INTERNATIONAL STANDARD

ISO 3746

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Acoustics — Determination of sound power levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit à partir de la pression acoustique — Méthode de contrôle employant une surface de mesure enveloppante au-dessus d'un plan réfléchissant

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Contents

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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.

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.

International Standard ISO 3746 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 3746:1979), which has been technically revised.

Annexes A, B and C form an integral part of this International Standard. Annexes D and E are for information only.

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 their 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 purposes of the noise test. General guidelines to assist in the selection are provided in ISO 3740. The ISO 3740 series gives only general principles regarding the operating and mounting conditions of the machine or equipment under test. Reference should be made to the 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 method for measuring the sound pressure levels on a measurement surface enveloping the source and for calculating the sound power level produced by the source. The enveloping surface method can be used for any of three grades of accuracy (see table 0.1), and is used in this International Standard for grade 3 accuracy.

The use of this International Standard requires certain qualification criteria to be fulfilled as described in table 0.1. If the relevant qualification criteria cannot be met, it might be possible to use ISO 3747 or ISO 9614.

Noise test codes for specific families of machines or equipment should be based without any contradiction on the requirements of one or more of the basic documents of the ISO 3740 or ISO 9614 series.

If measurements are made in typical machine rooms, where sources are normally installed, corrections may be required to account for background noise or undesired reflections.

The methods specified in this International Standard permit the determination of sound power level as an A-weighted value directly from the A-weighted sound pressure level measurements.

0.3 In this International Standard, the computation of sound power level from sound pressure level measurements is based on the premise that the sound power output of the source is directly proportional to the mean-square sound pressure averaged in time and space.

Table 0.1 — Overview of International Standards for determination of sound power levels of noise sources using enveloping surface methods over a reflecting plane and giving different grades of accuracy

Parameter	ISO 3745 Precision method Grade 1	ISO 3744 Engineering method Grade 2	ISO 3746 Survey method Grade 3
Test environment	Hemi-anechoic room	Outdoors or indoors	Outdoors or in-doors
Criterion for suitability of test environment 1)	$K_2 \leqslant$ 0,5 dB	$K_2 \leqslant$ 2 dB	$K_2 \leqslant$ 7 dB
Volume of sound source	Preferably less than 0,5 % of test room volume	No restriction: limited only by available test environment	No restriction: limited only by available test environment
Character of noise	Any (broad-band, narrow-band, discrete-frequency, steady, non-steady, impulsive)		
Limitation for background noise 1)	$\Delta L \geqslant$ 10 dB (if possible, exceeding 15 dB) $K_1 \leqslant$ 0,4 dB	$\Delta L \geqslant$ 6 dB (if possible, exceeding 15 dB) $K_1 \leqslant$ 1,3 dB	$\Delta L \geqslant$ 3 dB $K_1 \leqslant$ 3 dB
Number of measurement points	$\geqslant$ 10	$\geqslant$ 9 2)	$\geqslant$ 4 2)
Instrumentation: a) Sound level meter at least complying with b) Integrating sound level meter at least complying with c) Frequency band filter set at least complying with	a) type 1 as specified in IEC 651 b) type 1 as specified in IEC 804 c) class 1 as specified in IEC 1260	a) type 1 as specified in IEC 651 b) type 1 as specified in IEC 804 c) class 1 as specified in IEC 1260	a) type 2 as specified in IEC 651 b) type 2 as specified in IEC 804 —
Precision of method for determining L_{WA} expressed as standard deviation of reproducibility	$\sigma_R \leqslant$ 1 dB	$\sigma_R \leqslant$ 1,5 dB	$\sigma_R \leqslant$ 3 dB (if $K_2 <$ 5 dB) $\sigma_R \leqslant$ 4 dB (if 5 dB $\leqslant K_2 \leqslant$ 7 dB) If discrete tones are predominant, the value of σ_R is 1 dB greater

1) The values of K_1 and K_2 given shall be met in each frequency band within the frequency range of interest for determining the sound power spectrum. For determining A-weighted sound power levels, the same criteria apply to K_{1A} and K_{2A}.

2) Under given circumstances, it is permissible to use a reduced number of microphone positions.

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Acoustics — Determination of sound power levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane

1 Scope

1.1 General

This International Standard specifies a method for measuring the sound pressure levels on a measurement surface enveloping the source in order to calculate the sound power 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 of the source is calculated, leading to results which have a grade 3 accuracy.

It is important that specific noise test codes for various types of equipment be established and used in accordance with this International Standard. For each type of equipment, such noise test codes will give detailed requirements on mounting, loading and operating conditions for the equipment under test as well as a selection of the measurement surface and the microphone array as specified in this International Standard.

NOTE 1 The noise test code for a particular type of equipment should give detailed information on the particular surface that is selected, as the use of differently shaped measurement surfaces may yield differing estimates of the sound power level of a source.

1.2 Types of noise and noise sources

The method specified in this International Standard is suitable for measurements of all types of noise.

NOTE 2 A classification of different types of noise (steady, non-steady, quasi-steady, impulsive, etc.) is given in ISO 12001.

This International Standard is applicable to noise sources of any type and size (e.g. device, machine, component, sub-assembly).

NOTE 3 Measurements according to this International Standard may be impracticable for very tall or very long sources such as chimneys, ducts, conveyors and multi-source industrial plants.

1.3 Test environment

The test environment that is applicable for measurements made in accordance with this International Standard may be located indoors or outdoors, with one or more reflecting planes present, meeting specified requirements.

1.4 Measurement uncertainty

For sources which radiate steady broad-band noise, determinations made in accordance with this International Standard result, with few exceptions, in standard deviations of reproducibility of the A-weighted sound power level equal to or less than 3 dB (if K_{2A} determined in accordance with annex A is lower than 5 dB) or 4 dB (if K_{2A} is within the range of 5 dB to 7 dB). For discrete-tone sources, the standard deviation of reproducibility is normally 1 dB greater (see table 1).

A single value of the sound power level of a noise source determined in accordance with the procedures given in this International Standard is likely to differ from the true value by an amount within the range of the measurement uncertainty. The uncertainty in determinations of the sound power level arises from several factors which affect the results, some associated with environmental conditions at the test site and others with experimental techniques.

If a particular noise source were to be transported to each of a number of different test sites, and if, at each test site, 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, annex B). 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, are 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 measurement uncertainty depends on the standard deviation of reproducibility tabulated in table 1 and on the degree of confidence that is desired. As examples, for a normal distribution of sound power levels, there is a 90 % confidence that the expected value of the sound power level of a source lies within the range $\pm$ 1,656σ_R of the measured value and a 95 % confidence that it lies within the range $\pm$ 1,96σ_R of the measured value. For further examples, reference should be made to the ISO 7574 series and ISO 9296.

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

Application	Highest standard deviation of reproducibility, σ_R dB
For a source which emits noise with a relatively "flat" spectrum over the frequency range of interest	3
For a source which emits noise that contains predominant discrete tones	4

NOTES

4 If K_{2A} is greater than or equal to 5 dB, σ_R may be 1 dB greater than the values given in table 1.

5 A noise test code for a particular family of sound sources may have lower values of the standard deviation of reproducibility (see note 8).

6 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 test sites, changes in atmospheric conditions if outdoors, the geometry of the test room or outdoor environment, the acoustical properties of the reflecting plane, absorption at the test room boundaries if indoors, background noise, and the type and calibration of instrumentation. They are also due to variations in experimental techniques, including the size and shape of the measurement surface, number and location of microphone positions, sound source location, integration times, and determination of environmental corrections, if any. The standard deviations are also affected by errors associated with measurements taken in the near field of the source; such errors depend upon the nature of the sound source, but generally increase for smaller measurement distances and lower frequencies (below 250 Hz).

7 If measurements are made at several test sites, the results of sound power determinations on a given source may be in better agreement than would be implied by the standard deviations of table 1.

8 For a particular family of sound sources, a similar size with similar sound power spectra and similar operating conditions, 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 result of suitable interlaboratory tests.

9 The standard deviations of reproducibility, as tabulated in table 1, include the uncertainty associated with repeated measurements on the same noise under the same conditions (standard deviation of repeatability, see ISO 7574-1). This uncertainty is usually much smaller than the uncertainty associated with variability from one test site to another. 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.

10 The procedures of this International Standard and the standard deviations given in table 1 are applicable to measurements on an individual machine. Characterization of the sound power levels of batches of machines of the same family or type involves the use of random sampling techniques in which confidence intervals are specified, and the results are expressed in terms of statistical upper limits. In applying these techniques, the total standard deviation must be known or estimated, including the standard deviation of production, as defined in ISO 7574-1, which is a measure of the variation in sound power output between individual machines within the batch. Statistical methods for the

characterization of batches of machines are described in ISO 7574-4.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 354:1985, *Acoustics — Measurement of sound absorption in a reverberation room.*

ISO 3744:1994, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane.*

ISO 3745:1977, *Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms.*

ISO 3747:1987, *Acoustics — Determination of sound power levels of noise sources — Survey method using a reference sound source.*

ISO 4871:—[1)], *Acoustics — Declaration and verification of noise emission values of machinery and equipment.*

ISO 6926:1990, *Acoustics — Determination of sound power levels of noise sources — Requirements for the performance and calibration of reference sound sources.*

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.*

IEC 651:1979, *Sound level meters*, and Amendment 1:1993.

IEC 804:1985, *Integrating-averaging sound level meters*, and Amendment 1:1989 and Amendment 2:1993.

IEC 942:1988, *Sound calibrators.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 sound pressure, p**:** A fluctuating pressure superimposed on the static pressure by the presence of sound. It is expressed in pascals.

NOTE 11 The magnitude of the sound pressure can be expressed in several ways, such as instantaneous sound pressure, maximum sound pressure, or as the square root of the mean-square sound pressure over designated time and space (i.e. over the measurement surface).

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 to the square of the reference sound pressure. Sound pressure levels are expressed in decibels.

The frequency weighting or the width of the frequency band used and the time weighting (S, F, or I, see IEC 651) shall be indicated. The reference sound pressure is 20 µPa (2×10^{-5} Pa).

NOTE 12 For example, the A-weighted sound pressure level with time weighting S is L_{pAS}.

3.2.1 time-averaged sound pressure level, $L_{peq,T}$**:** Sound pressure level of a continuous steady sound that, within a measurement time interval T, has the same mean-square sound pressure as a sound under consideration which varies with time:

$$L_{peq,T} = 10 \lg \left[\frac{1}{T} \int_0^T 10^{0,1 L_p(t)} \, dt \right] \text{dB}$$

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

Time-averaged sound pressure levels are expressed in decibels and shall be measured with an instrument which complies with the requirements of IEC 804.

NOTES

13 Time-averaged sound pressure levels are usually A-weighted and denoted by $L_{pAeq,T}$ which is usually abbreviated to L_{pA}.

1) To be published. (Revision of ISO 4871:1984)

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

3.2.2 single-event sound pressure level, $L_{p,1s}$: Time-integrated sound pressure level of an isolated single sound event of specified duration T (or specified measurement time T) normalized to $T_0 = 1$ s. It is expressed in decibels and is given by the following formula:

$$L_{p,1s} = 10 \lg \left[\frac{1}{T_0} \int_0^T \frac{p^2(t)}{p_0^2} \, dt \right] \text{ dB}$$

$$= L_{peq,T} + 10 \lg \frac{T}{T_0} \text{ dB} \qquad \ldots (2)$$

3.2.3 measurement time interval: A portion or a multiple of an operational period or operational cycle for which the time-averaged sound pressure level is determined.

3.3 measurement surface: A hypothetical surface of area S, enveloping the source on which the measurement points are located. The measurement surface terminates on one or more reflecting planes.

3.4 surface sound pressure level, $\overline{L_{pf}}$: The 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 (3.13) and the environmental correction K_2 (3.14) applied. It is expressed in decibels.

3.5 sound power, W: The rate per unit time at which airborne sound energy is radiated by a source. It is expressed in watts.

3.6 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. It is expressed in decibels.

The frequency weighting or the width of the frequency band used shall be indicated. The reference sound power is 1 pW (10^{-12} W).

NOTE 15 For example, the A-weighted sound power level is L_{WA}.

3.7 frequency range of interest: For general purposes, the frequency range of interest includes the octave bands with centre frequencies from 25 Hz to 8 000 Hz.

3.8 reference box: A hypothetical surface which is the smallest rectangular parallelepiped that just encloses the source and terminates on the reflecting plane or planes.

3.9 characteristic source dimension, d_0: Half the length of the diagonal of the box consisting of the reference box and its images in adjoining reflecting planes.

3.10 measurement distance, d: The distance from the reference box to a box-shaped measurement surface.

3.11 measurement radius, r: The radius of a hemispherical measurement surface.

3.12 background noise: Noise from all sources other than the source under test.

NOTE 16 Background noise may include contributions from airborne sound, structure-borne vibration, and electrical noise in instrumentation.

3.13 background noise correction, K_1: A correction term to account for the influence of background noise on the surface sound pressure level; K_1 is frequency dependent and is expressed in decibels. The correction in the case of A-weighting is denoted K_{1A}.

3.14 environmental correction, K_2: A correction term to account for the influence of reflected or absorbed sound on the surface sound pressure level; K_2 is frequency dependent and is expressed in decibels. The correction in the case of A-weighting is denoted K_{2A}.

3.15 impulsive noise index (impulsiveness)**:** A quantity by means of which the noise emitted by a source can be characterized as "impulsive". (See annex D.) It is expressed in decibels.

4 Acoustic environment

4.1 General

Test environments that are suitable for measurements in accordance with this International Standard include a flat outdoor area or a room which meets the qualification requirements of 4.2 and which is adequately isolated from background noise in accordance with the requirements of 4.3.

4.2 Criterion for adequacy of the test environment

Annex A describes procedures for determining the magnitude of the environmental correction K_{2A}, to account for deviations of the test environment from the ideal condition. For this International Standard, the environmental correction K_{2A} (see table 0.1 and 8.3) shall be numerically less than or equal to 7 dB.

NOTE 17 If the environmental correction K_{2A} exceeds 7 dB, it is recommended that either a reference sound source method (ISO 3747) or the method of ISO 9614 be used.

4.3 Criterion for background noise

Averaged over the microphone positions, the A-weighted sound pressure level of the background noise shall be at least 3 dB below the sound pressure level to be measured (see table 0.1 and 8.2).

5 Instrumentation

5.1 General

The instrumentation system, including the microphones and cables, shall meet the requirements for a type 2 instrument specified in IEC 651 or, in the case of integrating-averaging sound level meters, the requirements for a type 2 instrument specified in IEC 804.

5.2 Calibration

During each series of measurements, a sound calibrator with an accuracy of ± 0,3 dB (class 1 as specified in IEC 942) 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 compliance of the calibrator shall be verified with the requirements of IEC 942 once a year and the compliance of the instrumentation system with the requirements of IEC 651 (and IEC 804 in the case of integrating systems) at least every 2 years in a laboratory making calibrations traceable to appropriate measurement standards.

The date of the last verification of the compliance with the relevant IEC standards shall be recorded.

5.3 Microphone windscreen

If measurements are to be made outdoors, a windscreen is recommended. Ensure that the windscreen does not affect the accuracy of the instrumentation.

6 Installation and operation of source under test

6.1 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 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.

Particularly for large sources, it is important that a noise test code specify which components, sub-assemblies, auxiliary equipment, power sources, etc. are to be included in the reference box.

6.2 Source location

The source to be tested shall be installed with respect to the reflecting plane or planes in one or more locations as if it were being installed for normal usage. If several possibilities exist, or if typical installation conditions are unknown, special arrangements shall be made and described in the test report. If the location of the source within the test environment can be selected, sufficient space shall be allowed so that the measurement surface can develop the source under test in accordance with the requirements of 7.1.

6.3 Source mounting

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 feasible.

If a typical condition of mounting does not exist or cannot be utilized for the test, 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 equipment may be mounted.

NOTES

18 Many small sound sources, although themselves poor radiators of low-frequency sound, may, 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, if practicable, resilient mountings should be interposed be-

tween the device to be measured and the supporting surfaces 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 have a sufficiently high mechanical impedance to prevent it from vibrating and radiating sound excessively. Such resilient mounts should not be used if the device under test is not resiliently mounted in typical field installations.

19 Coupling conditions, e.g. between prime movers and driven machines, may exert considerable influence on the sound radiation of the source under test.

6.3.1 Hand-held machinery and equipment

Such machinery and equipment shall be suspended or guided by hand, so that no structure-borne sound is transmitted via any attachment that does not belong to the machine under test. 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.

6.3.2 Base-mounted and wall-mounted machinery and equipment

Such machinery and equipment shall be placed on a reflecting (acoustically hard) plane (floor, wall). Base-mounted machines intended exclusively for mounting in front of a wall shall be installed on an acoustically hard floor surface in front of an acoustically hard wall. Table-top equipment shall be placed on the floor at least 1,5 m from any wall of the room, unless a table or stand is required for operation in accordance with the test code for the equipment under test. Such equipment shall be placed in the centre of the top of the test table.

6.4 Auxiliary equipment

Care shall be taken to ensure that any typical electrical conduits, piping or air ducts connected to the source under test do not radiate significant amounts of sound energy into the test environment.

If practicable, all auxiliary equipment necessary for the operation of the source under test and which is not a part of the source (see 6.1) shall be located outside the test environment.

If impracticable, the auxiliary equipment shall be included in the reference box and its operating conditions described in the test report.

6.5 Operation of source during test

During the measurements, the operating conditions specified in the relevant test code, if one exists for the particular type of machinery or 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:

— device under specified load and operating conditions;

— device under full load (if different from above);

— device under no load (idling);

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

— device with simulated load operating under carefully defined conditions;

— device under operating conditions with characteristic work cycle.

The sound power level of the source may be determined for any desired set of operating conditions (i.e. loading, device speed, temperature, etc.). These test conditions shall be selected beforehand and shall be held constant during the 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 rise 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 machines of the same family is highly reproducible and that the operating conditions which are most common and typical for the family of machines 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.