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
ISO 3745:2003(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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/IEC/IFCC/ISO/IUPAC/IUPAP/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 × 10^{-5} Pa)]

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

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
$L_{p\text{eq},T}$
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

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

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 K_1 (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 ith 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 W_0 [W_0 = 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_0 = 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

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

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)]

$$L_J = 10 \lg \frac{E}{E_0}\ \mathrm{dB} \tag{7}$$

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, σ_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.