may be used as an estimate of the combined standard uncertainty of determinations of the sound power levels or sound energy levels. A value may then be selected for the coverage factor, and the product of the two will yield an estimate of the expanded uncertainty with the chosen coverage probability. By convention, a coverage probability of 95 % is usually chosen. To avoid any misinterpretations, the chosen coverage probability should always be stated in test reports, together with the expanded measurement uncertainty.

Annex K
(informative)

Guidelines for the design of test rooms

K.1 General

To realize free-field conditions, a test room should have

a) adequate volume,

b) large sound absorption over the frequency range of interest,

c) absence of acoustically reflecting surfaces and obstructions other than those associated with the sound source under test (and the reflecting plane, if any), and

d) sufficiently low background noise levels.

K.2 Volume of test room

In order to make measurements in the far radiation field of the source, it is recommended that the volume of the test room be at least 200 times greater than the volume of the source whose sound power level is to be determined.

K.3 Absorption of test room

The normal incidence sound absorption coefficient of the wall and ceiling treatments should be equal to or greater than 0,99 over the frequency range of interest, when measured in a plane-wave impedance tube. The absorptive treatment should be uniformly distributed over the surfaces. In an anechoic room, the same treatment as used for the walls and ceiling should also be applied to the floor. In a hemi-anechoic room, the floor should consist of a hard, smooth plane whose normal incidence sound absorption coefficient should not exceed 0,06 over the frequency range of interest.

K.4 Absorptive treatment

A satisfactory surface treatment consists of wedges of absorptive material, mounted on the inner walls of the anechoic room and pointing into the interior of the room. Wedges may be mounted with a small air space behind them. The total depth of treatment (wedge and air space) should exceed $\lambda/4$, where λ is the wavelength of sound corresponding to the centre frequency of the lowest frequency band of interest.

K.5 Unwanted reflections

Reflections can occur from pipes, braces, grillwork, hardware cloth, cables or supports of various kinds. All objects and instruments other than those which must be in the test room should be located outside the room. Hollow pipes should be blocked off or filled with an absorptive material to prevent them from resonating.

K.6 Suspended floor construction

Atypical floor construction which has been found acceptable in anechoic rooms consists of a grid of stretched stainless steel wires about 2,5 mm in diameter and spaced 2 cm to 5 cm apart.

K.7 Background noise

Problems with acoustical background noise are usually most severe at low frequencies. To make satisfactory measurements at low frequencies, it may be necessary to surround the anechoic room with a massive wall and support the whole structure on vibration isolators. At high frequencies, electrical noise can be bothersome.

K.8 Air absorption

In large rooms (volumes greater than 200 m^3), a correction for the absorption of sound by the air in the room may be required at high frequencies.

Bibliography

[1] ISO 140-3, *Acoustics— Measurement of sound insulation in buildings and of building elements — Part 3: Laboratory measurement of airborne sound insulation of building elements*

[2] ISO 3740, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards*

[3] 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*

[4] ISO 3746, *Acoustics— Determination of sound power levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

[5] ISO 4871, *Acoustics— Declaration and verification of noise emission values of machinery and equipment*

[6] ISO 9614-1, *Acoustics— Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points*

[7] ISO 9614-2, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning*

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

[9] MALING, G.C.Jr., WISE, R.E. and NOBILE, M.A. Qualification of hemi-anechoic rooms for noise emission measurements. *Proc. Inter-Noise 90,* 1990, pp. 685-690

[10] TOMIOKA, H., FUJIMORI, T., TAKAHASHI.T. and MIURA, H. *Inverse square law versus accuracies of acoustic power level in an anechoic room.* Proc. of Noise Committee, Acoustical Society of Japan, N 86-04-3 (April 1986) (in Japanese)

[11] HUBNER, G. Qualification procedures for free-field conditions for sound power determination of sound sources and methods for the determination of the appropriate environmental correction. *J. Acoust. Soc. Am*., **61**, 1977, pp. 454-456

[12] NOBILE, M.A., DONALD, B. and SHAW, J.A. The cylindrical microphone array: A proposal for use in International standards for sound power level measurements. *Proc. Noise Con. 2000,* December, 2000

Annex ZA
(normative)

Normative references to international publications with their relevant European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated referenaces, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE Where an International Publication has been modified by common modifications, indicated by (mod.), the relevant EN/HD applies.

Publication	Year	Title	EN	Year
ISO 7574-1	1985	Acoustics - Statistical methods for determining and verifying stated noise emission values of machinery and equipment - Part 1: General considerations and definitions	EN 27574-1	1988
ISO 7574-4	1985	Acoustics - Statistical methods for determining and verifying stated noise emission values of machinery and equipment - Part 4: Methods for stated values for batches of machines	EN 27574-4	1988

Annex ZB
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 98/37 EEC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 98/37 EEC.

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national standard in at least one Member State, compliance with the normative clauses of this standard confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

WARNING: Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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