International Standard 3744

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

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit — Méthodes d'expertise pour les conditions de champ libre au-dessus d'un plan réfléchissant

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

International Standard ISO 3744 was developed by Technical Committee ISO/TC 43, *Acoustics*, and was circulated to the member bodies in February 1977.

It has been approved by the member bodies of the following countries :

Australia	Hungary	Portugal
Austria	India	Romania
Belgium	Israel	South Africa, Rep. of
Canada	Japan	Spain
Czechoslovakia	Mexico	Sweden
Denmark	Netherlands	Switzerland
Finland	New Zealand	United Kingdom
France	Norway	USA
Germany, F. R.	Poland	USSR

No member body expressed disapproval of the document.

This International Standard cancels and replaces ISO Recommendation R 495-1966, of which it constitutes a technical revision.

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

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 must be in accordance with the general principles stated in these basic documents.

Guidelines for operating and mounting conditions are provided in ISO 3740. If no sound test code is specified for a particular machine, the mounting and operating conditions shall be fully described in the test report.

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; 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

* See clause 2.

** See ISO 2204.

0.2 Synopsis of ISO 3744

Applicability

Test environment

Free field over a reflecting plane (indoors or outdoors).

Type of source

Device, machine, component, subassembly.

Size of noise source

Greatest linear dimension less than 15 m.

Character of noise radiated by the source

All types (as defined in ISO 2204 : steady, non-steady, broad-band, discrete-frequency, narrow-band).

Accuracy

Engineering or grade 2 (as defined in ISO 2204)(standard deviation for determining sound power levels for 1 kHz octave band is about 1,5 dB).

Quantities to be measured

Sound pressure levels (weighted and in frequency bands) at prescribed microphone positions.

Quantities to be determined

Weighted sound power levels (A-weighting is required; other weightings are optional); sound power levels in frequency bands; directivity characteristics of the source (optional).

0.3 Introduction

This International Standard specifies engineering methods for measuring the sound pressure levels on a given surface which envelops the noise source under investigation. The sound power level of the source is calculated from the results of these measurements. The method may be applied in laboratory rooms which provide a free field over a reflecting plane or in field installations whose acoustical characteristics meet the requirements of this International Standard. If the test room does not meet the requirements of this International Standard, measurements made in accordance with ISO 3746 might nevertheless be possible.

Free-field conditions are usually not encountered in typical machine rooms where sources are normally installed. If measurements are made of such installations, corrections may be required to account for background noise or undesired reflections. These corrections reduce the accuracy of the sound power determination.

The methods described in this International Standard conform to the general recommendations included in ISO 2204. The methods specified in this International Standard permit the determination of sound power level both in frequency bands and directly as an A-weighted value.

Data obtained in accordance with this International Standard may be used for the following purposes amongst others :

a) comparison of machines which are similar in size and kind;

b) comparison of machines which are different in size and kind;

c) rating of apparatus in terms of its sound power output;

d) prediction of the sound pressure levels produced by a device or machine at a given point in a given enclosure or environment.

In this International Standard the computation of sound power from sound pressure level measurements is based on the premise that the mean-square sound pressure averaged over the enveloping measuring surface and over time is

a) directly proportional to the sound power output of the source;

b) inversely proportional to the area S of the measurement surface;

c) otherwise dependent only on the physical constants of air density and sound velocity.

This International Standard, together with the others in this series (see table 1), supersedes ISO/R 495.

1 Scope and field of application

1.1 General

This International Standard specifies engineering methods for measuring the sound pressure levels on a measurement surface enveloping the source and for calculating the sound power level produced by the source. It gives requirements for the test environment and instrumentation as well as techniques for obtaining the surface sound pressure level from which the A-weighted sound power level of the source and octave or one-third octave band sound power levels are calculated.

This International Standard is concerned with specification of the basic acoustic requirements for the measurement of noise under free-field conditions over a reflecting plane. It is important that specific test codes for various types of equipment be established and used as the basis for measurements according to this International Standard. Such test codes will, for each type of equipment, give detailed requirements on mounting, loading and operating conditions for the equipment under test as well as descriptions of the measurement surface, the number of microphone positions, and the measurement distance to be used.

The use of different measurement surfaces may yield differing estimates of the sound power level of a source. Measurements on a given family of equipment should all be based on the same shape of measurement surface. The test code for a particular type of equipment should give detailed information on the particular measurement surface that is selected.

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 of such components. The procedures given are applicable to steady noise. These procedures may also be applied to non-steady noise as defined in ISO 2204, with the exception of an isolated burst of sound energy or a burst train with a repetition rate less than 10 per second.

1.2.2 Size of source

This International Standard is not applicable to noise sources with any linear dimension (length, width or height) which exceed 15 m.

1.3 Measurement uncertainty

Measurements made in conformity with this International Standard should result in standard deviations which are equal to or less than those given in table 2. The uncertainties in table 2 depend not only on the accuracies with which sound pressure levels and measurement surface areas are determined but also on the "near field error" which increases for smaller measurement distances and lower frequencies (i.e. those below 250 Hz). The contribution to the uncertainty of the error caused by small measurement distances may be checked by repeating the measurements at a larger measurement distance and comparing the resulting sound power levels. The near field error always leads to sound power levels which are higher than those determined with larger measurement distances.

NOTES

1 If the methods specified in this International Standard are 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 standard deviations which are less than that given in table 2, provided that the measurements are performed in the same environment with the same shape of measurement surface.

2 The standard deviations given in table 2 reflect the cumulative effects of all causes of measurement uncertainty, excluding variations in the sound power level 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 For a source which emits noise with a relatively "flat" spectrum in the 100 to 10 000 Hz frequency range, the A-weighted sound power level is determined with a standard deviation of approximately 2 dB. For outdoor measurements, the standard deviations in the octave band centered on 63 Hz will be approximately 5 dB.

Table 2 — Uncertainty in determining sound power levels for engineering measurements indoors or outdoors

Octave band centre frequencies	One-third octave band centre frequencies	Standard deviation of mean value
Hz	Hz	dB
125	100 to 160	3,0
250 to 500	200 to 630	2,0
1 000 to 4 000	800 to 5 000	1,5
8 000	6 300 to 10 000	2,5

2 References

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

ISO/R 354, *Measurement of absorption coefficients 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.*

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

1) At present at the stage of draft.

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.*

3 Definitions

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

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

3.2 free field over a reflecting plane : A sound field in the presence of one reflecting plane on which the source is located.

3.3 anechoic room : A test room whose surfaces absorb essentially all the incident sound energy over the frequency range of interest, thereby affording free-field conditions over the measurement surface.

3.4 semi-anechoic room : A test room with a hard reflecting floor whose other surfaces absorb essentially all the incident sound energy over the frequency range of interest, thereby affording free-field conditions above a reflecting plane.

3.5 surface sound pressure : The sound pressure averaged in time on a mean-square basis, averaged over the measurement surface using the averaging procedures specified in 8.1 *and corrected for the effects of background noise and the influence of reflected sound at the measurement surface.*

3.6 surface sound pressure level, in decibels, $\overline{L_{pf}}$: Ten times the logarithm to the base 10 of the ratio of the square of the surface sound pressure to the square of the reference sound pressure. The weighting network or the width of the frequency band used shall be indicated : for example, A-weighted sound pressure level, octave band sound pressure level, one-third octave band sound pressure level, etc. The reference sound pressure is 20 µPa.

3.7 sound power level, in decibels, L_W : Ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power. The weighting network or the width of the frequency band used shall be indicated; for example, A-weighted sound power level, octave band sound power level, one-third octave band sound power level, etc. The reference sound power is 1 pW (= 10^{-12} W).

NOTE — The mean sound pressure level at some reference radius is numerically different from the sound power level and its use in lieu of the sound power level is not recommended.

3.8 frequency range of interest : For general purposes, the frequency range of interest includes the octave bands with centre frequencies between 125 and 8 000 Hz and the one-third octave bands with centre frequencies between 100 and 10 000 Hz. Any band may be excluded in which the level is more than 50 dB below the highest band pressure level. For special purposes, the frequency range of interest may be extended at either end, provided the test environment and instrument accuracy are satisfactory for use over the extended frequency range. For sources which radiate predominantly high (or low) frequency sound, the frequency range of interest may be limited in order to optimize the test facility and procedures.

3.9 measurement surface : A hypothetical surface of area S enveloping the source on which the measuring points are located.

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

3.11 measurement distance : The minimum distance from the reference box to the measurement surface.

4 Acoustic environment

4.1 General

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

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.

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 Criteria for adequacy of the test environment

Ideally, the test environment should 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 (if any) to account for departures of the test environment from the ideal condition. Test environments which are suitable for engineering measurements permit the sound power level to be determined with an uncertainty that does not exceed the values given in table 2.

NOTE — If it is necessary to make measurements in spaces which do not meet the criteria of annex A, standard deviations of the test results may be greater than those given in table 2. In those cases, ISO 3746 describes applicable test procedures. In spite of this limitation, the sound power level determined according to this International Standard may be useful for obtaining a valid upper limit for the sound power level of a source.

4.3 Criterion for background noise

At the microphone positions, the sound pressure levels of the background noise shall be at least 6 dB and preferably more than 10 dB below the sound pressure level to be measured in each frequency band within the frequency range of interest.

NOTE — Levels of background noise less than 6 dB below the sound pressure levels to be measured are too high for the purposes of this International Standard. Under such circumstances, the survey method of ISO 3746 should be used.

Care shall be taken to minimize the effects of wind which may increase the apparent background noise. The appropriate instructions provided by the microphone manufacturer shall be followed.

5 Instrumentation

5.1 General

The instrumentation shall be designed to measure the mean-square value of the weighted sound pressure level and the octave or one-third octave band levels, averaged over time and over the measurement surface. Surface averaging is usually carried out by measuring the time-averaged sound pressure levels with a prescribed time constant for a fixed number of microphone positions (7.1) and computing the average value according to 8.1.

The instrumentation used can perform the required time-averaging in two different ways :

a) By continuous averaging of the squared signal using RC-smoothing with a time-constant τ_A. Such continuous averaging provides only an approximation of the true time-average, and it places restrictions on the "settling" time and observation time (see 7.4.3).

NOTE — An example of an instrument employing such averaging is a sound level meter fulfilling at least the requirements for a type 1 instrument in accordance with IEC Publication 651 with the time weighting characteristic "S". For noise which is impulsive in character, refer to annex F.

b) By integrating the squared signal over a fixed time-interval τ_D. This integration may be performed by either digital or analogue means.

Examples of suitable instrumentation systems are given in annex E.

5.2 The microphone and its associated cable

A condenser microphone, or the equivalent in accuracy, stability and frequency response, shall be used. The microphone shall have a flat frequency response, over the frequency range of interest, for the angle of incidence specified by the manufacturer.

NOTE — This requirement is met by a microphone of a standardized sound level meter fulfilling at least the requirements for a type 1 instrument in accordance with IEC Publication 651 and calibrated for free field measurements.

The microphone and its associated cable shall be chosen so that their sensitivity does not change over the temperature range encountered during the measurement. If the microphone is moved, care shall be exercised to avoid introducing acoustical noise (for example, wind noise) or electrical noise (for example, from gears, flexing cables, or sliding contacts) that could interfere with the measurements.

5.3 Frequency response of the instrumentation system

The frequency response of the instrumentation system for the angle of incidence specified by the manufacturer shall be flat over the frequency range of interest within the tolerances given for a type 1 instrument in IEC Publication 651.

5.4 Weighting network, frequency analyser

An A-weighting network fulfilling at least the requirements for a type 1 instrument in accordance with IEC Publication 651 and an octave band or one-third octave band filter set fulfilling the requirements of IEC Publication 225 shall be used. The centre frequencies of the frequency bands shall correspond to those of ISO 226.

NOTE — If other weighting networks are used in addition to A-weighting, the characteristics of such networks shall be reported.

5.5 Calibration

During each series of measurements, an acoustical calibrator with an accuracy of ± 0,5 dB shall be applied to the microphone for checking the calibration of the entire measuring system at one or more frequencies over the frequency range of interest. The calibrator shall be checked at least once every year to verify that its output has not changed. In addition, an acoustical and an electrical calibration of the instrumentation system over the entire frequency range of interest shall be carried out at least every 2 years.

6 Installation and operation of source

6.1 General

In many cases, the sound power emitted by a source depends upon its support or mounting conditions as well as the manner in which the source is operated. This clause gives general recommendations concerning the installation and operation of sources. Reference should be made to specific test codes for more detailed information concerning installation and operation of specific classes of sources (for example, rotating electrical machines).

Particularly for large machines, it is necessary to make a decision as to which components, subassemblies, auxiliary equipment, power sources, etc., belong to the source under test.

6.2 Source location

The source to be tested shall be installed and mounted with respect to the reflecting plane in one or more positions that are typical of normal usage, if practicable. If several possibilities exist, or if typical installation and mounting conditions are unknown, special arrangements are to be made and described in the test report. In locating the source within the test environment, it is important that sufficient space be allowed so that the measurement surface can envelop the machine according to the requirements of 7.1.

The source 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.

NOTE — The typical installation conditions for some sources involve two reflecting surfaces (for example an appliance installed against a wall) or free space (for example, 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 microphone arrays should be based on the general requirements of this International Standard and specified in specific test codes for such sources.

6.3 Source mounting

Many small sound sources (for example, ballasts for fluorescent lamps, electrical clocks), 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. Resilient mounting should be interposed if possible 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. However, such resilient mounts shall not be used if the device under test is not resiliently mounted in typical field installations.

6.4 Auxiliary equipment

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

6.5 Operation of source during test

During the acoustical measurements, the source shall be operated in a specified manner typical of normal use. One or more of 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 operating condition corresponding to maximum sound generation representative of normal use;

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

The sound power levels of sources may be determined for any desired set of operating conditions (i.e. temperature, humidity, device speed, etc.). These test conditions shall be selected beforehand and shall be held constant during the test. The source shall be in a stable operating condition before any noise measurements are made.

7 Sound pressure levels on measurement surface

7.1 Measurement surface

7.1.1 Reference surface and measurement surface

To facilitate the location of the microphone positions, a hypothetical reference surface is defined. This reference surface is the smallest possible rectangular box, i.e., rectangular parallelepiped, that just encloses the source and terminates on the reflecting plane. 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 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.

7.1.2 Co-ordinate system and definition of distance d_o

The location of the source under test, the measurement surface and the microphone positions are defined by a co-ordinate system with the horizontal axes x and y in the ground plane parallel to the length and width of the reference box and with the vertical axis z passing through the geometric centre of the box. The characteristic distance d_o is the distance from the origin of the co-ordinate system to one of the upper corners of the reference box :

$$d_o = [(0,5\, l_1)^2 + (0,5\, l_2)^2 + l_3^2]^{1/2}$$

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

7.1.3 Shape of measurement surface

Any one of the following three shapes may be used for the measurement surface :

1) a hemispherical surface of radius r;

2) *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;

3) a conformal surface which is the same as the rectangular parallelepiped except that the corners are rounded, the corners being formed by portions of cylinders and spheres. The measurement distance, d, is the distance from

the measurement surface to the reference box. Each point on the conformal surface is the same distance, d, from the closest point on the reference box.

For measurements on a series of similar sources (for example, machines of the same type), the use of the same shape of measurement surface is recommended. The specific 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.

7.1.4 Selection of measurement surface

7.1.4.1 General

When environmental conditions permit, use of the hemispherical measurement surface is usually preferred. When measurements are to be made close to the source because of adverse environmental conditions or other constraints, either a rectangular parallelepiped or a conformal surface may be used for the measurement surface. In general, the conformal surface is expected to yield a more accurate value of the sound power level than the rectangular parallelepiped, but use of the conformal surface requires more effort to position the microphones. The microphone positions on the conformal surface are at a uniform distance from the reference box which may be an advantage under some environmental conditions.

7.1.4.2 Hemispherical measurement surface

The hemisphere shall be centred on the projection on the reflecting plane of the geometric centre of the reference box. The radius, r, of the hemispherical measurement surface shall be equal to or greater than twice the characteristic distance, d_o, or four times the average distance of the geometric centre of the source from the reflecting plane, whichever is the larger, and not less than 1 m. The radius of the hemisphere is preferably in the series 1 — 2 — 4 — 6 — 8 — 10 — 12 — 14 or 16 m. Some of these radii may be so large that the environmental requirements given in annex A of this International Standard cannot be satisfied; such large values of the radii may not be used.

7.1.4.3 Parallelepiped and conformal measurement surfaces

If a hemispherical measurement surface is not selected, either a rectangular parallelepiped or a conformal surface may be selected as the shape of the 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 must be at least 0,25 m. The value of d shall preferably be one of the following : 0,25 — 0,5 — 1 — 2 — 4 or 8 m. Measurement distances larger than 1 m may be used only if the environmental requirements given in annex A of this International Standard are satisfied.

7.1.4.4 Additional considerations concerning choice of measurement surface

For machines 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 or conformal measurement surface. For machines 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.

If the dimensions of the reference box, l_1, l_2 and l_3, are all less than 1,0 m, the hemispherical surface is preferred. If one or more dimensions of the reference box exceeds 1,0 m, but the reference box is "approximately cubical" in shape, the hemisphere is still preferred. "Approximately cubical" means that the largest dimension is less than twice the smallest dimension. If any dimension of the reference box exceeds 1,0 m and the reference box is not approximately cubical in shape, then the parallelepiped (or conformal) measurement surface is preferred.

7.1.5 Key microphone positions on the hemispherical measurement surface

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. The centre of the hemisphere is the projection of the geometric centre of the reference box on the reflecting plane. The key microphone positions of the hemispherical surface are shown in figures 2 and 3 in annex B. Figure 3 prescribes the locations of ten key microphone positions each associated with equal areas on the surface of the hemisphere of radius r. The hemispherical array of figures 2 and 3 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.

7.1.6 Key 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 key microphone positions on the parallelepiped measurement surface are shown in figure 4 in annex C. The area S of the measurement surface is given by the formula

$$S = 4(ab + bc + ca)$$

where

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

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

$$c = l_3 + d$$

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

Figure 4 prescribes the locations of nine key microphone positions.

7.1.7 Key microphone positions on the conformal measurement surface

The microphone positions lie on the measurement surface, a hypothetical surface of area S enveloping the source which consists of an enclosure formed by a rectangular parallelepiped with rounded corners, the corners being formed by portions of cylinders and spheres. The measurement distance d is the distance from the perpendicular side of the measurement surface to the reference box. The conformal surface is that surface which is defined as being located everywhere a distance d from the nearest point on the envelope of the reference box (see figure 5 in annex D). The eight key microphone positions are shown in figure 6 in annex D.

The area S of the measurement surface is given approximately by the formula

$$S = 4\,(ab + bc + ca) \times \frac{a + b + c}{a + b + c + 2d}$$

where a, b, c and d are the same as for the rectangular parallelepiped.

7.2 Additional microphone positions on measurement surface

7.2.1 General

In 7.1, the key microphone positions on the three alternative measurement surfaces are described. Sound pressure level measurements shall always be obtained at all of the key microphone positions unless the criterion of 7.3 is satisfied. Sound pressure level measurements may be required at additional microphone positions 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) if any dimension of the reference box is larger than $2d$, or

c) if the source radiates noise with a high directivity, or

d) if 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 conditions a) or b) exist, additional microphone positions defined in 7.2.2 shall be used. If conditions c) or d) exist, additional measurement positions on the measurement surface in the region of high noise radiation shall be used (see 7.2.4).

7.2.2 Location of additional microphone positions

7.2.2.1 Hemispherical measurement surface

For the microphone array on the hemisphere, an additional ten-point array is defined by rotating the original array of figure 3 through 180° about the z-axis. 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 ten to twenty.

7.2.2.2 Rectangular parallelepiped

For the rectangular parallelepiped array, the additional microphone positions are shown in figure 4. The total number of microphone positions is increased from nine to seventeen.

7.2.2.3 Conformal surface

For the conformal surface, the additional microphone positions are shown in figure 6. The total number of microphone positions is increased from eight to sixteen.

7.2.3 Sufficiency of number of microphone positions

In general, the key microphone positions and the additional microphone positions defined in 7.2.2.1, 7.2.2.2 or 7.2.2.3 are sufficient for the purposes of measurements obtained according to this International Standard. The only exception is for very large sources, i.e., those for which the characteristic distance d_0 exceeds 5,0 m. In this case, additional microphone positions are required. They should be uniformly distributed over the measurement surface and preferably not more than $2d$ apart.

7.2.4 Additional localized microphone positions on measurement surface

If conditions c) or d) of 7.2.1 exist, a detailed investigation may be 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 level 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, sub-clause 7.7.1.2 (unequal areas), for the determination of L_W shall be used.

7.3 Reduction of number of microphone positions

For sources that produce a symmetrical radiation pattern, it may be sufficient to distribute the measurement points over only a portion of the measurement surface. This is permissible if preliminary investigation shows that the surface sound pressure levels so determined according to the calculation procedures of clause 8 do not deviate by more than 1 dB from those determined from measurements over the entire measurement surface.

7.4 Conditions of measurement

7.4.1 General

Environmental conditions may have an adverse effect on the microphone used for the measurements. Such conditions (for example, strong electric or magnetic fields, wind, impingement of air discharge from the equipment being tested, high or low temperatures) must be avoided by proper selection or