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Acoustics — Determination of sound power levels of noise sources — Survey method using a reference sound source

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Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit — Méthode de contrôle faisant appel à une source sonore de référence

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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International Standard ISO 3747 was prepared by Technical Committee ISO/TC 43, *Acoustics*.

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Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Acoustics — Determination of sound power levels of noise sources — Survey method using a reference sound source

0.1 Related International Standards

This International Standard is one of a series specifying various methods for determining the sound power levels of machines and equipment. These basic documents specify only the acoustical requirements for measurements appropriate for different test environments as shown in table 1.

When applying these basic documents, it is necessary to decide which one is most appropriate for the conditions and purposes of the test. The operating and mounting conditions of the machine or equipment to be tested are given as general principles stated in each of the basic documents. Guidelines for making these decisions are provided in ISO 3740. If no noise test code is specified for a particular machine, the mounting and operating conditions shall be fully described in the test report.

The method described in this International Standard supplements the method described in ISO 3746.

0.2 Synopsis of ISO 3747

0.2.1 Applicability

0.2.1.1 Test environment

Installation (indoors or outdoors) with no restrictions.

0.2.1.2 Type of source

Device, machine, component or sub-assembly not movable from its installed location for the purposes of acoustical measurements.

0.2.1.3 Dimensions of the source

No restrictions.

0.2.1.4 Character of noise radiated by the source

Steady, broad-band, discrete-frequency or narrow-band.

0.2.2 Accuracy

Survey (standard deviation for determining A-weighted sound power levels is less than 5 dB for discrete tone sources and less than 4 dB for sources which radiate steady, broad-band noise).

0.2.3 Quantities to be measured

Sound pressure levels with A-weighting and, if required, in octave bands at specified microphone positions for the noise source under test and for a reference sound source which is installed on top of or beside the source under test.

0.2.4 Quantities to be determined

Weighted sound power level (A-weighting is required; other weightings are optional).

0.3 Introduction

In the set of basic documents ISO 3741 to ISO 3746, various methods are described for determining the sound power levels of machines and equipment. These methods, which are of various accuracies, permit the evaluation of the effects produced by the test environment on the sound pressure levels at a given distance from the source. These methods also permit the reduction of the data to free-field conditions by means of environmental corrections which have to be determined.

It is, however, not always a simple matter to determine the magnitude of the environmental corrections. On the other hand, a reference sound source with known acoustical characteristics, stable in time and available for immediate use, can offer many advantages, particularly for taking account of environmental factors.

This International Standard describes the procedures to be used for determining the sound power levels of machines and equipment which cannot be moved from their installed locations for acoustical testing purposes. A reference sound source is used which fulfils the requirements of ISO 6926; the reference sound source is located in the immediate vicinity of the source under test.

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Table 1 — International Standards specifying various methods for determining the sound power levels of machines and equipment

International Standard No.*	Classification of method**	Test environment	Volume of source	Character of noise	Sound power levels obtainable	Optional information available
3741	Precision (grade 1)	Reverberation room meeting specified requirements	Preferably less than 1 % of test room volume	Steady, broad-band	In one-third octave or octave bands	A-weighted sound power level
3742				Steady, discrete-frequency or narrow-band		
3743	Engineering (grade 2)	Special reverberation test room		Steady, broad-band, narrow-band, or discrete-frequency	A-weighted and in octave bands	Other weighted sound power levels
3744	Engineering (grade 2)	Outdoors or in large room	Greatest dimension less than 15 m	Any	A-weighted and in one-third octave or octave bands	Directivity information and sound pressure levels as a function of time; other weighted sound power levels
3745	Precision (grade 1)	Anechoic or semi-anechoic room	Preferably less than 0,5 % of test room volume	Any		
3746	Survey (grade 3)	No special test environment	No restrictions: limited only by available test environment	Any	A-weighted	Sound pressure levels as a function of time; other weighted sound power levels
3747	Survey (grade 3)	No special test environment; source under test not movable	No restrictions	Steady, broad-band narrow-band, or discrete-frequency	A-weighted	Sound power levels in octave bands
3748	Engineering (grade 2)	Essentially free-field over a reflecting plane (indoors or outdoors)	Less than 1 m^3	Any	A-weighted and in one-third octave or octave bands	Sound pressure levels as a function of time; other weighted sound power levels

* See clause 2.

** See ISO 2204.

This International Standard complements the methods given in ISO 3741, ISO 3742, ISO 3743, ISO 3744, ISO 3745, ISO 3746 and ISO 3748 by giving specific requirements for the use of a reference sound source in test sites which may include several reflecting planes in the vicinity of the source under test. In contrast with the comparison methods described in ISO 3741, ISO 3742 and ISO 3743, the method described in this International Standard does not require a special test environment.

The sound power level of the source is calculated from the measured values of the sound pressure levels at specified microphone positions for the noise source under test and for a reference sound source which is operated in a position beside or on top of the source under test. This method requires that the background noise level be lower than the sound level produced by the source under test and by the reference sound source.

1 Scope and field of application

1.1 General

This International Standard specifies a survey method for measuring the sound pressure levels produced at specified measurement points by the noise source under test and by a reference sound source.

The sound power level of the source under test is calculated from the measured values of the sound pressure level by using environmental corrections. These environmental corrections are calculated from the differences between the values obtained with a reference sound source and those given by its calibration.

Different microphone arrays and different positions for the reference sound source are given for different acoustical situations, depending on the size of the source under test as well as the size, number and orientation of the reflecting planes which are situated in proximity to the source under test.

The positions of the reference sound source also depend on whether it is possible to place the reference sound source on the uppermost outer surface of the source under test.

1.2 Field of application

1.2.1 Types of noise

This International Standard applies to sources which radiate broad-band noise, narrow-band noise, discrete tones and combinations thereof. The procedures specified in this International Standard are primarily applicable to sources that radiate steady noise as defined in ISO 2204. These procedures are not applicable to isolated bursts of sound energy or burst trains with repetition rates less than 5 per second.

1.2.2 Size of source

The method specified in this International Standard applies to noise sources irrespective of size. It applies particularly to machines and equipment which cannot be moved from their installed location for the purposes of measuring noise.

1.3 Measurement uncertainty

Measurements made in conformity with this International Standard tend to result in standard deviations which are equal to or less than those given in table 2.

Table 2 — Uncertainty in determining A-weighted sound power level by the survey method

Application	Standard Deviation dB
For a source which produces sounds that contain prominent discrete tones	5
For a source which produces sounds that are uniformly distributed in frequency over the frequency range of interest	4

NOTES

1 If the method specified in this International Standard is used to compare the sound power levels of similar machines that are omnidirectional and radiate broad-band noise, the uncertainty in this comparison tends to result in a standard deviation which is equal to or less than 3 dB, provided that the measurements are performed in similar environments.

2 The standard deviations given in this table reflect the cumulative effects of all causes of measurement uncertainty, excluding variations in the sound power level from machine to machine or from test to test which may be caused, for example, by changes in the mounting or operating conditions of the source. The reproducibility and repeatability of the test results may be considerably better (i.e. smaller standard deviations) than the uncertainties given in table 2 would indicate.

3 The standard deviations given above are considered, in the light of the experimental evidence available, to be conservative.

2 References

ISO 266, *Acoustics — Preferred frequencies for measurements.*

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

ISO 2204, *Acoustics — Guide to International Standards on the measurement of airborne acoustical noise and evaluation of its effects on human beings.*

ISO 3740, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards and for the preparation of noise test codes.*

ISO 3741, *Acoustics — Determination of sound power levels of noise sources — Precision methods for broad-band sources in reverberation rooms.*

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ISO 3742, *Acoustics — Determination of sound power levels of noise sources — Precision methods for discrete-frequency and narrow-band sources in reverberation rooms.*

ISO 3743, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for special reverberation test rooms.*

ISO 3744, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane.*

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

ISO 3746, *Acoustics — Determination of sound power levels of noise sources — Survey method.*

ISO 3748, *Acoustics — Determination of sound power levels of noise sources — Engineering method for small nearly omnidirectional sources under free-field conditions over a reflecting plane.* [1)]

ISO 6926, *Acoustics — Determination of sound power levels of noise sources — Characterization and calibration of reference sound sources.* [1)]

IEC Publication 50(08), *International Electrotechnical Vocabulary — Electro-acoustics.*

IEC Publication 225, *Octave, half-octave and third-octave band filters intended for the analysis of sound and vibrations.*

IEC Publication 651, *Sound level meters.*

IEC Publication 804, *Integrating-averaging sound level meters.*

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3 Definitions

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

3.1 reference sound source: A stable source emitting steady broad-band noise with an adequate sound power level, calibrated for free-field conditions over a reflecting plane in accordance with the requirements of ISO 6926.

3.2 substitution procedure: A method applied when the source under test can be moved from its installed location and the reference sound source takes the place of the source under test.

3.3 superposition procedure: A method applied when the source under test cannot be moved from its installed location and the reference sound source is placed on top of the source under test.

3.4 juxtaposition procedure: A method applied when the substitution or the superposition procedure cannot be applied and where the reference sound source is placed close to the sides of the source under test.

3.5 sound pressure level, L_p, in decibels: 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. The weighting network used is indicated: for example, A-weighted sound pressure level, L_{pA}. The reference sound pressure is 20 µPa.

3.6 sound power level, L_W, in decibels: Ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power. The weighting network used is indicated: for example, A-weighted sound power level, L_{WA}. The reference sound power is 1 pW ($= 10^{-12}$ W).

3.7 measurement surface: A hypothetical surface of area S enveloping the source on which the microphone positions are located.

3.8 reference surface: A hypothetical surface which is the smallest rectangular parallelepiped (i.e. rectangular box) that just encloses the source and terminates on the reflecting plane(s).

3.9 measurement distance, d: The distance between the reference surface and the measurement surface.

3.10 background noise: The A-weighted sound pressure level at each microphone position with the source under test inoperative.

3.11 frequency range of interest: Unless otherwise stated, the range of frequencies comprising the octave bands with centre frequencies between 125 and 8 000 Hz.

4 Acoustic environment

4.1 Test site

This International Standard applies to all types of test site and places no restrictions on acoustical and geometrical properties. For example: ordinary rooms with more or less reflecting surfaces or reflecting objects near the source, large industrial workshops irregularly filled with solid objects, outdoor spaces with reflecting walls in the vicinity of the machine under test.

4.2 Criterion for background noise

The A-weighted sound pressure level due to steady background noise, averaged over the measurement surface, shall be at least 3 dB below the A-weighted sound pressure level, averaged over the measurement surface and observed with either the source under test or the reference sound source in operation. Refer to 7.5 for corrections to be applied. If octave band levels are measured, this requirement shall be met for sound pressure levels in each octave band.

1) At present at the stage of draft.

NOTE — Levels of background noise less than 3 dB below the sound pressure level of the source under test are too high for the purposes of this International Standard. Under such circumstances, it is not possible to determine the A-weighted sound power level of the source within the accuracy limits specified in 1.3. However, the result determined with higher levels of background noise may be useful as an indication of the upper limit of the sound power level of the source.

4.3 Wind

Measurements may be made outdoors when the wind speed is less than 5 m/s. Wind effects which may increase the level of background noise shall be minimized. The instructions of the microphone manufacturer shall be complied with.

5 Instrumentation

5.1 General

A sound level meter that meets the requirements for a type 1 or type 2 instrument as laid down in IEC Publication 651 shall be used with the time-weighting characteristic S. If integrating-averaging sound level meters are used, they shall meet the requirements for a type 1 or type 2 instrument as laid down in IEC Publication 804.

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NOTES

1 The time-weighting characteristic F may be used to check that interfering events are not influencing the measurements.

2 To check the impulsive character of a noise, the time-weighting characteristic I may be used, and the difference between the time-averaged sound pressure levels measured using the time-weighting characteristics I and S may be stated in the test report.

3 If a level recorder, integrating sound level meter or tape recorder is used, care should be taken to ensure that the averaging procedure is appropriate for determining the level of the mean-square pressure, especially if the noise is fluctuating in character (i.e. range of readings of the sound level meter on the time-weighting characteristic S exceeds 5 dB).

To minimize the influence of the observer on the measurements, a cable should preferably be used between the microphone and the sound level meter. The observer shall not stand between the microphone and the source the sound power level of which is being determined.

5.2 Calibration

At least before each series of measurements, a sound calibrator with an accuracy of ±0,5 dB shall be applied to the microphone to check the calibration of the entire measuring system, including cable if used, at one or more frequencies. One calibration frequency shall be in the range from 250 to 1 000 Hz. The calibrator shall be calibrated annually to verify that its output has not changed.

5.3 Reference sound source

The reference sound source (RSS) to be used shall satisfy the requirements of ISO 6926.

6 Installation and operation of sources

6.1 Source under test

The source to be tested shall be clearly defined: all components excluded from the definition (for example, auxiliary equipment) shall be treated as background noise sources (see 4.2).

During the acoustical measurements, the source shall be operated in a specified manner typical of normal use. The operating conditions specified in the test code, if any, for the particular type of machinery or equipment shall be used. Otherwise, the following operational conditions may be appropriate:

a) device under specified load and operating conditions;

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

c) device under no load (idling);

d) device under the operating condition corresponding to maximum sound generation representative of normal use;

e) device with simulated load operating under carefully defined conditions.

6.2 Reference sound source

The methods described in this International Standard involve substitution, superposition or juxtaposition. The reference sound source shall be substituted for the source under test or shall be placed at one or more locations either on top of the source under test or adjacent to it.

The mode of installation and the number of positions of the reference sound source depend on the size of the source under test and the possibilities of installing the reference sound source either on top of the source or adjacent to it. Various possibilities are described in 7.3 and in figures 11, 12, 13, 14 and 15.

NOTE — The sound power level of some reference sound sources, especially non-aerodynamic sources, may be affected when the source is used in the presence of reflecting surfaces other than the surface present when the source was calibrated. However, corrections in the power output of the reference sound sources to account for these effects are not required by the survey method.

7 Sound pressure levels on measurement surface

7.1 Reference and measurement surfaces

To facilitate the location of the microphone positions, a hypothetical reference surface is defined according to 3.8. This reference surface is the smallest possible rectangular parallelepiped, i.e. rectangular box, that just encloses the source and the reference sound source(s), and terminates on one or more reflecting plane(s). When defining the dimensions of this reference surface, elements protruding from the source which are not significant radiators of sound energy may be disregarded. These protruding elements should be identified in

specific test codes for different types of equipment. The microphone positions lie on the measurement surface, a hypothetical surface of area S enveloping portions of the source and the reference surface and terminating on one or more reflecting plane(s). Such planes are characterized as having acoustical absorption coefficient(s), α, less than 0,2, e.g. walls of stone or concrete. The measurement surface extends along absorptive planes, ($\alpha > 0,2$), if any.

Typical arrangements of the reference and measurement surfaces are given in figures 1 to 10.

The measurement surface is usually shaped as a rectangular parallelepiped (or portion of same) with sides parallel to those of the reference surface spaced at a distance d which is usually equal to 1 m, but is not less than 1 m.

7.2 Microphone positions

7.2.1 General

The microphone positions lie on the measurement surface as described in 7.1.

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7.2.2 Number of microphone positions

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7.2.2.1 More than one reflecting plane

The rules given in 7.2.2.1.1 to 7.2.2.1.5 will be adopted depending upon the number of the faces of the measurement surface (parallelepiped) on which microphone positions may be located.

7.2.2.1.1 Four faces (two reflecting planes)

One microphone position at the centre of each free face and one in each of the free corners (see figure 6).

7.2.2.1.2 Three faces (three reflecting planes)

One microphone position at the centre of each free face and one in the free corner (see figure 7).

7.2.2.1.3 Two faces (four reflecting planes)

One microphone position at the centre of each free face and one at the centre of the line intersecting the two free faces (see figure 8).

7.2.2.1.4 One face (five reflecting planes)

Three microphone positions regularly spaced on the free face (see figure 9).

7.2.2.1.5 No faces (six reflecting planes)

Three microphone positions regularly spaced in the aperture of the test room used as the measurement surface (see also figure 9).

7.2.2.2 Five faces (one reflecting plane)

The minimum number of microphone positions is five; i.e. the five key measurement positions shown in figure 10.

For sources with one horizontal dimension which exceeds 1,0 m, four additional microphone positions at the top corners of the measurement surface as shown in figure 10 shall be used.

For sources with one horizontal dimension which exceeds 5 m, microphone positions in addition to those specified above shall be used in a uniform distribution. The distance between adjacent points should be no more than 2 d, where d is the measurement distance.

7.3 Position(s) of the reference sound source (RSS)

7.3.1 General

The positions of the reference sound source are

— on the upper surface of the machine under test when the height of the reference parallelepiped does not exceed 1,5 d (see 7.3.2), or

— against the sides of the machines under test if the height of the reference parallelipiped is greater than 1,5 d, or if it is not possible (e.g. for safety or other emergency reasons) to place the RSS directly on the machine under test (see 7.3.3), or

— in the space previously occupied by the machine after the machine under test has been removed.

7.3.2 Superposition procedure

This position is always preferred when the height l_3 of the reference box does not exceed 1,5 d.

7.3.2.1 If neither of the dimensions l_1 or l_2 of the reference box exceeds 2 d, the reference sound source shall be located in only one position on the upper surface of the reference box (see figure 11).

7.3.2.2 If the width l_2 of the reference box does not exceed 2 d, but the length l_1 is greater than 2 d, the number of RSS positions ($j = 1, \ldots, m$) is at least two. These RSS positions are uniformly distributed along the longitudinal symmetry axis parallel to the l_1 dimension on the upper surface of the reference box in such a way that they are no more than 3 d apart (see figure 13 for an example in which $3\,d < l_1 \leqslant 6\,d$).

7.3.2.3 If both the width l_2 and length l_1 of the reference box exceed 2 d, the number of RSS positions (j = 1, ..., m) is at least four. These RSS positions are located on two lines along the l_1 dimension on the upper surface of the reference box in such a way that they are no more that 3 d apart from each other (see figure 14 for an example in which $3\,d < l_1 \leqslant 6\,d$ and $2\,d < l_1 \leqslant 3\,d$).

NOTE — For three, four and five reflecting planes (see figures 3, 4 and 5), the number of RSS positions will be limited to three (see figure 13).

7.3.3 Juxtaposition procedure

This is the preferred arrangement when the height l_3 of the reference box exceeds 1,5 d.

The positions described in 7.3.3.1 to 7.3.3.4 apply only when it is not possible (for example, for safety reasons or because of interferences) to place the RSS directly on top of the machine under test.

7.3.3.1 The height of the RSS above ground, H, shall be

$$H = 0{,}5\,(l_3 + d)$$

(see upper part of figure 12)

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7.3.3.2 The minimum number of RSS positions is four; the RSS shall be placed at the middle of each lateral face of the reference box.

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7.3.3.3 If the length l_1 or the width l_2 exceeds 3 d, the number of RSS positions (j = 1, ..., m) is at least two per face. These RSS positions are located on the sides that exceed 3 d and are distributed regularly (for example, $l/4$, 3 $l/4$, etc.) on a line at the height, H, indicated in 7.3.3.1.

7.3.3.4 The number of RSS positions is limited to one on those side(s) of the machine under test where no location is available for the microphone.

7.3.4 Substitution procedure

If the source under test can be moved and its largest dimension is less than 2 m, it is recommended to use the substitution procedure where the reference sound source takes the place of the source under test after its removal. The reference sound source shall then be placed on the floor at the projection of the centre of the reference box.

7.4 Measurement procedure

The sound pressure levels (A-weighted or in octave bands over the frequency range of interest) shall be measured at each microphone position i = 1, . . ., n with the machine under test in operation and with the RSS operating at each assigned position (with the machine under test not operating).

If the shapes of the spectra of the reference sound source and the source under test are similar, a direct determination of the A-weighted sound power level of the source under test may be made.

If the shape of the spectra are different, the A-weighted sound power level shall be calculated from octave band data.

The shapes of two spectra are considered to be similar if, after adjustment of the spectra to have the same level in the 1 000 Hz octave band, the levels in any octave band over the frequency range of interest do not differ by more than 5 dB.

In most cases it will be necessary to calculate the A-weighted sound power level from octave band data.

If the range of measured levels (in decibels) exceeds 1,5 times the number of microphone positions, the uncertainty in determining the sound power level may be greater than the values given in table 2.

The following data shall be obtained in octave bands or as A-weighted levels:

a) sound pressure levels for each microphone position i = 1, ..., n during the specified operation (see clause 7) of the source under test: $L_{pi\,(ST)}$;

b) sound pressure levels for each microphone position i = 1, ..., n for the background noise: $L_{pi\,(B)}$;

c) sound pressure levels produced by the RSS at each of its locations and for each microphone position i = 1, ..., n: $L_{pi\,(RSS)}$.

7.5 Corrections for background noise

All measured sound pressure levels shall be corrected for background noise according to table 3. These corrections apply to both A-weighted and octave band sound pressure levels.

Table 3 — Corrections for background sound pressure levels

Difference between sound pressure level measured with noise source operating and background sound pressure level alone	Correction to be subtracted from sound pressure level measured with noise source operating to obtain sound pressure level due to noise source alone
dB	dB
3	3
4	2
5	2
6	1
7	1
8	1
9	0,5
10	0,5
> 10	0