INTERNATIONAL STANDARD

ISO 3744

Second edition
1994-05-01

Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit à partir de la pression acoustique — Méthode d'expertise dans des conditions approchant celles du champ libre sur plan réfléchissant

Reference number
ISO 3744:1994(E)

Contents

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

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 3744 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Sub-Committee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 3744:1981), which has been technically revised.

Annexes A, B and C form an integral part of this International Standard. Annexes D, E and F 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 noise test code for a specific type of machine or equipment, if available, for specifications on mounting and operating conditions.

0.2 This International Standard specifies a 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 2 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, other basic standards with different environmental requirements are suggested (table 0.1; see also ISO 3740 and 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 ISO 3740 series or ISO 9614.

Free-field conditions are usually not encountered in typical machine rooms where sources are normally installed. If measurements are made in such installations, 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 both as an A-weighted value and in frequency bands.

The A-weighted value calculated from frequency band data may differ from that determined from measured A-weighted sound pressure levels.

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 over 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 indoors
Criterion for suitability of test environment1)	$K_2 \leqslant 0{,}5$ 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 noise1)	$\Delta L \geqslant 10$ 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: — Sound level meter at least complying with — Integrating sound level meter at least complying with — 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 225	a) type 1 as specified in IEC 651 b) type 1 as specified in IEC 804 c) class 1 as specified in IEC 225	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 (see 7.2 to 7.4), 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 — Engineering method in an essentially free field 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 a noise source, under essentially free-field conditions near one or more reflecting planes, 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 2 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 2204.

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 is an essentially free field near one or more reflecting planes (indoors or outdoors).

1.4 Measurement uncertainty

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 1,5 dB (see table 1).

A single value of the sound power level of a noise source determined according to 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 in the measurement laboratory and others with experimental techniques.

If a particular noise source were to be transported to each of a number of different laboratories, and if, at each laboratory, the sound power level of that source were to be determined in accordance with this International Standard, the results would show a scatter. The standard deviation of the measured levels could be calculated (see examples in ISO 7574-4:1985, annex B) and would vary with frequency. With few exceptions, these standard deviations would not exceed those listed in table 1. The values given in table 1 are standard deviations of reproducibility, σ_R, as defined in ISO 7574-1. The values of table 1 take into account the cumulative effects of measurement uncertainty in applying the procedures of this International Standard, but exclude variations in the sound power output caused by changes in operating conditions (e.g. rotational speed, line voltage) or mounting conditions.

The 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 90 % confidence that the true value of the sound power level of a source lies within the range $\pm$ 1,645 σ_R of the measured value and a 95 % confidence that it lies within the range $\pm$ 1,96 σ_R of the measured value. For further examples, reference should be made to the ISO 7574 series and ISO 9296.

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

Octave-band centre frequencies	One-third-octave band centre frequencies	Standard deviation of reproducibility σ_R
Hz	Hz	dB
63	50 to 80	5 1)
125	100 to 160	3
250	200 to 315	2
500 to 4 000	400 to 5 000	1,5
8 000	6 300 to 10 000	2,5
A-weighted		1,5 2)

1) Normally for outdoor measurements; many rooms are not qualified for this frequency band.

2) Applicable to a source which emits noise with a relatively "flat" spectrum in the frequency range 100 Hz to 10 000 Hz.

NOTES

4 The standard deviations listed in table 1 are associated with the test conditions and procedures defined in this International Standard and not with the noise source itself. They arise in part from variations between measurement laboratories, 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).

5 If several laboratories use similar facilities and instrumentation, the results of sound power determinations on a given source in those laboratories may be in better agreement than would be implied by the standard deviations of table 1.

6 For a particular family of sound sources, of 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 results of suitable interlaboratory tests.

7 The standard deviations of reproducibility, as tabulated in table 1, include the uncertainty associated with repeated measurements on the same noise source under the same conditions (for standard deviation of repeatability, see ISO 7574-1). This uncertainty is usually much smaller than the uncertainty associated with interlaboratory variability. However, if it is difficult to maintain stable operating or mounting conditions for a particular source, the standard deviation of repeatability may not be small compared with the values given in table 1. In such cases, the fact that it was difficult to obtain repeatable sound power level data on the source should be recorded and stated in the test report.

8 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 2204:1979, *Acoustics — Guide to International Standards on the measurement of airborne acoustical noise and evaluation of its effects on human beings.*

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 4871:1984, *Acoustics — Noise labelling 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 225:1966, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

IEC 651:1979, *Sound level meters.*

IEC 804:1985, *Integrating-averaging sound level meters.*

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 9 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 10 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

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

12 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:

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

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

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 (3.15) and the environmental correction K_2 (3.16) 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 13 For example, the A-weighted sound power level is L_{WA}.

3.7 free field: A sound field in a homogeneous, isotropic medium free of boundaries. In practice, it is a field in which reflections at the boundaries are negligible over the frequency range of interest.

3.8 free field over a reflecting plane: A sound field in a homogeneous, isotropic medium in the half-space above an infinite, rigid plane surface on which the source is located.

3.9 frequency range of interest: For general purposes, the frequency range of interest includes the octave bands with centre frequencies from 125 Hz to 8 000 Hz.

NOTE 14 For special purposes, it is permissible to extend or reduce the frequency range of interest at either end, provided the test environment and instrument accuracy are satisfactory for use over the extended or reduced frequency range. For sources which radiate predominantly high (or low) frequency sound, it is permissible to extend or reduce the frequency range of interest, in order to optimize the test facility and procedures.

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

3.11 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.

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

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

3.14 background noise: The noise from all sources other than the source under test.

NOTE 15 Background noise may include contributions from airborne sound, structure-borne vibration, and electrical noise in instrumentation.

3.15 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}.

3.16 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}.

3.17 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.

3.18 directivity index, DI: A measure of the extent to which a source radiates sound predominantly in one direction. (See annex E.) It is expressed in decibels.

4 Acoustic environment

4.1 General

The test environments that are applicable for measurements according to this International Standard are:

a) a laboratory room which provides a free field over a reflecting plane;

b) a flat outdoor area that meets the requirements of 4.2 and annex A;

c) a room in which the contributions of the reverberant field to the sound pressures on the measurement surface are small compared with those of the direct field of the source.

NOTE 16 Conditions described under c) above are usually met in very large rooms as well as in smaller rooms with sufficient sound-absorptive materials on their walls and ceilings.

4.2 Criterion for adequacy of the test environment

As far as is practicable, the test environment shall be free from reflecting objects other than a reflecting plane so that the source radiates into a free field over a reflecting plane.

Annex A describes procedures for determining the magnitude of the environmental correction K_2, 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 8.4) shall be numerically less than or equal to 2 dB. For spectral quantities determined according to this International Standard, K_2 for each frequency band of interest shall not exceed 2 dB.

NOTE 17 If it is necessary to make measurements in spaces in which K_{2A} exceeds 2 dB, see table 0.1 and 8.4 or ISO 3746 or ISO 9614.

4.3 Criterion for background noise

Averaged over the microphone positions, the level of background noise shall be at least 6 dB and preferably more than 15 dB below the sound pressure level to be measured (see table 0.1 and 8.3).

NOTE 18 If the difference between the sound pressure levels of the background noise and the source noise is less than 6 dB, see table 0.1 and 8.3 or ISO 3746. The effects of wind which may increase the background noise should be minimized.

5 Instrumentation

5.1 General

The instrumentation system, including the microphones and cables, shall meet the requirements for a type 1 instrument specified in IEC 651 or, in the case of integrating-averaging sound level meters, the requirements for a type 1 instrument specified in IEC 804. The filters used shall meet the requirements of IEC 225.

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 standards.

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

5.3 Microphone windbreak

If measurements are to be made outdoors, a windbreak is recommended. Ensure that the windbreak 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 the installation and operating conditions of the source under test. The instructions of a noise test code, if any exists, shall be followed in so far as installation and operation of the source under test is concerned.

Particularly for large sources, it is important that a noise test code specify which components, subassemblies, 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. In locating the source within the test environment, it is important to allow sufficient space so that the measurement surface can envelop the source under test in accordance with the requirements of 7.1.

The source under test shall be located at a sufficient distance from any reflecting wall or ceiling or any reflecting object so that the requirements given in annex A are satisfied on the measurement surface.

The typical installation conditions for some sources involve two or more reflecting surfaces (see figures C.7 and C.8; for example, an appliance installed against a wall) or free space (e.g. a hoist) or an opening in an otherwise reflecting plane (so that radiation may occur on both sides of the vertical plane). Detailed information on installation conditions and the configuration of the microphone array should be based on the general requirements of this International Standard and specific noise test codes for such sources.

The source shall only be installed near two or more reflecting surfaces when this is truly representative of normal use.

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

19 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 mounting should be interposed between 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.

20 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 according to the test code for the equipment under test. Such equipment shall be placed in the centre of the top of the test table.

6.4 Auxiliary equipment

Care shall be taken to ensure that any 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.

The operating conditions of the source during the acoustical measurements shall be fully described in the test report.

7 Measurement of sound pressure levels

7.1 Selection of the measurement surface

To facilitate the location of the microphone positions on the measurement surface, a hypothetical reference box shall be defined. When defining the dimensions of this reference box, elements protruding from the source which are not significant radiators of sound energy may be disregarded. These protruding elements should be identified in specific noise test codes for different types of equipment. The microphone positions lie on the measurement surface, a hypothetical surface of area S which envelops the source as well as the reference box and terminates on the reflecting plane(s).

The location of the source under test, the measurement surface and the microphone positions are defined by a coordinate system with the horizontal axes x and y in the ground plane parallel to the length and width of the reference box. The characteristic source dimension, d_0, is shown in figure 1.

One of the following two shapes shall be used for the measurement surface:

a) a hemispherical surface or partial hemispherical surface of radius r;

b) a rectangular parallelepiped whose sides are parallel to those of the reference box; in this case, the measurement distance, d, is the distance between the measurement surface and the reference box.

For sources usually mounted and/or to be measured in rooms or spaces under unfavourable acoustical conditions (for example, many reflecting objects and high levels of background noise), the selection of a small measurement distance is appropriate and usually dictates the selection of a parallelepiped measurement surface. For sources usually mounted and/or to be measured in large open areas under satisfactory acoustical conditions, a large measurement distance is usually selected and in this case the hemispherical measurement surface is preferred. For directivity measurements, a hemispherical or partial hemispherical measurement surface is required.

For measurements on a series of similar sources (for example, machines of the same type or machines from the same family), the use of the same shape of measurement surface is required.

NOTE 21 The specific noise test code pertinent to the particular source under investigation should be consulted for detailed information.

The construction of the reference box, the size and shape of the measurement surface, as well as the measurement distance, d, or the radius of the hemisphere, r, shall be described in the test report.

7.2 Hemispherical measurement surface

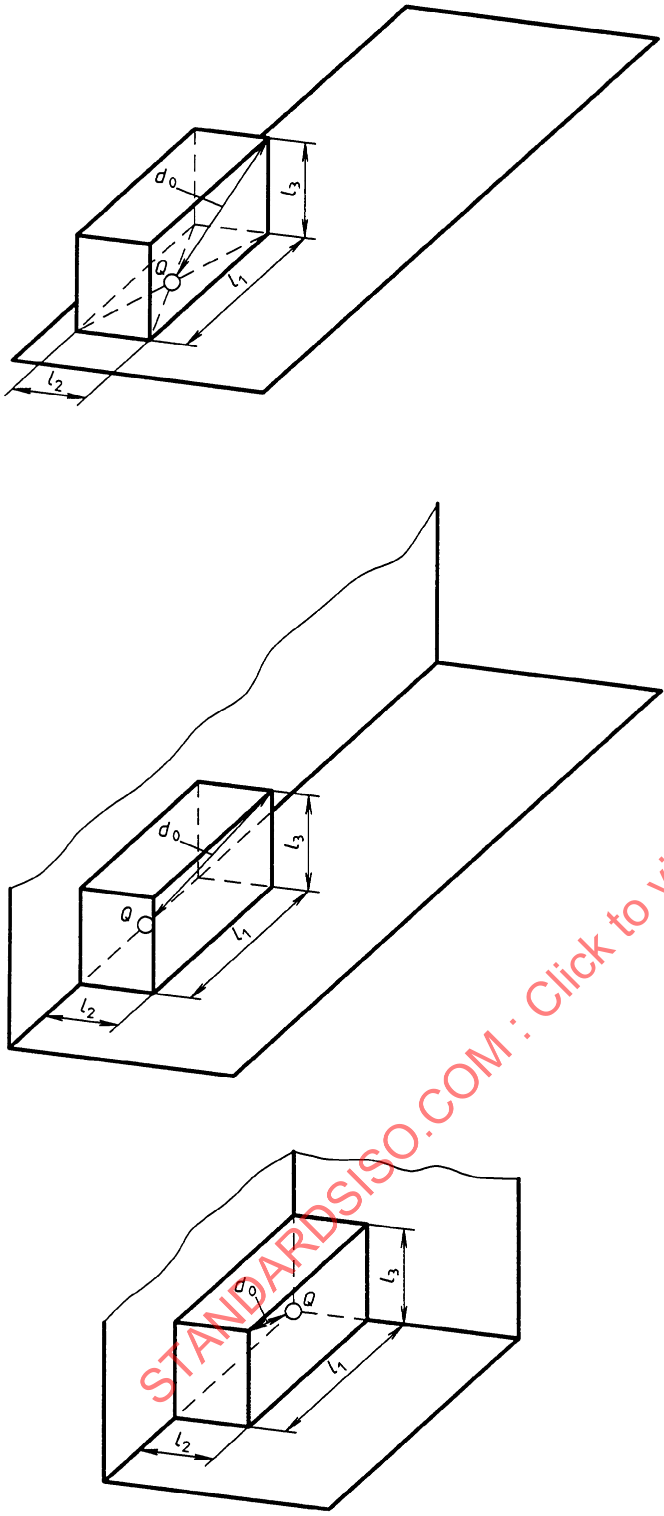
The hemisphere shall be centred in the middle of the box consisting of the reference box and its images in adjoining reflecting planes (point Q in figure 1). The radius, r, of the hemispherical measurement surface shall be equal to or greater than twice the characteristic source dimension, d_0, and not less than 1 m.

NOTE 22 The radius of the hemisphere should be one of the following values (in metres): 1, 2, 4, 6, 8, 10, 12, 14 or 16. Some of these radii may be so large that the environmental requirements given in annex A cannot be satisfied; such large values of the radii may not be used.

7.2.1 Area and key microphone positions on the hemispherical measurement surface

If there is only one reflecting plane, the microphone positions lie on the hypothetical hemispherical surface of area $S = 2\pi r^2$, enveloping the source and terminating on the reflecting plane. If the source under test is in front of a wall, $S = \pi r^2$. If it is in the corner, $S = 0{,}5\pi r^2$. The key microphone positions of the hemispherical surface are shown in figures B.1 and B.2 in annex B. Figure B.1 specifies the locations of 10 key microphone positions, each associated with equal areas, on the surface of the hemisphere of radius r. The hemispherical array of figures B.1 and B.2 has been selected to minimize the errors which can be caused by interference between the sound wave reaching the microphone directly and the wave reflected by the reflecting plane.

If a source is installed adjacent to more than one reflecting plane, reference shall be made to figure B.3 a) and figure B.3 b) in annex B to define a suitable measurement surface and the microphone positions.



a) Reference box on one reflecting plane

$$d_0 = \sqrt{(l_1/2)^2 + (l_2/2)^2 + l_3^2}$$

b) Reference box on two reflecting planes

$$d_0 = \sqrt{(l_1/2)^2 + l_2^2 + l_3^2}$$

c) Reference box on three reflecting planes

$$d_0 = \sqrt{l_1^2 + l_2^2 + l_3^2}$$

Figure 1 — Examples illustrating reference boxes and characteristic source dimensions, d_0, with respect to the origin of the coordinate system, Q

In special cases (i.e. for families of machines, such as construction equipment or earthmoving machinery, which are to be measured in a moving state or in a driving mode) a different number and arrangement of microphone positions can be used. However, this is only possible if preliminary investigation has shown that the resulting sound power level value is equal to or larger by less than 1 dB than that determined with the array specified in this International Standard.

7.2.2 Additional microphone positions on the hemispherical measurement surface

Sound pressure level measurements are required at additional microphone positions on the hemispherical measurement surface if

a) the range of sound pressure level values measured at the key microphone positions (i.e. the difference in decibels between the highest and lowest sound pressure levels) exceeds the number of key measurement points, or

b) the source radiates noise with a high directivity, or

c) the noise from a large source is radiated only from a small portion of the source, for example, the openings of an otherwise enclosed machine.

If condition a) exists, additional microphone positions shall be used. For the microphone array on the hemisphere, an additional 10-point array is defined by rotating the original array of figure B.1 through 180° about the z-axis (see table B.1 and figure B.2). Note that the top point on the z-axis of the new array is coincident with the top point of the original array. The total number of microphone positions is increased from 10 to 19.

If conditions b) or c) exist, additional measurement positions on the measurement surface in the region of high noise radiation shall be used (see 7.4.1).

7.3 Parallelepiped measurement surface

The measurement distance, d, is the perpendicular distance between the reference box and the measurement surface. The preferred value of d is 1 m and it shall be at least 0,25 m.

NOTE 23 The value of d should be one of the following values (in metres): 0,25, 0,5, 1, 2, 4 or 8. Measurement distances larger than 1 m may be selected for large sources. The environmental requirements given in annex A should be satisfied for the value of d selected.

7.3.1 Area and microphone positions on the parallelepiped measurement surface

The microphone positions lie on the measurement surface, a hypothetical surface of area S enveloping the source whose sides are parallel to the sides of the reference box and spaced out a distance d (measurement distance) from the box.

The microphone positions on the parallelepiped measurement surface are shown in figures C.1 to C.8 in annex C. The area S of the measurement surface according to figures C.2 to C.6 is given by the formula

$$S = 4(ab + bc + ca) \quad \ldots (3)$$

where

$a = 0{,}5l_1 + d$

$b = 0{,}5l_2 + d$

$c = l_3 + d$

l_1, l_2 and l_3 are the length, width and height of the reference box.

If a source is installed adjacent to more than one reflecting plane, reference shall be made to figures C.7 and C.8 in annex C to define a suitable measurement surface. The calculation of the area S of the measurement surfaces under these conditions is given in the respective figures. The microphone positions shall be located according to figures C.1 to C.6.

7.3.2 Additional microphone positions on the parallelepiped measurement surface

Sound pressure level measurements are required at additional microphone positions on the parallelepiped measurement surface if

a) the range of sound pressure level values measured at the key microphone positions (i.e. the difference in decibels between the highest and the lowest sound pressure levels) exceeds the number of measurement points, or

b) the source radiates noise with a high directivity, or

c) the noise from a large source is radiated only from a small portion of the source, for example, the openings of an otherwise enclosed machine.

If condition a) exists, additional microphone positions shall be used. For the microphone array on the parallelepiped, the number of measurement points is increased as shown in figure C.1, annex C , by increasing the number of equally-sized rectangular partial areas.

If conditions b) or c) exist, additional measurement positions on the measurement surface in the region of high noise radiation shall be used (see 7.4.1).

7.4 Additional procedures for selection of microphone positions

7.4.1 Additional localized microphone positions on the measurement surface

If additional localized microphone positions are required, in accordance with 7.2.2 or 7.3.2, a detailed investigation is necessary of the sound pressure levels over a restricted portion of the measurement surface. The purpose of this detailed investigation is to determine the highest and lowest values of the sound pressure levels in the frequency bands of interest. The additional microphone positions will usually not be associated with equal areas on the measurement surface. In this case, the calculation procedure of ISO 3745:1977, 8.1.2 (unequal areas) for the determination of L_W shall be used.

7.4.2 Reduction in the number of microphone positions

The number of microphone positions can be reduced if preliminary investigations for a particular family of machines show that by using the reduced number of microphone positions the determined surface sound pressure levels do not deviate by more than 0,5 dB from those determined from measurements over the complete set of microphone positions in accordance with 7.2 and 7.3. An example is when the radiation pattern is shown to be symmetrical.

NOTE 24 The overhead position(s) may be deleted for safety reasons, if so stated in the relevant noise test code.

7.4.3 Measurement paths for a traversing microphone

If the source under test emits steady noise, it is permissible to measure the surface sound pressure level by traversing a microphone at constant velocity along measurement paths, as described in annex B and annex C, instead of at the individual microphone positions. The maximum traversing speed along a path and microphone orientation shall be reported.

7.5 Measurement

7.5.1 Environmental conditions

Environmental conditions having an adverse effect on the microphone used for the measurements (for example, strong electric or magnetic fields, wind, impingement of air discharge from the equipment being tested, high or low temperatures) shall be avoided by proper selection or positioning of the microphone. The instructions of the manufacturers of the measurement instruments regarding adverse environmental conditions shall be followed. The microphone shall always be oriented in such a way that the angle of incidence of the sound waves is that for which the microphone is calibrated.

7.5.2 Measuring instruments

In addition to the specifications given in clause 5 , the following apply.

The time-averaged sound pressure level (3.2.1) shall be measured using an integrating sound level meter complying with IEC 804, unless it is shown that the sound pressure fluctuations measured with time-weighting characteristic S are less than $\pm$ 1 dB; in this case it is also permissible to use a sound level meter complying with IEC 651. In the latter case, express the time-averaged sound pressure level as the average of the maximum and minimum levels during the period of measurement.

7.5.3 Procedure

Observe the time-averaged sound pressure level over a typical period of operation of the source. Take readings of the time-averaged sound pressure level at each microphone position within the frequency range of interest.

Determine the following:

a) the A-weighted sound pressure levels or the band pressure levels L'_p during operation of the source under test;

b) the A-weighted sound pressure levels or the band pressure levels L''_p produced by the background noise.

For frequency bands centred on or below 160 Hz, the period of observation shall be at least 30 s. For the frequency bands centred on or above 200 Hz, the period of observation shall be at least 10 s.

When using a traversing microphone, the integrating time shall include at least two full traverses.

For the measurement of isolated single sound events, determine the single-event sound pressure level $L_{p,1s}$ (see 3.2.2).

For noise that varies with time, it is important to specify carefully the period of observation, and this will usually depend on the purpose of the measurements. For a machine with modes of operation having different noise levels, select an appropriate measuring period for each mode and state this in the test report.

8 Calculation of surface sound pressure level and sound power level

8.1 Calculation of sound pressure level averaged over the measurement surface

For the A-weighted sound pressure level or the level in each frequency band of interest, calculate an average sound pressure level over the measurement surface, $\overline{L'_p}$, from the measured sound pressure levels L'_{pi}, and $\overline{L''_p}$ from the background noise levels L''_{pi} using the following equations:

$$\overline{L'_p} = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1 L'_{pi}} \right] \text{ dB} \qquad \ldots (4)$$

$$\overline{L''_p} = 10 \lg \left[\frac{1}{N} \sum_{i=1}^{N} 10^{0,1 L''_{pi}} \right] \text{ dB} \qquad \ldots (5)$$

where

$\overline{L'_p}$ is the sound pressure level averaged over the measurement surface, in decibels, with the source under test in operation;

$\overline{L''_p}$ is the sound pressure level of the background noise averaged over the measurement surface, in decibels;

L'_{pi} is the sound pressure level measured at the i^{th} microphone position, in decibels;

L''_{pi} is the sound pressure level of the background noise measured at the i^{th} microphone position, in decibels;

N is the number of microphone positions.

NOTE 25 The averaging procedure in equations (4) and (5) is based on a uniform distribution of the microphone positions on the measurement surface.

8.2 Calculation of A-weighted sound pressure levels from frequency band data

If A-weighted sound pressure levels are calculated from frequency band pressure levels, use the following equation:

$$L_{pA} = 10 \lg \left[\sum_{j} 10^{0,1(L_{pj} + A_j)} \right] \text{ dB} \qquad \ldots (6)$$

where

L_{pj} is the frequency band pressure level, in decibels, in band j;

A_j is the A-weighting value at the centre frequency of band j, as given in table 2.

NOTE 26 If the noise source emits strong discrete frequency components, it is recommended that the calculation be performed using one-third-octave band A-weighting values.

Table 2 — A-weighting values, A_j

Octave-band centre frequencies	One-third-octave band centre frequencies	A-weighting values A_j
Hz	Hz	dB
	50	−30,2
63	63	−26,2
	80	−22,5
	100	−19,1
125	125	−16,1
	160	−13,4
	200	−10,9
250	250	−8,6
	315	−6,6
	400	−4,8
500	500	−3,2
	630	−1,9
	800	−0,8
1 000	1 000	0
	1 250	0,6
	1 600	1,0
2 000	2 000	1,2
	2 500	1,3
	3 150	1,2
4 000	4 000	1,0
	5 000	0,5
	6 300	−0,1
8 000	8 000	−1,1
	10 000	−2,5

8.3 Corrections for background noise

Calculate the correction K_1 (A-weighted or in frequency bands) by using the following equation:

$$K_1 = -10 \lg (1 - 10^{-0,1 \Delta L}) \text{ dB} \qquad \ldots (7)$$

where

$$\Delta L = \overline{L'_p} - \overline{L''_p}$$

If $\Delta L > 15$ dB, no correction is made. If $\Delta L \geqslant 6$ dB, the measurement is valid according to this International Standard (see table 0.1).

For values of ΔL between 6 dB and 15 dB, make corrections according to equation (7). Even if the measurement is invalid for a single frequency band, it can still be valid for the A-weighted value, provided that ΔL_A is greater than 6 dB, where ΔL_A is the difference between the values of $\overline{L'_{pA}}$ and $\overline{L''_{pA}}$.

If the 6 dB criterion is not satisfied, the accuracy of the result(s) is reduced. The maximum correction to be applied to these measurements is 1,3 dB. The result may, however, be reported and may be useful for determining an upper boundary to the sound power level of the source under test. If such data are reported, it shall be clearly stated in the text of the report, as well as in graphs and tables of results, that the background noise requirements of this International Standard have not been fulfilled.

8.4 Corrections for the test environment

The environmental correction K_2 (A-weighted or in frequency bands) is determined by one of the procedures described in annex A.

Measurements according to this International Standard are valid for A-weighting if $K_{2A} \leqslant 2$ dB and for the j^{th} frequency band if $K_{2j} \leqslant 2$ dB (see table 0.1).

NOTE 27 If K_2 is greater than 2 dB, the criterion is not satisfied and the accuracy of the result(s) is reduced. The measurement method given in this International Standard may, however, be used, but when reporting the results either a maximum correction of 2 dB can be applied and reference can be made to ISO 3744 if it is stated that the sound power level is equal to or less than that so determined, or the full correction can be applied, but in this case reference should be made to ISO 3746.

8.5 Calculation of surface sound pressure level

Determine the surface sound pressure level $\overline{L_{pf}}$ by correcting the value of $\overline{L'_p}$ for background noise and for reflected sound by using the following equation with corrections K_1 and K_2:

$$\overline{L_{pf}} = \overline{L'_p} - K_1 - K_2 \qquad \ldots (8)$$

8.6 Calculation of sound power level

The sound power level, L_W, shall be calculated as follows:

$$L_W = \overline{L_{pf}} + 10 \lg \left(\frac{S}{S_0} \right) \text{ dB} \qquad \ldots (9)$$

where

$\overline{L_{pf}}$ is the A-weighted or frequency band surface sound pressure level according to equation (8);

S is the area of the measurement surface, in square metres;

S_0 = 1 m^2

8.7 Determination of optional quantities

The following optional quantities may be required by noise test codes for specific types of sources.

a) Information on impulsive noise, in accordance with one of the methods of annex D; and/or the presence of discrete tones determined by listening.

b) The sound pressure spectrum at a single microphone position on the measurement surface or averaged over the measurement surface.

c) The directivity index as specified in annex E.

d) The variation of the A-weighted sound pressure level with time at a defined microphone position and between the microphone positions on the measurement surface.

e) The sound pressure level with different time and/or frequency weighting at individual microphone position(s) on the measurement surface.

9 Information to be recorded

The information listed in 9.1 to 9.5, when applicable, shall be compiled and recorded for all measurements made in accordance with this International Standard.

9.1 Source under test

a) Description of the source under test, including its

- type,
- technical data,
- dimensions,
- manufacturer,
- machine serial number, and
- year of manufacture.

b) Operating conditions during test (in accordance with the specific test code for the source, if any, or the manufacturer's instructions).

c) Mounting conditions.

9.2 Acoustic environment

a) Description of the test environment:

- if indoors, description of physical treatment of walls, ceiling and floor; sketch showing the location of source and room contents;
- if outdoors, sketch showing the location of the source with respect to surrounding terrain, including a physical description of the test environment.

b) Acoustical qualification of the test environment in accordance with annex A.

c) Air temperature in degrees Celsius, barometric pressure in pascals, and relative humidity.

9.3 Instrumentation

a) Equipment used for measurements, including name, type, serial number and manufacturer.

b) Method used for checking the calibration of the microphones and other system components; the date, place and result of calibration shall be given.

c) Characteristics of windscreen (if any).

9.4 Acoustical data

a) A-weighted sound power level and sound power levels in frequency bands, if required.

NOTE 28 ISO 9296 requires that the declared A-weighted sound power levels of computers and business equipment be expressed in bels using the identity 1 B = 10 dB.

b) The shape of the measurement surface, the measurement distance of radius, and the location and orientation of microphone positions or paths.

c) The area S of the measurement surface.

d) The background noise correction K_1 (A-weighted or in frequency bands) for the surface sound pressure levels.

e) The environmental corrections K_2 (A-weighted or in frequency bands) and the method by which it was determined in accordance with one of the procedures of annex A.

f) Sound pressure levels L_{pi} (respectively $L_{p,1s,i}$) (A-weighted or in frequency bands) at each measuring point i.

g) The surface sound pressure level $\overline{L_{pf,x}}$ (A-weighted or in frequency bands), where x is the measurement distance d or the measurement radius r.

h) Place, date when the measurements were performed, and the name of the person responsible for the test.

9.5 Optional data

a) Sound power spectrum or sound pressure spectrum corrected for background noise and environmental influence.

b) Information on impulsive noise in accordance with one of the methods of annex D; and/or the presence of discrete tones determined by listening.

c) Variation of the measured sound pressure levels with time.

d) Directivity index in conjunction with the direction of the microphone position concerned, as described in annex E.

e) Sound pressure level with different time and/or frequency weighting at a specified microphone position on the measurement surface.

f) Wind speed and direction.

g) Standard deviation of reproducibility, σ_R.

h) Any noise data required by the noise test code.

10 Information to be reported

Only those recorded data (see clause 9) are to be reported which are required for the purpose of the measurements (see ISO 4871).

The report shall state whether or not the reported sound power levels have been obtained in full conformity with the requirements of this International Standard.

The A-weighted sound power level of the source under test shall be reported to the nearest 0,5 dB.

Annex A
(normative)

Qualification procedures for the acoustic environment

A.1 General

An environment providing an approximately free field over a reflecting plane shall be used for measurements made in accordance with this International Standard. It is permissible to use a semi-anechoic room, an outdoor space or an ordinary room if the requirements given below are satisfied.

The test room shall be large enough and, as far as is practicable, free from reflecting objects with the exception of the reflecting plane(s).

The test room shall provide a measurement surface that lies

a) inside a sound field that is essentially free of undesired sound reflections from the room boundaries or nearby objects, and

b) outside the near field of the sound source under test.

For open test sites which consists of a hard, flat ground surface, such as asphalt or concrete, and with no sound-reflecting objects within a distance from the source equal to three times the greatest distance from the source centre to the lower measurement points, it is assumed that the environmental correction K_2 is less than or equal to 0,5 dB and is, therefore, negligible.

The environmental correction K_2 is also assumed to be negligible for measurements made in semi-anechoic rooms which meet the requirements of ISO 3745:1977, annex A.

NOTE 29 An object in the proximity of the source may be considered to be sound reflecting if its width (for example, diameter of a pole or supporting member) exceeds one-tenth of its distance from the reference box.

Evaluate environmental influences by selecting one of two alternative procedures used to determine the magnitude of the environmental correction K_2. Use these procedures to determine if any undesired environmental influences are present and to qualify a given measurement surface for an actual source under test in accordance with this International Standard.

The first qualification test (absolute comparison test, see A.3) is carried out with a reference sound source (RSS) and can be used outdoors and indoors. It is the preferred procedure, particularly if data in frequency bands are required.

The second qualification test (method based on room absorption, see A.4) requires the determination of the equivalent absorption area, A, of the test room with the aid of reverberation time measurements, or by estimating the mean absorption coefficient. This test procedure is based on the assumption that the room has approximately a cubic shape and is substantially empty and that there are absorption effects on the room boundaries. Under these conditions, if the source under test cannot be moved and if its dimensions are large, this is the preferred method.

The measurement surface in a given test environment is satisfactory for measurements complying with this International Standard only if the environmental correction K_2 is numerically less than or equal to 2 dB. If the environmental correction K_2 exceeds 2 dB, repeat the procedure using either a smaller measurement surface or a better test environment.

NOTE 30 If this is not practicable, determination of the sound power levels of the source under test using the methods described in ISO 3746 may be more suitable.

A.2 Environmental conditions

A.2.1 Properties of reflecting plane

Measurements are permissible in the following environments:

— over a reflecting plane outdoors;

— in a test room with sound absorptive walls and ceiling, a sound reflecting floor and up to two further perpendicular reflecting surfaces.

When a reflecting surface is not a ground plane or is not an integral part of a test room surface, particular care should be exercised to ensure that the plane does not radiate any appreciable sound due to vibrations.

A.2.1.1 Shape and size

The reflecting plane(s) shall extend at least $\lambda/2$ beyond the projection of the measurement surface on the plane(s) for the lowest frequency of the frequency range of interest.

A.2.1.2 Sound absorption coefficient

The sound absorption coefficient (see ISO 354) of the reflecting plane(s) should preferably be less than 0,06 over the frequency range of interest. Concrete or smooth sealed asphalt surface(s) should be satisfactory (see also table A.1).

A.2.2 Precautions for outdoor measurements

Take care to minimize the effects of adverse meteorological conditions (for example, temperature, humidity, wind, precipitation) on the sound propagation over the frequency range of interest or on the background noise during the course of the measurements.

If a device is used to shield the microphone from the effects of wind, proper corrections of the measured sound pressure levels shall be made.

A.3 Absolute comparison test

This procedure should preferably be used if the source under test can be removed from the test site.

A.3.1 Procedure

Mount a reference sound source (RSS) with characteristics that meet the requirements of ISO 6926 in the test environment, in essentially the same position as that of the source under test. Determine the sound power level of the reference sound source in accordance with the procedures of clauses 7 and 8 without the environmental correction K_2 (i.e. K_2 is initially assumed equal to zero). Use the same measurement surface as that used for the measurements of the source under test.

The environmental correction K_2 (A-weighted or in frequency bands) is given by

$$K_2 = L_W^* - L_{Wr} \qquad \ldots (A.1)$$

where

L_W^* is the environmentally uncorrected sound power level of the reference sound source, determined in accordance with clauses 7 and 8 when using the value 0 for K_2;

L_{Wr} is the calibrated sound power level of the reference sound source [reference 1 pW (= 10^{-12} W)], in decibels.

NOTE 31 This method is applicable to both directly measured A-weighted levels and frequency band levels. If the spectrum of the source under test is very different from that of the RSS, it is recommended that K_{2A} be determined from frequency band levels.

A.3.2 Locations of reference sound source in test environment

If the source under test can be removed from the test site, locate the reference sound source on the reflecting place, independent of the height of the source under test, except for special cases such as hand-held machine tools.

NOTE 32 If the reference sound source (RSS) is located above the reflecting plane or close to other reflecting surfaces, it should be calibrated in a similar location. At present a standardized calibration method is only available for an RSS located on a reflecting plane away from any other reflecting surfaces (see ISO 6926).

One single location is sufficient for small- and medium-sized sources (l_1, l_2, $l_3 \leqslant 2$ m). For larger sources and for those with ratios of length to width greater than 2, operate the reference sound source on the floor at four points. Assuming that the projection of the source under test on the floor is approximately rectangular in shape, the four points are located at the middle points of the sides of the rectangle. To obtain L_W, calculate the surface sound pressure level, L_{pf}, with the reference sound source located at each of the four points on the floor. At each point on the measurement surface, average the sound pressure level for the four source locations on a mean-square basis, i.e. using equation (4) in 8.1.

If the source under test cannot be removed from the test site, the reference sound source shall be placed at one or more positions in the same environment different from the position of the machine under test but equivalent with respect to room reflections. Furthermore, positions of the reference sound source on top of the source under test or adjacent to it, in accordance with ISO 3747, may be used, but for such locations the relevant calibration of the reference sound source must be known.

With regard to a sufficient number of microphone positions, care should be taken to fulfil the requirements of 7.2.2 a) and 7.3.2 a) respectively.

A.4 Determination of the environmental correction based on room absorption

Calculate the environmental correction K_2 from

$$K_2 = 10 \lg [1 + 4(S/A)] \text{ dB} \qquad \ldots (A.2)$$

where

A is the equivalent sound absorption area of the room, in square metres;

S is the area of the measurement surface, in square metres.

Environmental corrections as a function of A/S calculated using equation (A.2) are illustrated in figure A.1.

A.4.1 Approximate method

In order to ascertain the acoustic characteristics of the test environment, determine K_{2A} from equation (A.2) using a value of A given in square metres by the formula

$$A = \alpha \cdot S_V \qquad \text{... (A.3)}$$

where

α is the mean sound absorption coefficient, given for A-weighted quantities in table A.1;

S_V is the total area of the boundary surfaces of the test room (walls, ceiling and floor), in square metres.

Table A.1 — Approximate values of the mean sound absorption coefficient α

Mean sound absorption coefficient α	Description of room
0,05	Nearly empty room with smooth hard walls made of concrete, brick, plaster or tile
0,1	Partly empty room; room with smooth walls
0,15	Room with furniture; rectangular machinery room; rectangular industrial room
0,2	Irregularly shaped room with furniture; irregularly shaped machinery room or industrial room
0,25	Room with upholstered furniture; machinery or industrial room with a small amount of sound-absorbing material on ceiling or walls (for example, partially absorptive ceiling)
0,35	Room with sound absorbing materials on both ceiling and walls
0,5	Room with large amounts of sound-absorbing materials on ceiling and walls

A.4.2 Reverberation method

Calculate the equivalent sound absorption area of the room from the measured reverberation time (see ISO 354) by the Sabine reverberation time equation. At room temperatures between 15 °C and 30 °C:

$$A = 0{,}16(V/T) \qquad \text{... (A.4)}$$

where

V is the volume of the test room, in cubic metres;

T is the reverberation time, in seconds, for A-weighting or in frequency bands.

For the purpose of determining K_{2A} directly from A-weighted measured values, it is recommended to use the reverberation time measured in the frequency band with centre frequency of 1 kHz.

This method is not suitable for use in a laboratory-quality hemi-anechoic room nor for outdoor measurements.

A.4.3 Two-surface method

Use this test method only in room whose length and width are each less than three times the ceiling height. Select two surfaces that surround the sound source. The first surface shall be the measurement surface, in accordance with 7.1, for determination of sound power level. The area of the first surface shall be designated S. The second surface with area S_2 shall be geometrically similar to the first surface and located further away and symmetrical with respect to the machine under test. On both surfaces, the background noise criteria specified in 4.3 shall be fulfilled.

The microphone locations on the second surface shall correspond to those on the first surface. The ratio S_2/S shall not be less than 2 and preferably should be greater than 4. The quantity M is calculated from

$$M = 10^{0{,}1(\overline{L'_{p1}} - \overline{L'_{p2}})} \qquad \text{... (A.5)}$$

where

$\overline{L'_{p1}}$ is the average sound pressure level on S [see equation (4)] in decibels;

$\overline{L'_{p2}}$ is the average sound pressure level on S_2 [see equation (4)] in decibels.

For both average sound pressure levels, corrections for background noise shall be applied in accordance with 8.3.

The ratio A/S is calculated from

$$\frac{A}{S} = \frac{4(M-1)}{1 - MS/S_2} \qquad \text{... (A.6)}$$

The environmental correction K_2 for A-weighting or in frequency bands is obtained from equation (A.2) for the A/S ratio calculated from equation (A.6).

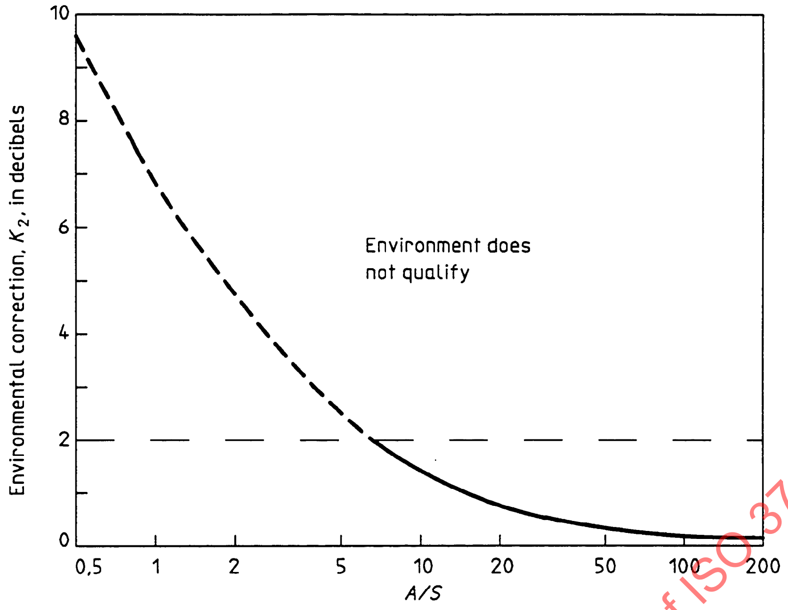


Figure A.1 — Environmental correction, K_2, in decibels

Annex B
(normative)

Microphone array on the hemispherical measurement surface

B.1 Key microphone positions and additional microphone positions

Ten key microphone positions associated with equal areas of the measurement surface are numbered 1 to 10 in figures B.1 and B.2, and their coordinates according to the coordinate system defined in 7.1 are listed in table B.1. Ten additional microphone positions are numbered 11 to 20 in figure B.2 and their coordinates are also listed in table B.1.

Table B.1 — Coordinates of key microphone positions (1-10) and additional microphone positions (11-20)

Microphone position	$\frac{x}{r}$	$\frac{y}{r}$	$\frac{z}{r}$
1	−0,99	0	0,15
2	0,50	−0,86	0,15
3	0,50	0,86	0,15
4	−0,45	0,77	0,45
5	−0,45	−0,77	0,45
6	0,89	0	0,45
7	−0,33	0,57	0,75
8	−0,66	0	0,75
9	0,33	−0,57	0,75
10	0	0	1,0
11	0,99	0	0,15
12	−0,50	0,86	0,15
13	−0,50	−0,86	0,15
14	0,45	−0,77	0,45
15	0,45	0,77	0,45
16	−0,89	0	0,45
17	−0,33	−0,57	0,75
18	0,66	0	0,75
19	−0,33	0,57	0,75
20 (≙10)	0	0	1,0

NOTE — The overhead positions 10 and 20 coincide, and it is permissible to omit these if so indicated in the relevant noise test code.

B.2 Microphone positions for sources emitting discrete tones

If the source emits discrete tones, strong interference effects can occur if several micorphone positions are placed at the same height above the reflecting plane. In such a case, the use of a microphone array with the coordinates given in table B.2 is recommended.

Table B.2 — Coordinates of microphone positions for sources emitting discrete tones

Microphone position	$\frac{x}{r}$	$\frac{y}{r}$	$\frac{z}{r}$
1	0,16	−0,96	0,22
2	0,78	−0,60	0,20
3	0,78	0,55	0,31
4	0,16	0,90	0,41
5	−0,83	0,32	0,45
6	−0,83	−0,40	0,38
7	−0,26	−0,65	0,71
8	0,74	−0,07	0,67
9	−0,26	0,50	0,83
10	0,10	−0,10	0,99

B.3 Microphone positions for sources adjacent to two reflecting planes

For a source installed adjacent to two reflecting planes, reference shall be made to figure B.3 for the purposes of defining a suitable measurement surface and microphone positions. The radius r of the spherical measurement surface shall be at least 3 m.

B.4 Measurement paths

Coaxial circular paths in parallel planes for microphone traverses in a free field over a reflecting plane are shown in figure B.4.

The paths are selected so that the annular area of the hemisphere associated with each path is the same.

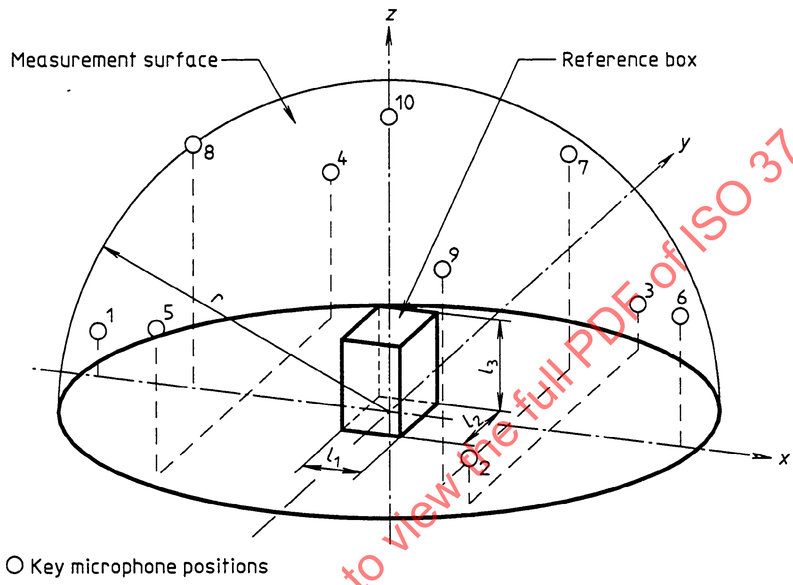
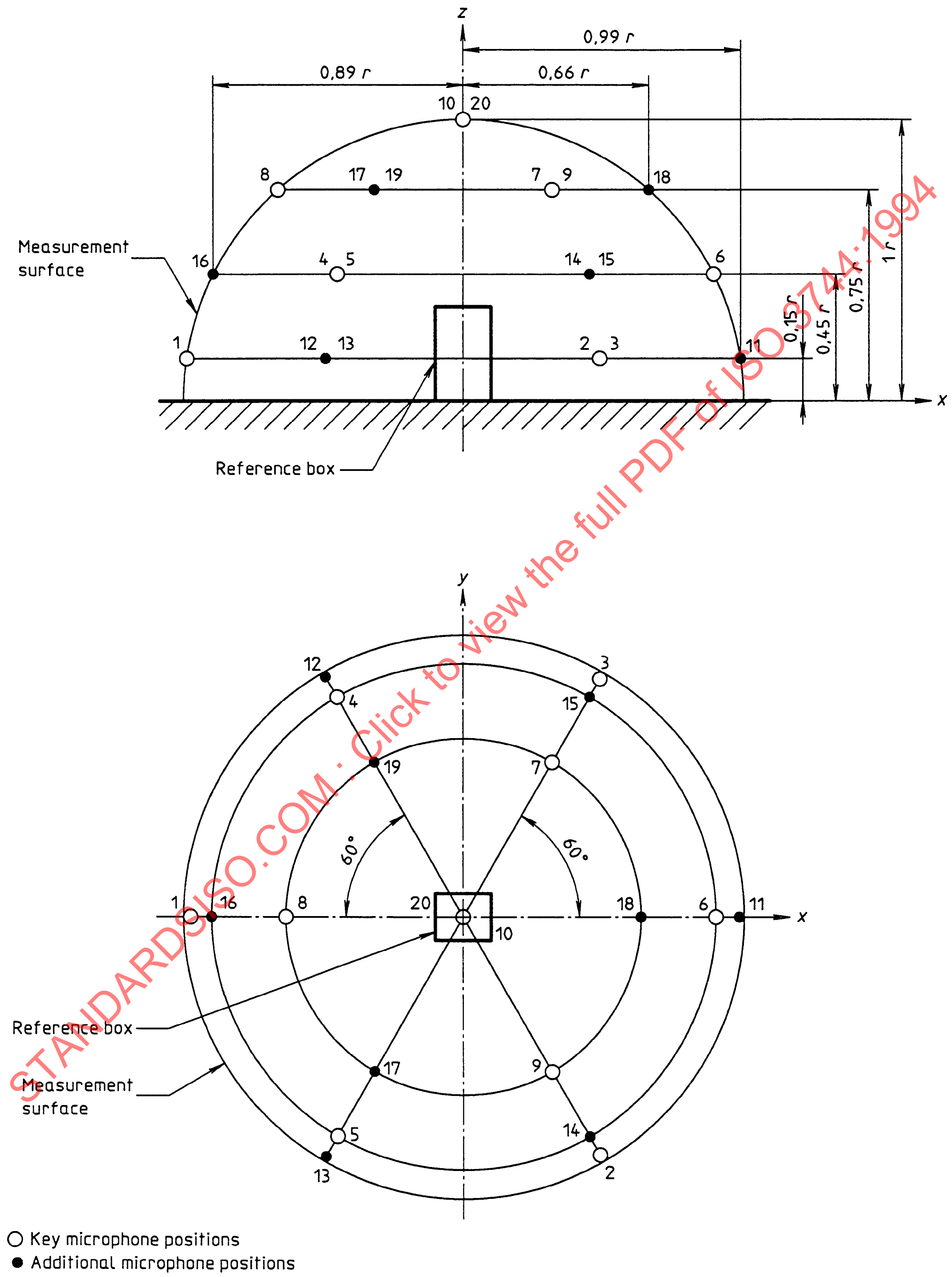


Figure B.1 — Microphone array on the hemisphere — Key microphone positions



NOTE — Key microphone positions are numbered 1 to 10; additional microphone positions are numbered 11 to 20.

Figure B.2 — Microphone array on the hemisphere

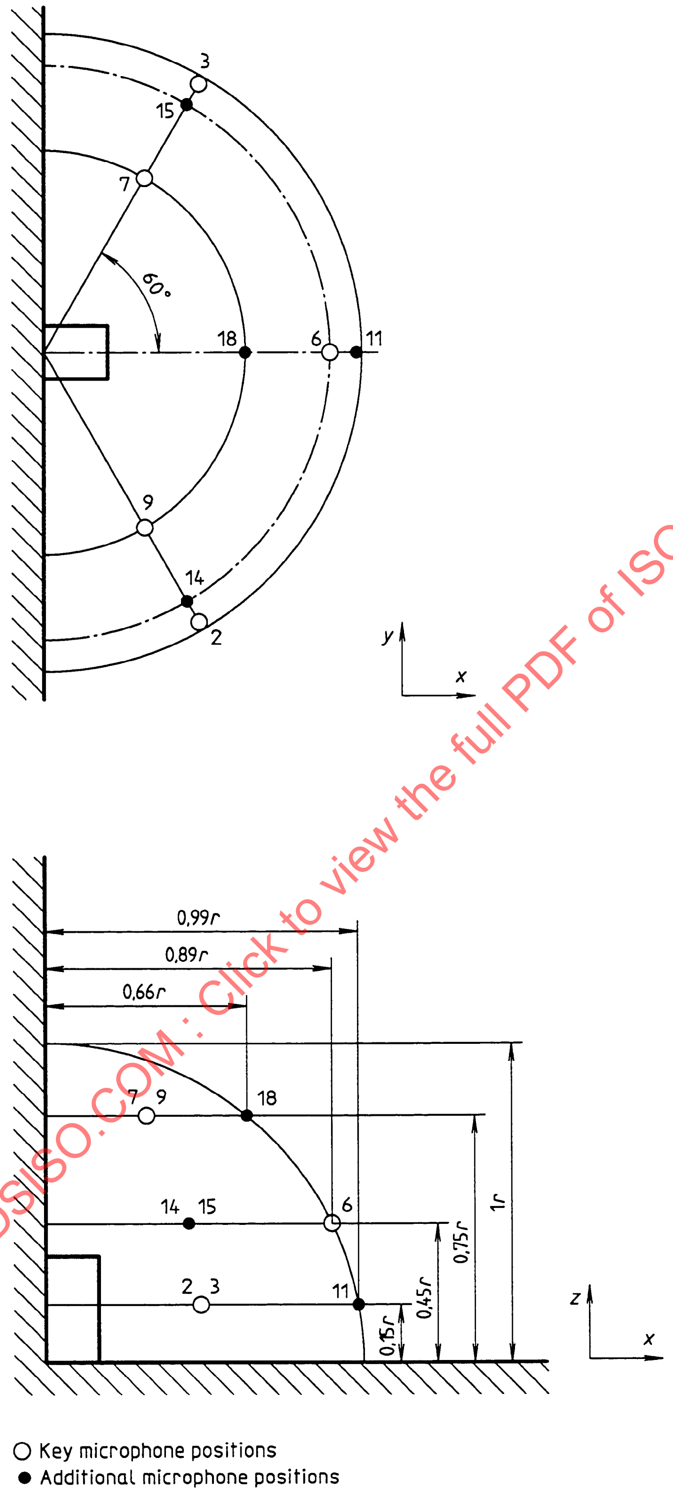
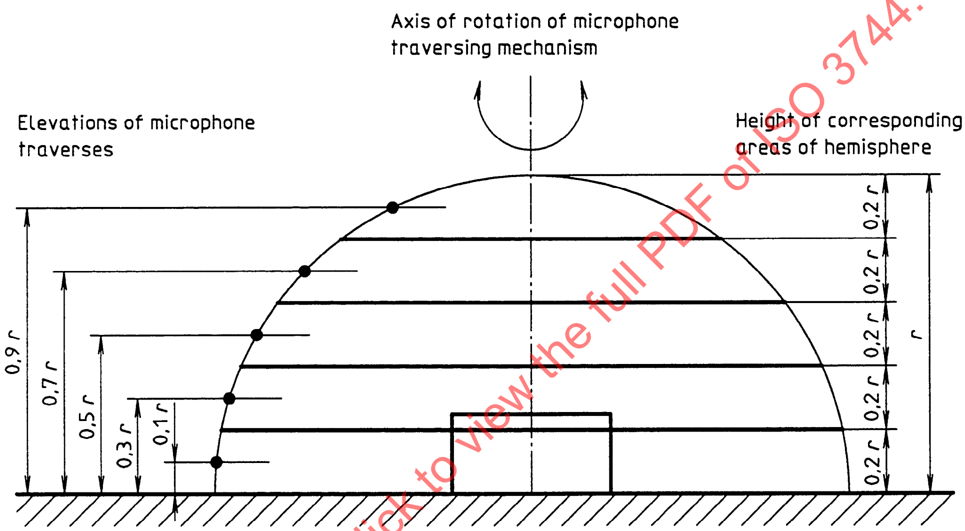


Figure B.3 — Plan view of a spherical measurement surface and microphone positions around a reference box adjacent to two reflecting planes



NOTE — The paths are selected so that the annular area of the hemisphere associated with each path is the same.

Figure B.4 — Coaxial circular paths in parallel planes for microphone traverses in a free field over a reflecting plane

Annex C
(normative)

Microphone array on the parallelepiped measurement surface

C.1 Microphone positions for sources mounted on one reflecting plane

Each plane of the measurement surface shall be considered on its own and so subdivided that the result is the smallest possible number of equal-sized rectangular partial areas with a maximum length of side equal to $3d$ (see figure C.1). The microphone positions are in the centre of each partial area and at each corner of the partial area (excluding the corners intruding into the reflecting plane(s)). In this way the microphone positions for figures C.2 to C.6 are obtained.

Adjacent microphone positions may be added to make measurement paths as shown in figures C.2 to C.6.

C.2 Microphone positions for sources adjacent to two or three reflecting planes

For a source installed adjacent to more than one reflecting plane, reference shall be made to figures C.7 and C.8 for the purpose of defining a suitable measurement surface. The microphone positions shall be as shown in figures C.2 to C.6.

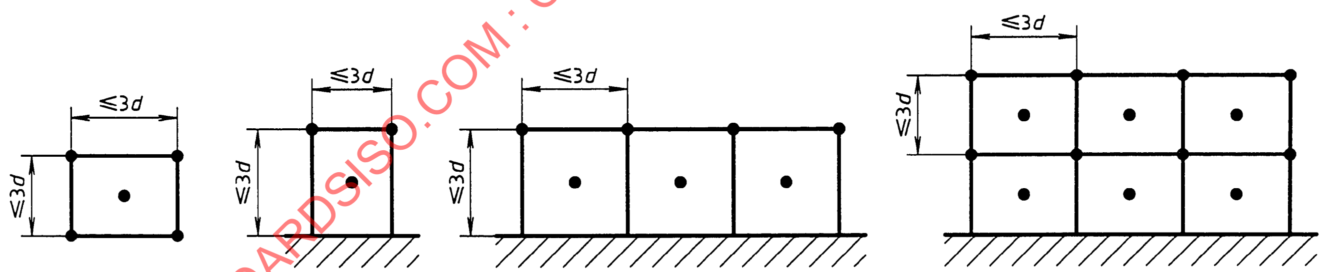


Figure C.1 — Procedure for fixing the specified microphone positions where a side of the measurement surface exceeds $3d$

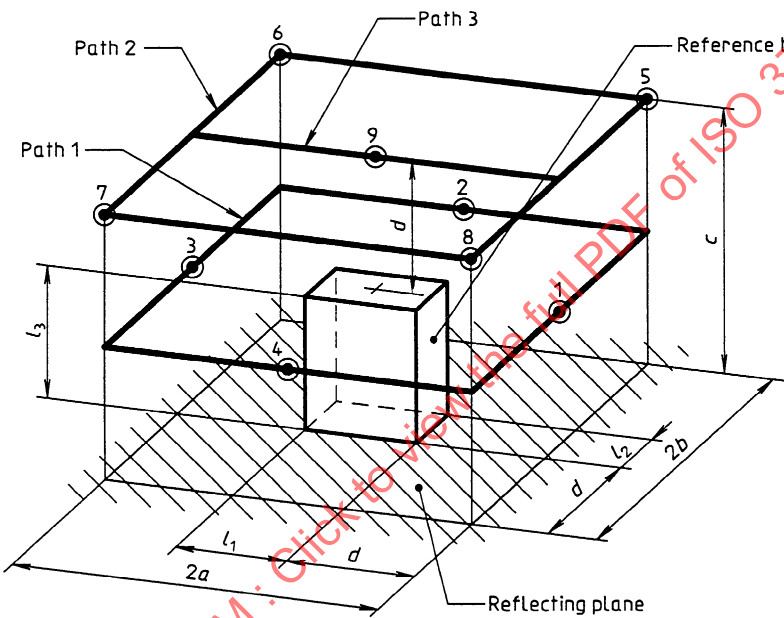


Figure C.2 — Example of a measurement surface and microphone positions (paths) for a small machine
($l_1 \leqslant d$, $l_2 \leqslant d$, $l_3 \leqslant 2d$, where d is the measurement distance, normally 1 m)

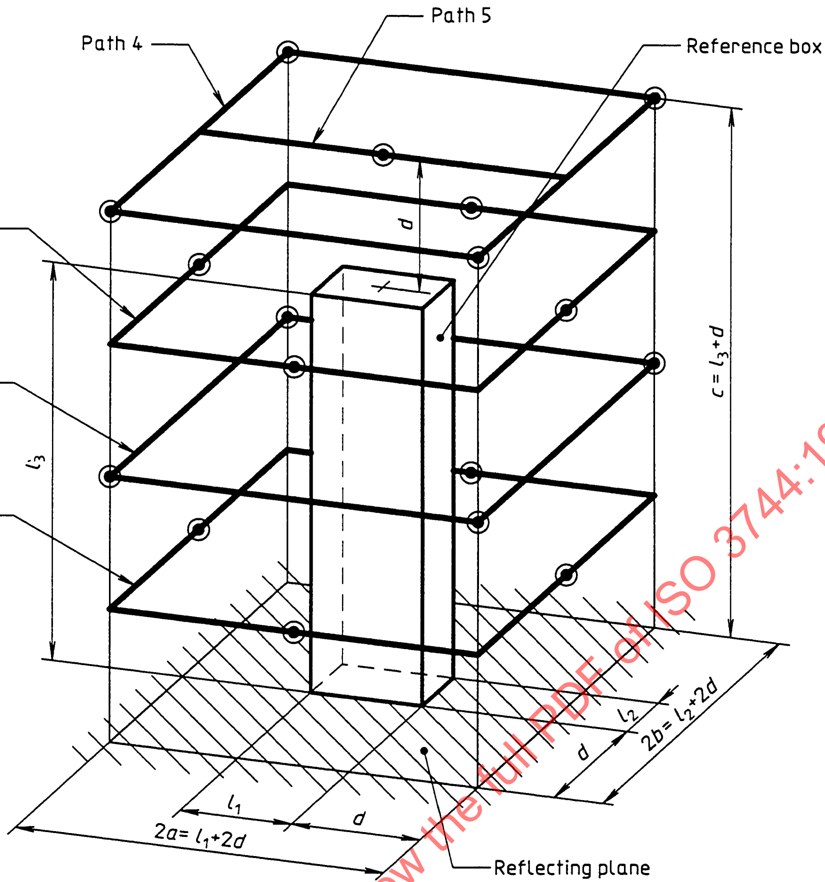


Figure C.3 — Example of a measurement surface and microphone positions (paths) for a tall machine with a small base area ($l_1 \leqslant d$, $l_2 \leqslant d$, $2d < l_3 \leqslant 5d$)

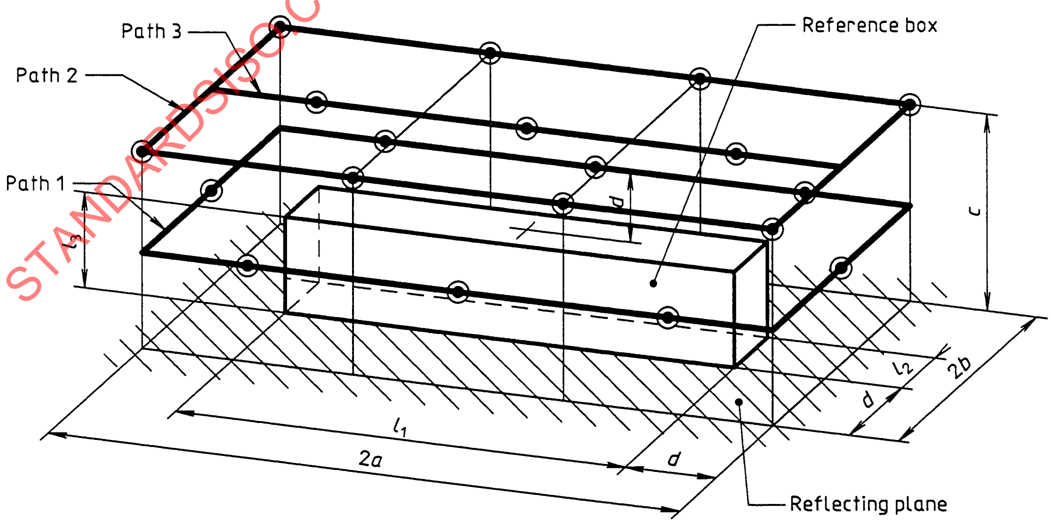


Figure C.4 — Example of a measurement surface and microphone positions (paths) for a long machine ($4d < l_1 \leqslant 7d$, $l_2 \leqslant d$, $l_3 \leqslant 2d$)

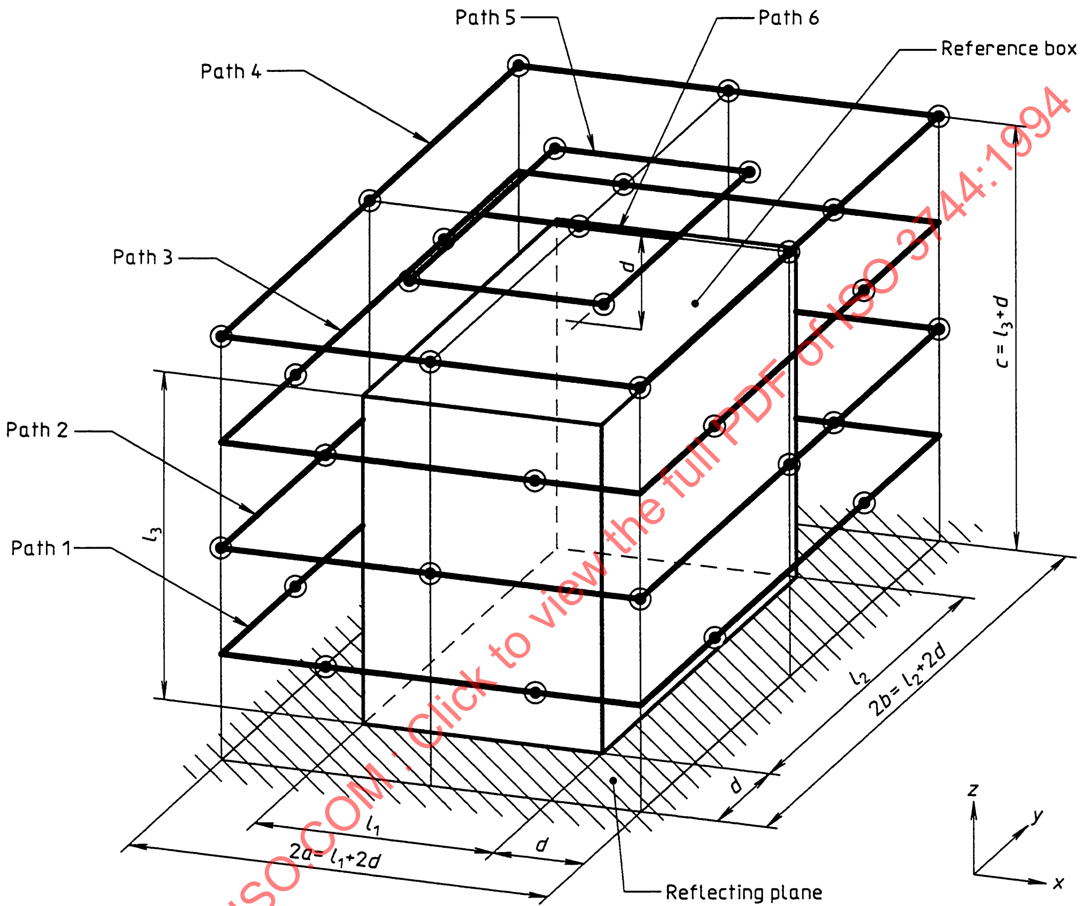


Figure C.5 — Example of a measurement surface and microphone positions (paths) for a medium-sized machine ($d < l_1 \leqslant 4d$, $d < l_2 \leqslant 4d$, $2d < l_3 \leqslant 5d$)