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Acoustics — Measurement of airborne noise emitted by construction equipment intended for outdoor use — Method for determining compliance with noise limits

Acoustique — Mesurage du bruit aérien émis par les machines et équipements de construction destinés à être utilisés à l'air libre — Méthode de vérification de la conformité en ce qui concerne les limites de bruit

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FOREWORD

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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 4872 was developed by Technical Committee ISO/TC 43, *Acoustics*, and was circulated to the member bodies in July 1976.

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

Austria	Hungary	Norway
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Czechoslovakia
Switzerland
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Acoustics — Measurement of airborne noise emitted by construction equipment intended for outdoor use — Method for determining compliance with noise limits

0 INTRODUCTION

This International Standard describes a method for measuring the noise emitted by construction equipment and machines intended for outdoor use. The method allows the determination of the acoustical characteristics of a sound source in terms of its A-weighted sound power level. The values obtained by this method are the fundamental quantities for characterizing the sound output. The results may be used for comparison with noise limits. In this case, the A-weighted sound power levels determined according to this International Standard are to be considered as guaranteed values which include all sources of measurement uncertainty.

The A-weighted sound power level of a device or machine is calculated from the measured values of the A-weighted sound pressure level at several microphone positions located on a hypothetical measurement surface which envelops the source. One of two alternative measurement surfaces may be selected :

- a hemispherical surface, or
- a rectangular parallelepipedal surface.

The method requires that the background noise be significantly lower than the noise produced by the source. Annex A gives procedures for qualifying the acoustic environment for the purpose of measurements made according to the requirements of this International Standard and for determining the magnitude of the environmental correction (if any).

Only the acoustical requirements for measurements in a free field over a reflecting plane are defined in this International Standard. The operating and mounting conditions of the device or machine are described in general terms. For specific types of machine, for example concrete mixers, compressors, earth-moving machinery, etc., reference should be made to special test codes which give detailed information on operating and mounting conditions and the array of microphone positions to be selected from those given in this International Standard.

1 SCOPE AND FIELD OF APPLICATION

1.1 General

This International Standard describes a method for measuring the weighted sound pressure levels at prescribed microphone positions in the proximity of a device or machine for outdoor use, in order to determine compliance with noise limits. The A-weighted sound power level of the source is calculated from the measured values.

NOTES

1 When nine or more microphone positions are prescribed in the proximity of the source (as in clause 7), the A-weighted sound power levels determined in accordance with this International Standard tend to result in standard deviations less than approximately 2,0 dB, provided that the spectrum does not contain pronounced discrete frequencies; if it does, the magnitude of the uncertainties will be larger and no general rules for the magnitude of the uncertainties can be given. These standard deviations reflect the cumulative effects of all causes of measurement uncertainty, excluding variations in the sound power level from machine to machine or from test to test, which may be caused, for example, by changes in the mounting or operating conditions of the source.

2 For measurements made using a hemispherical measurement surface, the directivity index of the source may be calculated according to the description of annex B.

3 Measurement of A-weighted sound pressure levels at the operator's position(s) is not described in this International Standard.

4 The results of noise measurements made according to this International Standard are obtained under prescribed conditions and will not necessarily correspond to the noise experienced from the equipment when it is in operation on a construction site.

1.2 Field of application

1.2.1 *Types of noise*

This International Standard applies to sources which radiate broad-band noise, narrow-band noise, discrete tones and combinations thereof. Procedures given in this International Standard are primarily applicable to sources that radiate steady noise. These procedures may also be applied to sources that radiate non-steady noise, quasi-steady noise and impulsive noise, provided that certain precautions are taken (see 7.8).

1.2.2 *Size of source*

In principle, the method given in this International Standard does not restrict the size of the machine to be measured; for very large machines the procedure may, however, lead to microphone positions which are impracticable to use.

NOTE — In such cases the noise source may often be defined as being part of the complete machine. In some cases of excessively large plant, for example conveyer systems extending to hundreds of metres in length, it will be possible to identify separate pieces of noisy machinery which are part of the whole and to which the procedure of this International Standard may be applied individually.

2 REFERENCES

ISO/R 1996, *Acoustics — Assessment of noise with respect to community response.*

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

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

IEC Publication 179, *Precision sound level meters.*

IEC Publication 179A, (First supplement to IEC Publication 179), *Additional characteristic for the measurement of impulsive noise.*

3 DEFINITIONS

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

3.1 sound pressure level, L_p : Twenty times the logarithm to the base 10 of the ratio of the sound pressure to the reference sound pressure, expressed in decibels. For the purposes of this International Standard, the A-weighting network shall always be used, yielding the A-weighted sound pressure level, L_{pA}. The reference sound pressure is 20 μPa.

3.2 surface sound pressure level, $\overline{L_{pA}}$: The mean sound pressure level A-weighted over the measurement surface as required in clause 8.

3.3 sound power level, L_W : Ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power, expressed in decibels. For the purposes of this International Standard, A-weighting shall always be used, yielding the A-weighted sound power level, L_{WA}. The reference sound power is 1 pW (= 10^{-12} W).

3.4 measurement surface : A hypothetical surface of area S which envelops the source and on which the microphone positions are located.

3.5 background noise : At the microphone positions on the measurement surface, the A-weighted sound pressure levels of the noise which is not generated by the source under test.

4 ACOUSTIC ENVIRONMENT

4.1 Criterion 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 a procedure for determining the magnitude of the environmental correction (if any) to account for departures of the test environment from the ideal condition.

4.2 Criterion for background noise

At the microphone positions, the A-weighted sound pressure level due to the background noise shall be at least 6 dB, and preferably more than 10 dB, below the A-weighted sound pressure level with the source operating.

4.3 Wind

The wind speed at the test site shall be less than 8 m/s. For wind speeds in excess of 1 m/s, a microphone windscreen shall be used and appropriate compensation for the effects of its use shall be allowed for in the calibration.

5 INSTRUMENTATION

5.1 General

The instrumentation shall be designed to permit the determination of the value of the A-weighted sound pressure level averaged over time on an energy basis. Tolerances of the several sections of the measuring chain shall not exceed the tolerances given in the relevant clauses of IEC Publications 179 and 179A.

NOTES

1 An example of an appropriate instrument for these measurements is a sound level meter that meets the requirements of IEC Publication 179 with a "slow" meter chatacteristic. For establishing the presence of impulsive noise, the "impulse" meter characteristic according to IEC Publication 179A shall be used in addition.

2 Another example of an appropriate instrumentation system is an integrator which effects an analogue or digital integration of the squared signal over a given time-interval.

5.2 Microphone and associated cable

To minimize the influence of the observer on the measurements, a cable should preferably be used between the microphone and the sound level meter. The observer shall not stand between the microphone and the source whose sound power level is being determined. The microphone shall comply with the specifications given in IEC Publication 179.

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 within the tolerances given in IEC Publication 179.

5.4 Calibration

At least before and after each series of measurements, an acoustical calibrator with an accuracy of ± 0,5 dB shall be applied to the microphone for calibration of the entire measuring cable, if used, at one or more frequencies. One calibration frequency should be in the range 250 to 1 000 Hz. The calibrator shall be checked annually to verify that its output has not changed.

6 INSTALLATION AND OPERATION OF SOURCE

6.1 General

In many cases, the sound radiated by a source depends upon its support and/or mounting conditions as well as the manner in which it is operated. This clause gives general recommendations concerning the installation and operation of sources. More detailed information concerning the installation and operation of specific kinds of machinery is given in special test codes which shall be referred to when carrying out detailed tests on a specific machine.

6.2 Auxiliary equipment

The description of the sound source under test (see 9.1) shall define precisely the items of equipment that are to be considered as integral parts of the sound source and the items of equipment that are to be considered auxiliary to the sound source.

If possible, all auxiliary equipment necessary for the operation of the device under test that is not a part of the source shall be located so as not to influence the results of the test; all such auxiliary equipment should be located outside of, or acoustically isolated from, the test environment. Sound sources which operate with interchangeable devices (for example pneumatic tools) shall be operated with at least one principal device with which the sound source is designed to operate and possibly with the device which yields the maximum noise.

6.3 Operation of source during tests

During the acoustical measurements, the source shall be operated in a specified manner typical of normal use. Before the measurements are made, the device or machine under test shall be permitted to reach a stable operating condition. Reference shall be made to the test code appropriate for the device or machine for detailed instructions concerning the operation of the source during the test.

Each test shall preferably include an evaluation of the sound source under no load (idling) at the rated engine speed and one or more tests carried out under load. When operating under load, either real or simulated working conditions may be prescribed.

If no special test code exists, one or more of the following operational conditions should be used :

a) device under specified 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.

In defining operating conditions for a machine under test, it is particularly important to consider noise generated not only by the machine itself but also by the tools, work materials or work surfaces in close contact with the machine or excited by the operation of the machine. For example, the noise emitted by a circular saw operating in free air is quite different from that emitted by the saw when cutting through a piece of plywood. For machines that operate in this manner it is necessary that the special test code for these machines describe in detail the test conditions including the tools, work materials and work surfaces that radiate sound energy when the machine itself is in operation.

7 MEASUREMENT OF A-WEIGHTED SOUND PRESSURE LEVELS

7.1 Reference parallelepiped and measurement surface

To facilitate the location of the microphone positions, the smallest possible imaginary rectangular parallelepiped (lenght l_1, width l_2, height l_3) just enclosing the source and terminating on the reflecting plane is used for reference purposes. When defining the reference parallelepiped, small elements protruding from the source which are unlikely to be major radiators of sound energy may be disregarded.

The microphone positions lie on the measurement surface, a hypothetical surface of area S which envelops the source as well as the reference parallelepiped and terminates on the reflecting plane. One of two alternative measurement surfaces may be used :

— a hemispherical surface, or

— a rectangular parallelepipedal surface shose sides are parallel to those of the reference parallelepiped (in this case, the measurement distance d is the shortest distance between the measurement surface and the reference parallelepiped).

The construction of the reference parallelepiped, the size and shape of the measurement surface as well as the measurement distance or the radius of the hemisphere shall be described as defined in the special test code for the kind of machine under investigation. For measurements on a series of similar sources (for example concrete mixers, compressors, etc.), the use of a measurement surface of the same shape is recommended.

7.2 Microphone positions on the hemispherical measurement surface

7.2.1 *General*

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 parallelepiped on the reflecting plane. The radius of the hemisphere (r) is at least twice the largest dimension of the reference parallelepiped (l_1, l_2 or l_3). The radius of the hemisphere shall be rounded off to the nearest higher integer value, preferably in the series 4–6–8–10 m ... The same value for the radius of the hemisphere shall be used for measurements on all machines of the same family unless otherwise directed by the test code. For large machines, the reference surface may be defined to enclose only the principal source or sources of noise, thus reducing the radius of the hemispherical measurement surface. In this case, preliminary measurements on at least one machine of a given type should be carried out (in addition to those measurements required by 7.3.2) to demonstrate that the calculated value of the sound power level is the same as that determined using a larger hemispherical measurement surface.

Two possibilities for the distribution of microphone positions on the hemispherical measurement surface are given as alternatives in 7.2.2 and 7.2.3.

It must be clearly stated in the test report which of the alternatives, A or B, for the distribution of microphone positions on the hemisphere has been chosen.

NOTE — For sources which radiate sound having a broad-band spectrum, the two distributions of microphone positions are likely to yield the same result within the given accuracy.

7.2.2 *Alternative A*

The locations of 10 microphone positions distributed on the surface of a hemisphere of radius r are shown in figure 1 and tabulated in table 1.

NOTES

1 The overhead position (microphone position No. 10 in figure 1) may be deleted for safety reasons or if it can be shown by preliminary investigation that the exclusion of the overhead position does not significantly influence the calculated sound power level of the source.

2 For non-directional machines and for machines having unusual configurations, any of the microphone positions in the array described in figure 1 may be deleted following the instructions of the special test code for the machine under investigation.

7.2.3 *Alternative B*

The location of 12 microphone positions distributed on the surface of a hemisphere of radius r are shown in figure 2 and tabulated in table 2.

NOTE — For non-directional machines and for machines having unusual configurations, any of the microphone positions in the array described in figure 2 may be deleted following the instructions of the special test code for the machine under investigation.

7.3 Microphone positions on the parallelepipedal 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 rectangular parallelepiped and situated at a distance d (measuring distance) from the parallelepiped. The measuring distance, d, is preferably selected from the series 1, 2, 4 m. The key measurement positions are shown in figure 3. For larger machines, the nine key measurement positions shall be supplemented by additional measurement positions as shown in figure 3. Additional measurement positions are necessary whenever the distance between two adjacent measurement positions is greater than twice the measuring distance, d (see also note 3). The height, h, of the four lower key microphone positions and the height of the upper five positions are given by the following expression :

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

NOTES

1 The overhead position may be deleted for safety reasons or if it can be shown by a preliminary investigation that the exclusion of the overhead position does not significantly influence the calculated sound power level of the source.

2 For non-directional machines and for machines having unusual configurations, any of the microphone positions in the array described in figure 3 may be deleted following the instructions of the special test code for the machine under investigation.

3 Measurements at additional microphone positions are not necessary if the difference, in decibels, between the highest and lowest sound pressure levels measured at the positions defined in figure 3 is numerically less than the number of measurement positions.

7.4 Choice of measurement surface

While the hemispherical measurement surface is an appropriate choice for many construction machines, it may not always be appropriate for very large machines, for test sites in which the background noise is relatively high and when an extended reflecting plane is not available. Under these circumstances, it may be appropriate to choose a parallelepipedal measurement surface.

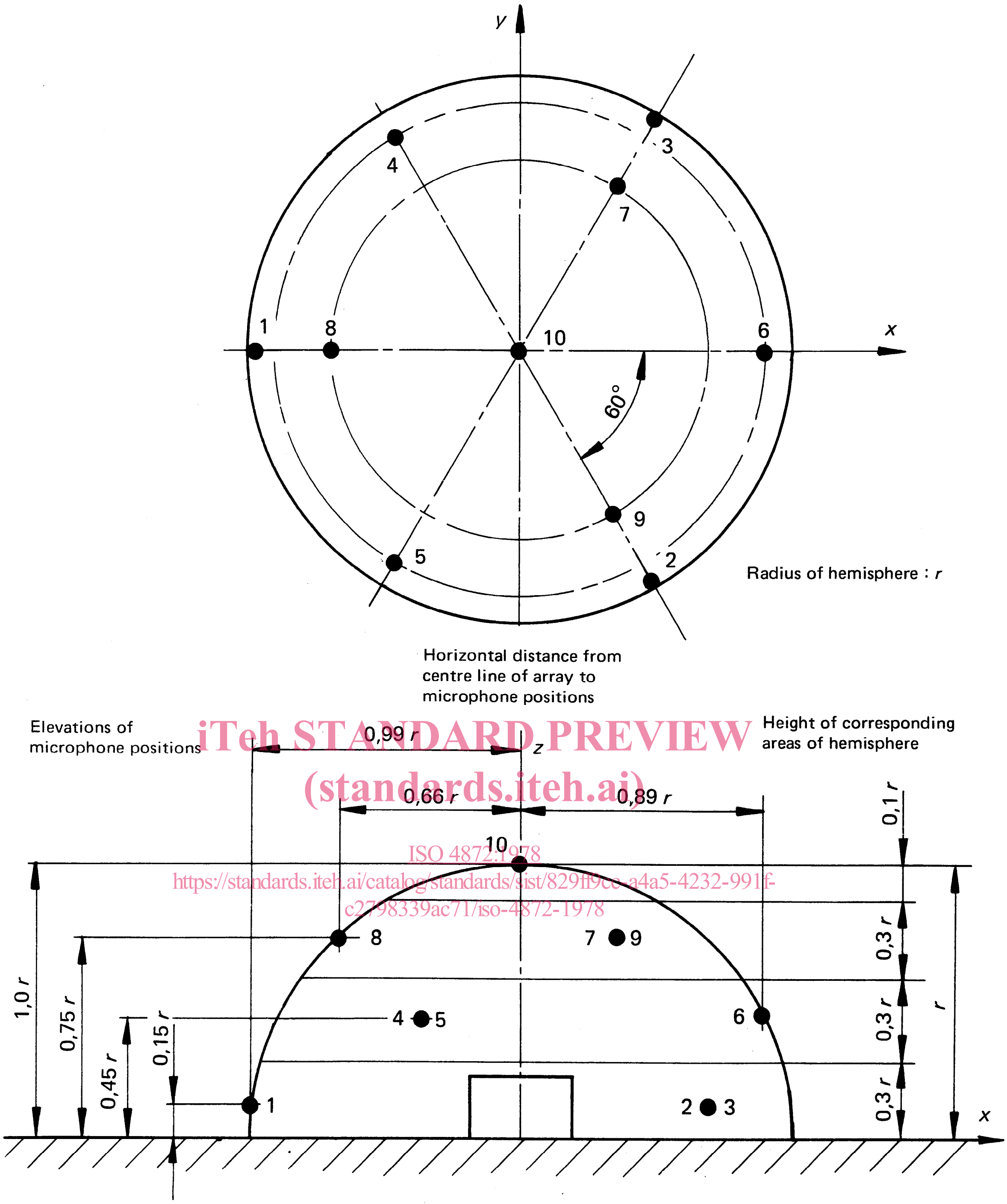

FIGURE 1 — **Microphone array on the hemisphere (Alternative A)** (see 7.2.2)

TABLE 1 — **Co-ordinates of the 10 measurement points**

No.	$\frac{x}{r}$	$\frac{y}{r}$	$\frac{z}{r}$
1	– 0,99	0	0,15
2	0,50	– 0,85	0,15
3	0,50	0,85	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

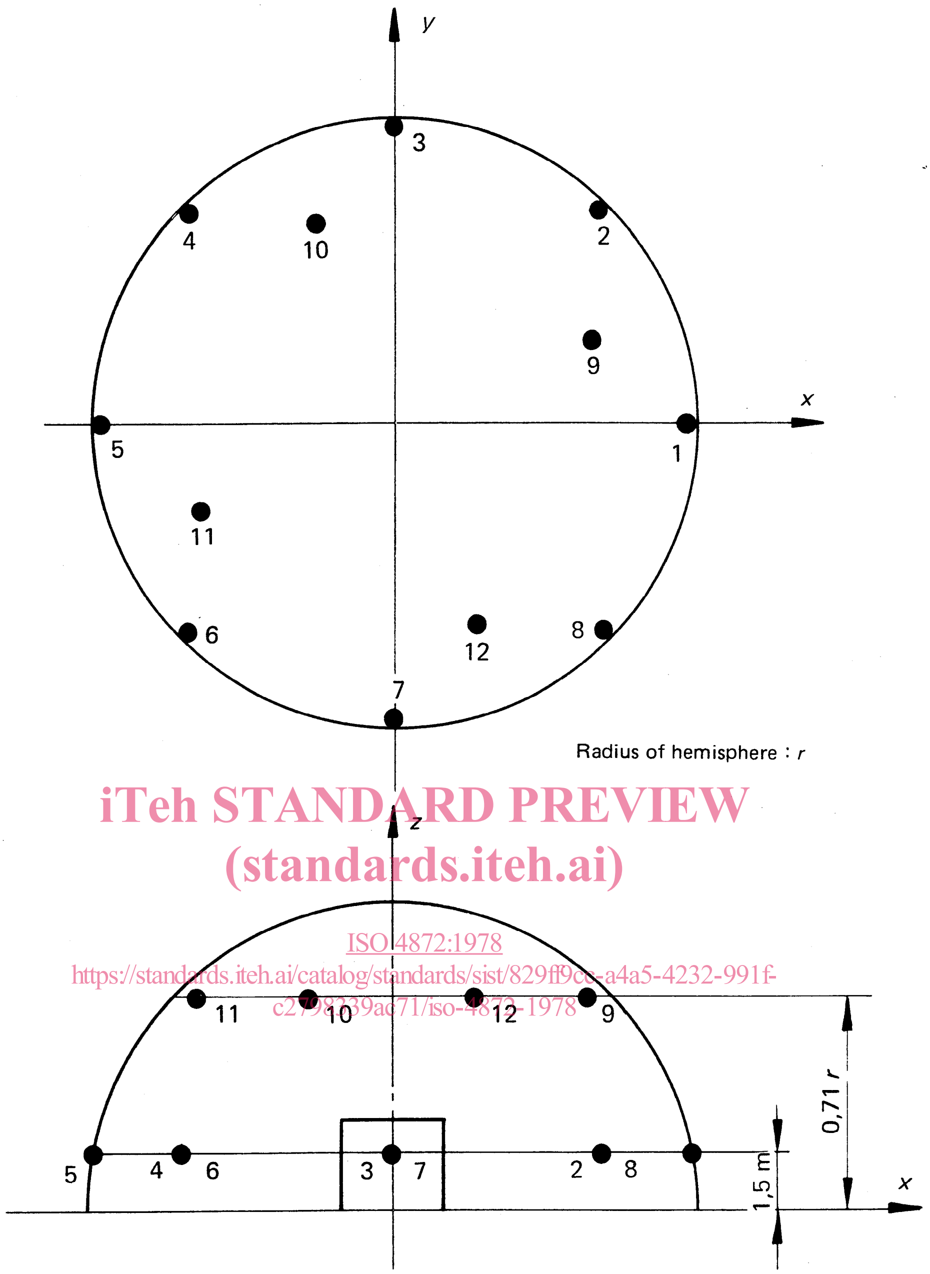

FIGURE 2 – **Microphone array on the hemisphere (Alternative B)** (see 7.2.3)

TABLE 2 – **Co-ordinates of the 12 measurement points**

No.	$\frac{x}{r}$	$\frac{y}{r}$	z
1	1	0	1,5 m
2	0,7	0,7	1,5 m
3	0	1	1,5 m
4	– 0,7	0,7	1,5 m
5	– 1	0	1,5 m
6	– 0,7	– 0,7	1,5 m
7	0	– 1	1,5 m
8	0,7	– 0,7	1,5 m
9	0,65	0,27	0,71 r
10	– 0,27	0,65	0,71 r
11	– 0,65	– 0,27	0,71 r
12	0,27	– 0,65	0,71 r

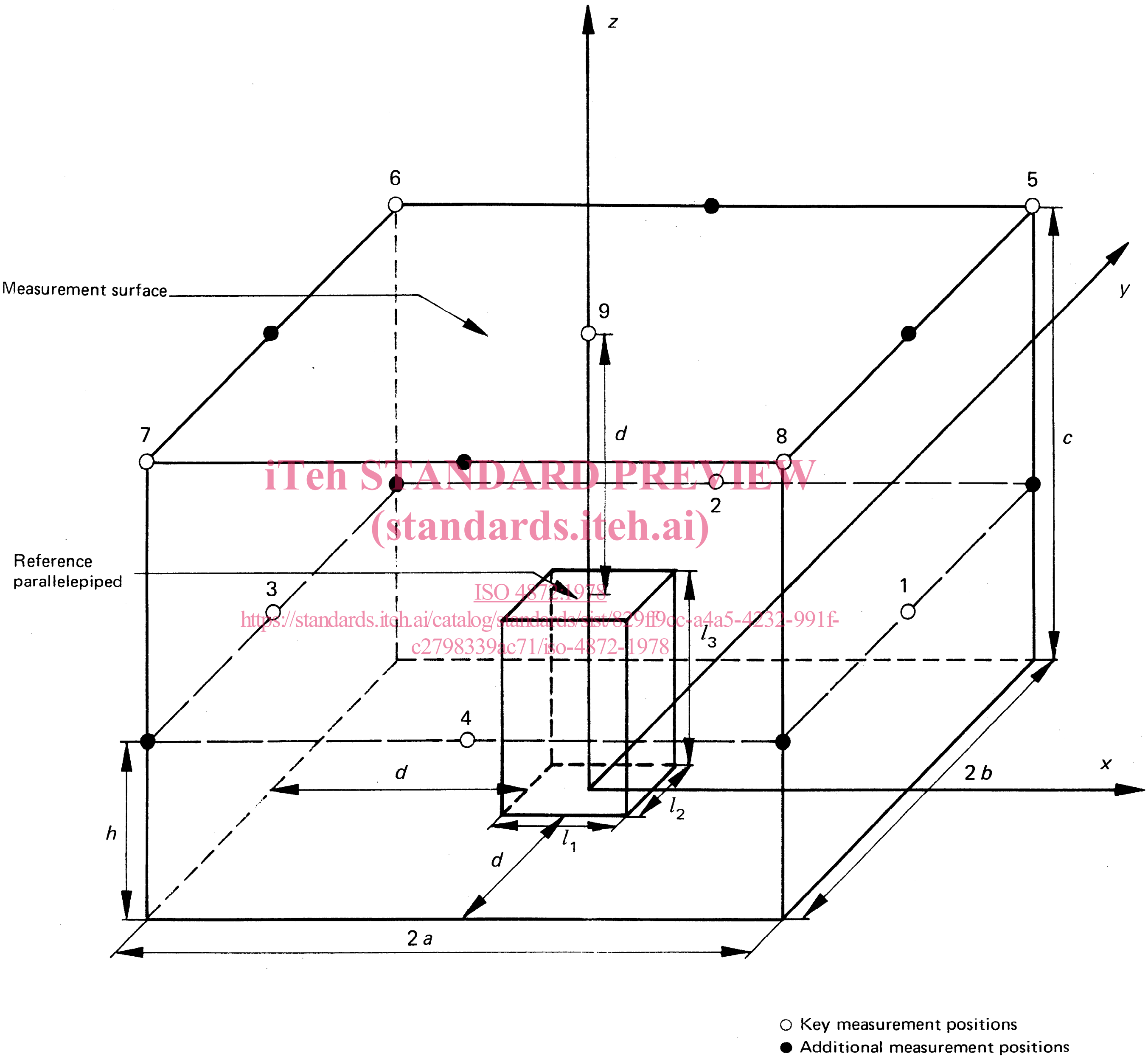

FIGURE 3 — **Microphone array on the parallelepiped** (see 7.3)