INTERNATIONAL STANDARD

ISO 3747

Third edition
2010-12-01

Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering/survey methods for use *in situ* in a reverberant environment

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 — Méthode d'expertise et de contrôle pour une utilisation in situ *en environnement réverbérant*

Reference number
ISO 3747:2010(E)

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 3747 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This third edition cancels and replaces the second edition (ISO 3747:2000), which has been technically revised.

Introduction

This International Standard is one of the series ISO 3741[2] to ISO 3747, 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[1]. ISO 3740[1] to ISO 3747 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 for mounting, loading, and operating conditions under which the sound power levels or sound energy levels are to be obtained.

The method given in this International Standard is based on a comparison of the sound pressure levels in octave frequency bands of a noise source under test with those of a calibrated reference sound source; A-weighted sound power levels or sound energy levels may be calculated from the octave-band levels. The method is applied where the noise source is found *in situ* and as such is suitable for larger pieces of stationary equipment which, due to their manner of operation or installation, cannot readily be moved.

The method specified in this International Standard permits the determination of the sound power level and the sound energy level in octave bands from which the A-weighted value is calculated.

This International Standard describes a method giving results of either ISO 12001:1996, accuracy grade 2 (engineering grade) or ISO 12001:1996, accuracy grade 3 (survey grade), depending on the extent to which the requirements concerning the test environment are met. For applications where greater accuracy is required, reference can be made to ISO 3741[2], ISO 3744[5] or an appropriate part of ISO 9614[17]-[19]. If the relevant criteria for the measurement environment specified in this International Standard are not met, it might be possible to refer to another standard from this series, or to an appropriate part of ISO 9614[17]-[19].

Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering/survey methods for use *in situ* in a reverberant environment

1 Scope

1.1 General

This International Standard specifies a method for determining the sound power level or sound energy level of a noise source by comparing measured sound pressure levels emitted by a noise source (machinery or equipment) mounted *in situ* in a reverberant environment, with those from a calibrated reference sound source. The sound power level (or, in the case of noise bursts or transient noise emission, the sound energy level) produced by the noise source, in frequency bands of width one octave, is calculated using those measurements. The sound power level or sound energy level with frequency A-weighting applied is calculated using the octave-band levels.

1.2 Types of noise and noise sources

The method specified in this International Standard is suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001. The method is primarily applicable to sources which emit broad-band noise. It can, however, also be used for sources which emit narrow-band noise or discrete tones, although there is a possibility that the measurement reproducibility is then degraded.

The noise source under test can be a device, machine, component or sub-assembly, especially one which is non-movable.

1.3 Test environment

The test environment that is applicable for measurements made in accordance with this International Standard is a room where the sound pressure level at the microphone positions depends mainly on reflections from the room surfaces (see 4.1). In measurements of ISO 12001:1996, accuracy grade 2 (engineering grade), background noise in the test environment is low compared to that of the noise source or reference sound source (see 4.2).

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 octave bands and for A-weighted frequency calculations performed on them. The uncertainty conforms with that of either ISO 12001:1996, accuracy grade 2 (engineering grade) or ISO 12001:1996, accuracy grade 3 (survey grade), depending on the extent to which the requirements concerning the test environment are met.

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 6926, *Acoustics — Requirements for the performance and calibration of reference sound sources used for the determination of sound power levels*

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 of measurement — Part 3: Guide to the expression of uncertainty in measurement* (*GUM:1995*)

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*

3 Terms and definitions

For the purposes of this document, the following 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[21], 2.2]

NOTE 1 If specific frequency and time weightings as specified in IEC 61672-1 and/or specific frequency bands are applied, this is indicated by appropriate subscripts; e.g. L_{pA} 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

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

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 $L_{p\mathrm{A},T}$, which is usually abbreviated to $L_{p\mathrm{A}}$.

NOTE 3 Adapted from ISO/TR 25417:2007[21], 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 $(20\ \mu\mathrm{Pa})^2\ \mathrm{s} = 4 \times 10^{-10}\ \mathrm{Pa}^2\ \mathrm{s}$

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

NOTE 2 When used to measure sound immission, this quantity is usually called "sound exposure level" (see ISO/TR 25417:2007[21]).

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.

3.6
comparison method
method by which the sound power level or sound energy level of a noise source under test is determined from a comparison of the sound pressure levels produced by the source under test with those of a reference sound source of known sound power output, when both sources are operated in the same environment

3.7
reverberant sound field
that portion of the sound field in the test room over which the influence of sound received directly from the source is negligible

3.8
reference sound source
sound source meeting specified requirements

NOTE For the purposes of this International Standard, the requirements are those specified in ISO 6926:1999, Clause 5.

3.9
calibration position
position, well-defined relative to reflecting surfaces, in which the reference sound source has been calibrated

3.10
excess of sound pressure level at a given distance
ΔL_f
difference, at a given distance, between the sound pressure level of a sound source in a given room and the sound pressure level that would be expected in a free sound field, expressed in decibels

NOTE This term and its definition differ from that given in ISO 14257:2001[20], 3.6, which relates to an average difference over a given distance range.

3.11
frequency range of interest
for general purposes, the frequency range of octave bands with nominal mid-band frequencies from 125 Hz to 8 000 Hz

NOTE For special purposes, the frequency range can be extended or reduced, provided that the test environment, reference sound source, and instrument specifications are satisfactory for use over the modified frequency range. Any change to the frequency range of interest is clearly indicated in the test report. Measurements are not valid if the A-weighted levels are predominantly determined by high or low frequencies outside the frequency range of interest.

3.12
reference box
hypothetical right parallelepiped terminating on the floor of the test environment on which the noise source under test is located, that just encloses the source including all the significant sound-radiating components and any test table on which the source is mounted

3.13
measurement distance
d_{m}
distance from the nearest point of the reference box to a microphone position

NOTE Measurement distance is expressed in metres.

3.14
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.

3.15
background noise correction
K_1
correction applied to the measured octave-band sound pressure levels at each microphone position 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.

3.16
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]

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.

3.17
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

$$L_W = 10 \lg \frac{P}{P_0} \text{ dB} \tag{4}$$

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_{WA} 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[21], 2.9]

3.18
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)

$$J = \int_{t_1}^{t_2} P(t)\, \mathrm{d}t \tag{5}$$

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[21], 2.10]

3.19
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

$$L_J = 10 \lg \frac{J}{J_0} \text{ dB} \tag{6}$$

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_{JA} denotes the A-weighted sound energy level.

[ISO/TR 25417:2007[21], 2.11]

4 Test environment

4.1 Criterion for acoustic adequacy of test environment

The test environment is where the noise source under test is found *in situ*, i.e. either where the source is built or where it normally operates. The method of test specified in this International Standard is for application in a reverberant sound field. The test environment shall therefore be sufficiently reverberant to cause the directivity of the source under test to have an insignificant influence on the sound pressure levels measured according to 7.5 and 7.6. The indicator, excess of sound pressure level at a given distance, ΔL_f, shall be determined in accordance with Annex A, and shall have a magnitude of at least 7 dB in regions where the requirement for a reverberant sound field is fulfilled. This indicator serves as the parameter by which to assess the measurement uncertainty, see Clause 9.

4.2 Criterion for background noise

At each microphone position, the octave-band sound pressure levels due to background noise shall be at least 6 dB and preferably more than 15 dB below the octave-band sound pressure levels from the noise source under test and from the reference sound source.

NOTE If it is necessary to make measurements where the difference between the sound pressure levels of the background noise and the sources is less than 6 dB, ISO 3746[7], ISO 9614-1[17] or ISO 9614-2[18] can be used.

5 Instrumentation and measurement equipment

5.1 General

The instrumentation system, including the microphones and cables, shall meet the requirements of IEC 61672-1:2002, class 1, and the filters shall meet the requirements of IEC 61260:1995, class 1. The reference sound source shall meet the requirements given in ISO 6926.

5.2 Calibration

Before and after each series of measurements, a sound calibrator meeting the requirements of IEC 60942:2003, class 1 shall be applied to each microphone to verify the calibration of the entire measurement system at one or more frequencies within the frequency range of interest. Without any adjustment, the difference between the readings before and after each series of measurements shall be less than or equal to 0,5 dB. If this value is exceeded, the results of the series of measurements shall be discarded.

The calibration of the sound calibrator, the compliance of the instrumentation system with the requirements of IEC 61672-1, and the compliance of the reference sound source with the requirements of ISO 6926, shall be verified at intervals in a laboratory making calibrations traceable to appropriate standards.

Unless national regulations dictate otherwise, it is recommended that the sound calibrator should be calibrated at intervals not exceeding 1 year, the reference sound source should be calibrated at intervals not exceeding 2 years, and the compliance of the instrumentation system with the requirements of IEC 61672-1 should be verified at intervals not exceeding 2 years.

6 Location, installation and operation of noise source under test

6.1 Source location and installation

Since the test procedure is designed for use *in situ*, the installation and location of the noise source under test have to be those where the source is found. However, the sound power or sound energy emitted by a source can be affected by the manner of installation and its location, for instance, relative to nearby walls or other reflecting surfaces.

Many small sound sources, although themselves poor radiators of low-frequency sound, can, as a result of the method of mounting, radiate more low-frequency sound when their vibrational energy is transmitted to surfaces large enough to be efficient radiators. In such cases, resilient mountings should if practicable be interposed between the noise source under test and the supporting structure, so that the transmission of vibration to the support and the reaction on the source are both minimized. In this case, the mounting base should be rigid (i.e. have a sufficiently high mechanical impedance) to prevent it from vibrating excessively and radiating sound. Such resilient mounts should not be used if the noise source under test is not resiliently mounted in typical usage.

Coupling conditions, e.g. between prime movers and driven machines, can exert considerable influence on the sound radiation of the noise source under test. It may be appropriate to use a flexible coupling, but similar considerations apply to these as to resilient mounts.

6.2 Auxiliary equipment

If practicable, all auxiliary equipment necessary for the operation of the noise source under test, but which is not an integral part of the source itself, including any electrical conduits, piping, air ducts, etc., connected to the source under test, shall be located outside the test environment. If this is impractical, care shall be taken to minimize any sound radiated into the test environment from such equipment. The noise source under test shall be taken to include all significant sources of sound emission, including auxiliary equipment which cannot either be removed or adequately quietened, and the reference box (see 7.2) shall be extended appropriately.

6.3 Operation of source during test

The sound power or sound energy emitted by a source can be affected by the load applied, the running speed, and the conditions under which it is operating. The source shall be tested, wherever possible, under conditions that are reproducible and representative of the noisiest operation in typical usage. The specifications given in a noise test code, if any exists, shall be followed, but in the absence of a noise test code one or more of the following modes of operation shall be selected for the test(s):

a) source under specified load and conditions;

b) source under full load [if different from a)];

c) source under no load (idling);

d) source at maximum operating speed under defined conditions;

e) source operating under conditions corresponding to maximum sound generation representative of normal use;

f) source with simulated loading, under defined conditions;

g) source undergoing a characteristic work cycle under defined conditions.

The source shall be stabilized in the desired operating condition, with any power source or transmission system running at a stable temperature, prior to the start of measurements for sound power level or sound energy level determination. The load, speed, and operating conditions shall either be held constant during the test, or varied through a defined cycle in a controlled manner.

If the sound power or sound energy emission depends on secondary operating parameters, e.g. the type of material being processed, the design of cutting tool, or the humidity, those parameters shall be selected, as far as is practicable, that give the smallest variations and that are typical of normal use. If simulated loading conditions are used, they shall be chosen such that the sound power levels or sound energy levels of the source under test are representative of normal use.

7 Measurement procedure

7.1 General

For determination of either the sound power level of a noise source emitting stationary noise or the sound energy level of a source which emits bursts of noise, two sets of measurements of sound pressure levels shall be made in the test environment, first with the noise source under test operating and then with the reference sound source operating; in some circumstances (see 7.3.1) the measurements with the reference sound source have to be repeated for different locations of the source. The specifications given in a noise test code, if any exists, shall be followed, but in the absence of a noise test code the procedures described hereafter shall be followed for the test(s).

7.2 Characterization of noise source under test

A preliminary aural examination of the noise emitted by the source under test shall be made to determine whether sound emitted from one component predominates. If so, the geometric centre of that component shall be assumed to be the acoustic centre of the source for the purpose of the test (see 7.3.2), and a reference box shall be delineated which just encloses that component and terminates on the floor on which the source under test is mounted. If no component appears to emit sound more than any other, any component which clearly emits no sound shall be excluded from consideration, the acoustic centre of the source shall be taken to be the geometric centre of the remainder, and the reference box shall be delineated accordingly.

Preliminary measurements shall be used to determine whether the sound emitted by the source is too directional for the method of this International Standard to be applied. The source directivity shall be evaluated by measuring sound pressure levels of the source (at intervals of 2 m or less along a given side for a large source) at a distance of 1 m from the reference box and a height normally of 1,5 m. If the source emits sound predominantly in an upward direction, the height at which the sound pressure levels are measured shall be sufficient to ensure that the microphone positions are in a direct line of sight to the acoustic centre of the source. If the A-weighted range of sound pressure levels so measured varies by no more than ±2 dB, the source shall be considered to be omnidirectional; if the variations exceed this amount, the source shall be considered to be directional. If the range of these directivity measurements exceeds ±7 dB, the engineering grade limits on source directivity are exceeded and the reported grade of accuracy shall not exceed that of ISO 12001:1996, accuracy grade 3 (survey grade) (see Clause 9).

7.3 Locations of the reference sound source

7.3.1 General

Normally, one location for the reference sound source is sufficient. For noise sources under test which are large or which have two or more clearly distinguishable sound sources far apart from one another, two or more locations may need to be used (see 7.3.3).

7.3.2 One location

If one location is sufficient, the reference sound source shall be positioned as close as possible to the acoustic centre of the noise source under test. For a directional source, the reference sound source should be located to simulate the emission pattern of the noise source under test or, if this is impractical, a position for the reference sound source on top of the source under test shall be chosen. If this is not possible, a location shall be selected alongside the source under test, at a height and position which best simulate the emission pattern of the source under test. In the latter case, positions closer than 0,5 m to the surface of the reference box should be avoided. For an omnidirectional source under test, care shall be taken to ensure that the reference sound source can emit sound equally in all directions.

NOTE 1 The more reverberant the test environment is, in other words, the larger ΔL_f is, the less critical is the selection of the location for the reference sound source. However, if a position is selected for the reference sound source for which it is not calibrated, the reproducibility of the sound power level or sound energy level determined is degraded, see Clause 9.

NOTE 2 Each reflecting surface within $\lambda/2$ (half a wavelength) of the reference sound source can increase its sound power, resulting in a possible underestimate of the noise source sound power level of up to 3 dB. Conversely, placing the reference sound source less than 0,5 m from the edge or edges of the reflecting floor plane can reduce its sound power output below 400 Hz, resulting in a possible overestimate of the noise source sound power level of up to 3 dB.

NOTE 3 Further guidance on selection of the location for the reference sound source is given in Annex B.

7.3.3 More than one location

The number of locations required for the reference sound source depends on the ratio a/d_m, where a is the largest dimension of the reference box and d_m is the measurement distance, see 7.4.1. The number of locations to be used is specified in a) to c).

a) If $a/d_\mathrm{m} > 1$ and if the source under test is omnidirectional, several locations shall be used for the reference sound source along the sides of the source under test, separated by a distance equal to d_m.

b) If $a/d_\mathrm{m} > 1$ and if the source under test has clearly definable sound emission areas, one location of the reference sound source shall be used for each emission area.

c) If $a/d_\mathrm{m} \leqslant 1$ and if the source under test is omnidirectional, but it is impossible to use a location on top of the source under test, four locations for the reference sound source shall be used, one adjacent to each vertical side of the reference box.

7.4 Microphone positions

7.4.1 General

The aim is to position the microphones around the sides of the noise source under test so that each position is situated similarly in relation to the sound-emitting areas of the source, i.e. for a particular microphone position, either there is a line of sight to each sound-emitting area or each area is screened. Positions to be avoided are those to which only a few parts of the source are emitting sound.

In total, three or four microphone positions are to be used (see 7.4.3), distributed as evenly as possible around the noise source under test. The same positions and microphone orientations are to be used for measurements made on the noise source under test, the reference sound source, and the background noise. The measurement distance, d_m, from the respective microphone positions to the nearest point of the reference box is to be selected so that, if possible, the microphone positions are in a part of the test environment where the sound field is reverberant, i.e. a region in which $\Delta L_f \geqslant 7$ dB (see Table 2).

No microphone position shall be closer than 0,5 m to any boundary surface of the test environment. If the environment is sufficiently spacious, and if the noise source under test is located away from all boundary surfaces, the microphones shall be positioned round all four vertical sides of the reference box. The microphone positions shall be spaced at least 2 m from each other. If the ceiling is high and sound absorbing, and frequencies greater than 2 000 Hz are important, if possible, at least two of the microphone positions shall be above the source.