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

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

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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 third edition cancels and replaces the second edition (ISO 3745:2003), which has been technically revised.

Introduction

This International Standard is one of the series ISO 3741[3] to ISO 3747[8], which specify various methods for determining the sound power levels and sound energy levels of noise sources including machinery, equipment and their sub-assemblies. The selection of one of the methods from the series for use in a particular application depends on the purpose of the test to determine the sound power level or sound energy level and on the facilities available. General guidelines to assist in the selection are provided in ISO 3740[2]. ISO 3741[3] to ISO 3747[8] give only general principles regarding the operating and mounting conditions of the machinery or equipment for the purposes of the test. It is important that test codes be established for individual kinds of noise source, in order to give detailed requirements on mounting, loading and operating conditions under which the sound power levels or sound energy levels are to be obtained and to select the appropriate measurement surface and microphone array from among those specified in this International Standard.

The methods given in this International Standard require the source to be mounted in either an anechoic room or a hemi-anechoic room having specified acoustical characteristics. The methods are then based on the premise that the sound power or sound energy of the source is directly proportional to the mean-square sound pressure over a hypothetical measurement surface enclosing the source and otherwise depends on the physical constants of air.

The methods specified in this International Standard permit the determination of the sound power level and the sound energy level in frequency bands and/or with frequency A-weighting applied.

The methods give a precision grade of accuracy (grade 1) as defined in ISO 12001. The resulting sound power levels and sound energy levels include corrections to allow for any differences that might exist between the meteorological conditions under which the tests are conducted and reference meteorological conditions. For applications where there are large uncertainties due to operating conditions or where reduced accuracy is acceptable, reference can be made to the more practical methods of ISO 3744[6] or ISO 3746[7]. Guidance on evaluation of measurement uncertainty is given in Annex I.

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

1 Scope

1.1 General

This International Standard specifies methods for measuring the sound pressure levels on a measurement surface enveloping a noise source (machinery or equipment) in an anechoic room or a hemi-anechoic room. The sound power level (or, in the case of impulsive or transient noise emission, the sound energy level) produced by the noise source, in frequency bands of width one-third octave or with frequency weighting A applied, is calculated using those measurements, including corrections to allow for any differences between the meteorological conditions at the time and place of the test and those corresponding to a reference characteristic acoustic impedance.

In general, the frequency range of interest includes the one-third-octave bands with mid-band frequencies from 100 Hz to 10 000 Hz. In practice, the range is extended or restricted to frequencies beyond or within these limits, to those between which the test room is qualified for the purposes of the measurements.

1.2 Types of noise and noise sources

The methods specified in this International Standard are suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001.

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

1.3 Test room

The test rooms that are applicable for measurements made in accordance with this International Standard are an anechoic room or hemi-anechoic room, also called, respectively, a free-field test room or hemi-free-field test room.

1.4 Measurement uncertainty

Information is given on the uncertainty of the sound power levels and sound energy levels determined in accordance with this International Standard, for measurements made in limited bands of frequency and with frequency weighting A applied. The uncertainty conforms to ISO 12001:1996, accuracy grade 1 (precision grade).

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 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*

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

ISO 12001:1996, *Acoustics — Noise emitted by machinery and equipment — Rules for the drafting and presentation of a noise test code*

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

IEC 60942:2003, *Electroacoustics — Sound calibrators*

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

IEC 61260:1995 + AM1:2001, *Electroacoustics — Octave-band and fractional-octave-band filters*

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

3 Terms and definitions

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

3.1
sound pressure
p
difference between instantaneous pressure and static pressure

NOTE 1 Adapted from ISO 80000-8:2007[22], 8-9.2.

NOTE 2 Sound pressure is expressed in pascals.

3.2
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the sound pressure, p, to the square of a reference value, p_0, expressed in decibels

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

where the reference value, p_0, is 20 µPa

[ISO/TR 25417:2007[20], 2.2]

NOTE 1 If specific frequency and time weightings as specified in IEC 61672-1 and/or specific frequency bands are applied, this should be indicated by appropriate subscripts; e.g. $L_{p\text{A}}$ denotes the A-weighted sound pressure level.

NOTE 2 This definition is technically in accordance with ISO 80000-8:2007[22], 8-22.

3.3
time-averaged sound pressure level
$L_{p,T}$
ten times the logarithm to the base 10 of the ratio of the time average of the square of the sound pressure, p, during a stated time interval of duration, T (starting at t_1 and ending at t_2), to the square of a reference value, p_0, expressed in decibels

$$L_{p,T} = 10 \lg \left[\frac{\frac{1}{T} \int_{t_1}^{t_2} p^2(t) \mathrm{d}t}{p_0^2} \right] \text{dB} \quad (2)$$

where the reference value, p_0, is 20 µPa

NOTE 1 In general, the subscript "T" is omitted since time-averaged sound pressure levels are necessarily determined over a certain measurement time interval.

NOTE 2 Time-averaged sound pressure levels are often A-weighted, in which case they are denoted by $L_{pA,T}$, which is usually abbreviated to L_{pA}.

NOTE 3 Adapted from ISO/TR 25417:2007[20], 2.3.

3.4
single event time-integrated sound pressure level
L_E
ten times the logarithm to the base 10 of the ratio of the integral of the square of the sound pressure, p, of an isolated single sound event (burst of sound or transient sound) over a stated time interval T (starting at t_1 and ending at t_2) to a reference value, E_0, expressed in decibels

$$L_E = 10\lg\left[\frac{\int_{t_1}^{t_2} p^2(t)\,\mathrm{d}t}{E_0}\right]\mathrm{dB} \tag{3}$$

where the reference value, E_0, is (20 μPa)^2 s = 4 × 10^{-10} Pa^2 s

[ISO 3741:2010[3], 3.4]

NOTE 1 This quantity can be obtained by $L_{p,T}$ + 10lg(T/T_0) dB, where T_0 = 1 s.

NOTE 2 When used to measure sound immission (see ISO 11690-1[19]), this quantity is usually called "sound exposure level" (see ISO/TR 25417:2007[20], 2.7).

3.5
measurement time interval
T
portion or a multiple of an operational period or operational cycle of the noise source under test for which the time-averaged sound pressure level is determined

NOTE Measurement time interval is expressed in seconds.

[ISO 3741:2010[3], 3.5]

3.6
free sound field
sound field in a homogeneous, isotropic medium free of boundaries

NOTE In practice, a free sound field is a field in which the influence of reflections at the boundaries or other disturbing objects is negligible over the frequency range of interest.

[ISO/TR 25417:2007[20], 2.17]

3.7
anechoic room
anechoic test room
free-field test room
test room in which a free sound field is obtained

3.8
free sound field over a reflecting plane
free sound field in the half-space above an infinite reflecting plane in the absence of any other obstacles

3.9
reflecting plane
sound reflecting planar surface on which the noise source under test is located

3.10
hemi-anechoic room
hemi-anechoic test room
hemi-free-field test room
test room in which a free sound field over a reflecting plane is obtained

3.11
frequency range of interest
for general purposes, the frequency range of one-third-octave bands with nominal mid-band frequencies from 100 Hz to 10 000 Hz

NOTE For special purposes, the frequency range may be extended or reduced, provided that the test environment and instrument specifications are satisfactory for use over the modified frequency range. Changes to the frequency range of interest should be made clear in the test report. For sources in which the A-weighted sound power levels are determined by sound at predominantly high or low frequencies, the frequency range of interest should be extended to include these frequencies.

3.12
measurement radius
r
radius of a spherical or hemispherical measurement surface

NOTE Measurement radius is expressed in metres.

3.13
measurement surface
hypothetical surface of area, S, on which the microphone positions are located at which the sound pressure levels are measured, enveloping the noise source under test and, in the case of a hemi-anechoic room, terminating on the reflecting plane on which the source is located

NOTE The measurement surface area is expressed in metres squared.

3.14
characteristic source dimension
d_0
distance from the origin of the co-ordinate system to the farthest corner of the reference box, where the reference box is defined as a hypothetical rectangular parallelepiped that just encloses the source including all the significant sound radiating components and any test table on which the source may be mounted; in the case of a hemi-anechoic room the reference box terminates on the reflecting plane

NOTE 1 Characteristic source dimension is expressed in metres.

NOTE 2 For illustration see Figure 1.

3.15
background noise
noise from all sources other than the noise source under test

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

3.16
background noise correction
K_1
correction applied to each of the measured sound pressure levels on the measurement surface to account for the influence of background noise

NOTE 1 Background noise correction is expressed in decibels.

NOTE 2 The background noise correction is frequency dependent; the correction in the case of a frequency band is denoted K_{1f}, where f denotes the relevant mid-band frequency; in the case of A-weighting, the quantity is denoted K_{1A}.

3.17
surface time-averaged sound pressure level
$\overline{L_p}$

mean (energy average) of the time-averaged sound pressure levels at all the microphone positions, or traverses, on the measurement surface, with the background noise corrections, K_1, applied at each microphone position or traverse

$$\overline{L_p} = 10\lg\left[\frac{\sum_{i=1}^{N_M} 10^{0,1L_{pi(ST)}}}{N_M}\right] \text{dB} \quad (4)$$

where

$L_{pi(ST)}$ is the background noise corrected time-averaged sound pressure level for the ith microphone position or traverse on the measurement surface, with the noise source under test in operation, in decibels;

N_M is the number of microphone positions or traverses.

NOTE Surface time-averaged sound pressure level is expressed in decibels.

3.18
surface single event time-integrated sound pressure level
$\overline{L_E}$

mean (energy average) of the single event time-integrated sound pressure levels at all the microphone positions on the measurement surface, with the background noise correction, K_1, applied at each microphone position

$$\overline{L_E} = 10\lg\left[\frac{\sum_{i=1}^{N_M} 10^{0,1L_{Ei(ST)}}}{N_M}\right] \text{dB} \quad (5)$$

where

$L_{Ei(ST)}$ is the background noise corrected single event time-integrated sound pressure level for the ith microphone position on the measurement surface, with the noise source under test in operation, in decibels;

N_M is the number of microphone positions.

NOTE Surface single event time-integrated sound pressure level is expressed in decibels.

3.19
sound power
P

through a surface, product of the sound pressure, p, and the component of the particle velocity, u_n, at a point on the surface in the direction normal to the surface, integrated over that surface

[ISO 80000-8:2007[22], 8-16 reproduced in ISO/TR 25417:2007[20], 2.8]

NOTE 1 Sound power is expressed in watts.

NOTE 2 The quantity relates to the rate per time at which airborne sound energy is radiated by a source.

3.20
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of the sound power of a source, P, to a reference value, P_0, expressed in decibels

$$L_W = 10 \lg \frac{P}{P_0} \text{ dB} \tag{6}$$

where the reference value, P_0, is 1 pW

NOTE 1 If a specific frequency weighting as specified in IEC 61672-1 and/or specific frequency bands are applied, this should be indicated by appropriate subscripts; e.g. $L_{W,\text{A}}$ denotes the A-weighted sound power level.

NOTE 2 This definition is technically in accordance with ISO 80000-8:2007[22], 8-23.

[ISO/TR 25417:2007[20], 2.9]

3.21
sound energy
J
integral of the sound power, P, over a stated time interval of duration T (starting at t_1 and ending at t_2)

$$J = \int_{t_1}^{t_2} P(t)\, \mathrm{d}t \tag{7}$$

NOTE 1 Sound energy is expressed in joules.

NOTE 2 The quantity is particularly relevant for non-stationary, intermittent sound events.

[ISO/TR 25417:2007[20], 2.10]

3.22
sound energy level
L_J
ten times the logarithm to the base 10 of the ratio of the sound energy, J, to a reference value, J_0, expressed in decibels

$$L_J = 10 \lg \frac{J}{J_0} \text{ dB} \tag{8}$$

where the reference value, J_0, is 1 pJ

NOTE If a specific frequency weighting as specified in IEC 61672-1 and/or specific frequency bands are applied, this should be indicated by appropriate subscripts; e.g. $L_{J\text{A}}$ denotes the A-weighted sound energy level.

[ISO/TR 25417:2007[20], 2.11]

3.23
directivity index
$D_{\mathrm{I}i}$
measure of the extent to which a noise source under test radiates sound in the direction of the ith microphone position on a measurement surface, relative to the mean sound radiation over the measurement surface

$$D_{\mathrm{I}i} = L_{pi} - \overline{L_p} \tag{9}$$

where

L_{pi} is the background noise corrected sound pressure level (either time-averaged or single event time-integrated) for the ith microphone position on the measurement surface, with the noise source under test in operation, in decibels;

$\overline{L_p}$ is the surface sound pressure level (either time-averaged or single event time-integrated), in decibels.

3.24
surface sound pressure level non-uniformity index
V_{I}
measure of the variability of measured sound pressure levels over the measurement surface

$$V_{\mathrm{I}} = \sqrt{\frac{1}{(N_{\mathrm{M}} - 1)} \sum_{i=1}^{N_{\mathrm{M}}} (L_{pi} - L_{p\mathrm{av}})^2} \tag{10}$$

where

L_{pi} is the background noise corrected sound pressure level (either time-averaged or single event time-integrated) for the ith microphone position on the measurement surface with the noise source under test in operation, in decibels;

$L_{p\mathrm{av}}$ is the arithmetic average of the background noise corrected sound pressure levels (either time-averaged or single event time-integrated) over all the microphone positions on the measurement surface for the noise source under test, in decibels;

N_{M} is the number of microphone positions.

NOTE When V_{I} is determined at a particular measurement radius, the quantity is denoted $V_{\mathrm{I}r}$.

4 Reference meteorological conditions

Reference meteorological conditions for the purpose of calculating the sound power level and sound energy level, corresponding to a reference characteristic acoustic impedance of air $\rho c = 411{,}5$ N s/m^3 (where ρ is the density of air and c is the speed of sound) are:

a) air temperature: 23,0 °C;

b) static pressure: 101,325 kPa;

c) relative humidity: 50 %.

5 Test rooms

5.1 Acoustic criterion for adequacy of the test room

Anechoic or hemi-anechoic rooms that are applicable for measurements in accordance with this International Standard either satisfy:

a) Annex A over the frequency range of interest, for use in general purpose measurements; or

b) Annex B over the frequency range of interest, for determination of sound power levels of a specific noise source.

Annex A and Annex B specify 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 in accordance with Annex A or Annex B.

For sources in which the A-weighted sound levels are determined by sound at predominantly high or low frequencies, outside the nominal frequency range of interest (see 3.11), the frequency range of interest shall be extended to include these frequencies, and this shall be clearly stated in the test report.

NOTE If it is necessary to make measurements in test rooms or spaces within test rooms where the requirements of Annex A or Annex B are exceeded, see ISO 3744[6], ISO 3746[7], ISO 9614-1[15] or ISO 9614-2[16].

5.2 Criteria for background noise

5.2.1 Relative criteria

5.2.1.1 General

The difference between the level of the background noise and that of the noise source under test (when measured in the presence of this background noise) averaged (see 9.4.3) over all microphone positions or traverses, shall be at least 6 dB for all frequency bands, and for one-third-octave bands of mid-band frequency from 250 Hz to 5 000 Hz shall be at least 10 dB. If this requirement is met, the background noise criteria of this International Standard are satisfied.

NOTE 1 The same criteria are applied to single event levels, where the measurement time interval used to measure the background noise is the same as the measurement time interval associated with the measurement of the single event.

NOTE 2 The noise associated with the microphone traversing mechanism, if one is used for the measurements, is considered to be part of the background noise. In such cases, the background noise should be measured with the traversing mechanism operating.

5.2.1.2 Frequency band measurements

The requirements of 5.2.1.1 may not be achievable in all frequency bands, even when the background noise levels in the test room are extremely low and well controlled. Therefore, for the purposes of determining compliance with the background noise criteria given in 5.2.1.1, any band may be excluded from the frequency range of interest if the A-weighted sound power level (see Annex C) of that band (after correcting for background noise) is at least 15 dB below the highest A-weighted sound power level in any frequency band.

5.2.1.3 A-weighted measurements

If the A-weighted sound power level or sound energy level is to be determined from frequency band levels and reported, the following steps shall be followed to determine whether this quantity meets the background noise criteria of this International Standard:

a) the A-weighted sound power level or sound energy level is computed in accordance with the procedures in this International Standard using the data from every frequency band within the frequency range of interest;

b) the computation is repeated, but excluding those bands for which $\Delta L_p < 6$ dB for one-third-octave bands of mid-band frequency 200 Hz and below and 6 300 Hz and above, and for which $\Delta L_p < 10$ dB for one-third-octave bands of mid-band frequency from 250 Hz to 5 000 Hz.

If the difference between these two levels is less than 0,5 dB, the A-weighted sound power level or sound energy level determined from the data for all bands shall be considered as conforming to the background noise criteria of this International Standard.

5.2.2 Absolute criteria

If it can be demonstrated that the background noise levels in the test room at the time of the measurements are less than or equal to those given in Table 1 for all bands within the frequency range of interest, the measurements can be taken as having met the background noise requirements of this International Standard, even if the 6 dB and 10 dB requirements (see 5.2.1.1) are not met for all bands. It can be assumed that the source emits little or no measurable noise in these frequency bands, and that the data reported represent an upper bound to the sound power level or sound energy level in these bands.

If levels of noise measured at the smallest possible distance from the source (see Clause 8) are less than or equal to those given in Table 1, the frequency range of interest may be restricted to a contiguous range of frequencies that includes both the lowest and highest frequencies at which the sound pressure level from the noise source exceeds the corresponding value in Table 1. In such cases, the applicable frequency range of interest shall be reported.

NOTE The absolute background criteria are intended for general sound power measurements; they exceed the threshold of audibility and may not be suitable for all uses.

5.2.3 Statement of non-conformity with criteria

If the above background noise criteria are not satisfied, the report shall clearly state that the background noise requirements of this International Standard have not been met, and, in the case of frequency band measurements, shall identify the particular frequency bands that do not meet the criteria. Furthermore, the report shall not state or imply that the measurements have been made “in full conformity” with ISO 3745.

5.3 Criterion for air temperature

The air temperature in the test room shall be within the range 15 °C to 30 °C.

NOTE The equations in Clause 9 used for the calculation of the sound power level and the sound energy level include a multiplication factor which is an approximation to cover a variety of possible sound-generating mechanisms (monopole, dipole, quadrupole, etc.) which pertain to different kinds of noise source; the range of air temperature is limited in order to guarantee a deviation smaller than 0,2 dB in the result.

6 Instrumentation

6.1 Instruments for acoustical measurements

6.1.1 General

The instruments for measuring sound pressure levels, including microphone(s) as well as cable(s), windscreen(s), recording devices and other accessories, if used, shall meet the requirements of IEC 61672-1:2002, class 1. Filters shall meet the requirements of IEC 61260:1995, class 1.

The microphone shall be oriented so that the reference direction of the microphone (as specified in IEC 61672-1) is normal to the measurement surface.

6.1.2 Calibration

At the beginning and the end of every measurement session and at least at the beginning and the end of each measurement day, the entire sound pressure level measuring system shall be checked at one or more