AS 1217.5—1985

Australian Standard®

ACOUSTICS—DETERMINATION OF SOUND POWER LEVELS OF NOISE SOURCES

Part 5—ENGINEERING METHODS FOR FREE-FIELD CONDITIONS OVER A REFLECTING PLANE

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PREFACE

This standard was prepared by the Association's Committee on Techniques for Measurement. It supersedes AS 1217 — 1972, Methods of Measurement of Airborne Sound Emitted by Machines.

This standard is based on ISO 3744 — 1981, Acoustics—Determination of Sound Power Levels of Noise Sources—Engineering Methods for Free-field Conditions Over a Reflecting Plane.

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STANDARDS ASSOCIATION OF AUSTRALIA

Australian Standard

for

ACOUSTICS — DETERMINATION OF SOUND POWER LEVELS OF NOISE SOURCES

PART 5 — ENGINEERING METHODS FOR FREE-FIELD CONDITIONS OVER A REFLECTING PLANE

FOREWORD

This standard is one of a series setting out 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 A.

In the application of 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 the basic documents.

Guidelines for making these decisions are provided in AS 1217.1. If no sound test method is specified for a particular machine, the mounting and operating conditions shall be fully described in the test report.

SYNOPSIS

Applicability. This standard sets out 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 comply with the requirements of this standard. If the test room does not comply with the requirements of this standard, measurements made in accordance with AS 1217.7 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 set out in this standard conform to the general recommendations included in ISO 2204. The methods permit the determination of sound power level both in frequency bands and directly as an A-weighted value.

TABLE A
BASIC STANDARDS SPECIFYING VARIOUS METHODS FOR DETERMINING THE SOUND POWER LEVELS OF MACHINES AND EQUIPMENT

AS number	Classification of method	Test environment	Volume of source	Character of noise	Sound power levels obtainable	Optional information available
AS 1217.2	Precision	Reverberation room complying with specified requirements	Preferably less than 1 percent of test room volume	Steady, broad-band	In one-third octave or octave bands	A-weighted sound power level
AS 1217.3				Steady, discrete-frequency, or narrow-band		
AS1217.4	Engineering	Special reverberation test room		Steady, broad-band narrow-band, or discrete-frequency	A-weighted and in octave bands	Other weighted sound power levels
AS 1217.5	Engineering	Outdoors or in large room	Greatest dimension less than 15 m	Most	A-weighted and in one-third octave or octave bands	Directivity information and sound pressure levels as a function of time; other weighted sound power levels
AS 1217.6	Precision	Anechoic or hemi-anechoic room	Preferably less than 0.5 percent of test room volume	Most		
AS 1217.7	Survey	No special test environment	No restrictions; limited only by available test environment	Most	A-weighted	Sound pressure levels as a function of time; other weighted sound power levels

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, steady, non-steady, broad band, discrete frequency, narrow-band as defined in AS 1633 and SAA MP 44, Part 1.
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 band; directivity characteristics of the source (optional).

SECTION 1. SCOPE AND GENERAL

1.1 SCOPE. This standard sets out 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.

NOTES:

1. This 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 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.
2. 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 method 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 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 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 standard is not applicable to noise sources with any linear dimension (length, width or height) which exceeds 15 m.

1.3 REFERENCED DOCUMENTS. The following documents are referred to in this standard:

AS 1045	Method of Measurement of Absorption Coefficients in a Reverberation Room
AS 1217.1	Acoustics — Determination of Sound Power Levels of Noise Sources, Part 1 — Guidelines for the Use of Basic Standards and for the Preparation of Noise Test Codes
	Acoustics — Determination of Sound Power Levels of Noise Sources, Part 2 — Precision Methods for Broadband Sources in Reverberation Rooms
	Acoustics — Determination of Sound Power Levels of Noise Sources, Part 3 — Precision Methods for Discrete-frequency and Narrow-band Sources in Reverberation Rooms
	Acoustics — Determination of Sound Power Levels of Noise Sources, Part 4 — Engineering Methods for Special Reverberation Test Room
	Acoustics — Determination of Sound Power Levels of Noise Sources, Part 6 — Precision Methods for Anechoic and Hemi-anechoic Rooms
	Acoustics — Determination of Sound Power Levels of Noise Sources, Part 7 — Survey Method
AS 1259	Sound Level Meters
AS 1633	Glossary of Acoustic Terms
AS 2533	Acoustics — Preferred Frequencies for Measurements
AS Z41	Octave, Half Octave and One-third Octave Band Pass Filters Intended for the Analysis of Sound and Vibrations
ISO 2204	Acoustics — Guide to International Standards on the Measurement of Airborne Acoustical Noise and Evaluation of Its Effects on Human Beings
ISO 6926	Acoustics — Determination of Sound Power Levels of Noise Sources — Characterization and Calibration of Reference Sound Sources

1.4 MEASUREMENT UNCERTAINTY. Measurements made in conformity with this standard should result in standard deviations which are equal to or less than those given in Table 1.1. The uncertainties in Table 1.1 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 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 1.1, provided that the measurements are performed in the same environment with the same shape of measurement surface.
2. The standard deviations given in Table 1.1 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 1.1 would indicate.
3. For a source which emits noise with a relatively 'flat' spectrum in the frequency range 100 Hz to 10 000 Hz, 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 centred on 63 Hz will be approximately 5 dB.

TABLE 1.1
UNCERTAINTY IN DETERMINATIONS OF SOUND POWER LEVELS FOR ENGINEERING MEASUREMENTS INDOORS OR OUTDOORS

Octave band centre frequencies Hz	One-third octave band centre frequencies Hz	Standard deviation 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

1.5 DEFINITIONS. For the purposes of this standard, the following definitions apply:

NOTE: For definitions of other related acoustics terms, see AS 1633.

1.5.1 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.

1.5.2 Free-field over a reflecting plane — a sound field in the presence of one reflecting plane on which the source is located.

1.5.3 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.

1.5.4 Hemi-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.

1.5.5 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 Clause 6.1 and corrected for the effects of background noise and the influence of reflected sound at the measurement surface.

1.5.6 Surface sound pressure level — 10 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. This quantity is denoted by $\bar{L}_{pf}$. The weighting network or the width of the frequency band used is indicated, e.g. A-weighted sound pressure level, octave band sound pressure level, one-third octave band sound pressure level. The reference sound pressure is 20 μPa. Unit: decibel (dB).

1.5.7 Sound power level — 10 times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power. This quantity is denoted by L_W. The weighting network or the width of the frequency band used is indicated, e.g. A-weighted sound power level, octave band sound power level, one-third octave band sound power level. The reference sound power is 1 pW (= 10^{-12} W). Unit: decibel (dB).

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.

1.5.8 Frequency range of interest — for general purposes, the frequency range of interest includes the octave bands with centre frequencies between 125 Hz and 8000 Hz and the one-third octave bands with centre frequencies between 100 Hz 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 that 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.

1.5.9 Measurement surface — a hypothetical reference surface area *S* enveloping the source on which the measuring points are located.

1.5.10 Reference box — a hypothetical reference surface which is the smallest rectangular parallelepiped that just encloses the source and terminates on the reflecting plane.

1.5.11 Measurement distance — the minimum distance from the reference box to the measurement surface.

SECTION 2 ACOUSTIC ENVIRONMENT

2.1 GENERAL. The test environments that are suitable for measurements according to this standard include —

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

(b) a flat outdoor area that complies with the requirements of Clause 2.2 and Appendix A; and

(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.

2.2 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. Appendix 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 1.1.

NOTE: If it is necessary to make measurements in spaces which do not comply with the criteria of Appendix A, standard deviations of the test results may be greater than those given in Table 1.1. In those cases, AS 1217.7 describes applicable test procedures. In spite of this limitation, the sound power level determined according to this standard may be useful for obtaining a valid upper limit for the sound power level of a source.

2.3 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 standard. Under such circumstances, the survey method of AS 1217.7 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.

SECTION 3. INSTRUMENTATION

3.1 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 (see Clause 5.1) and computing the average value according to Clause 6.1.

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

(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 'setting' time and observation time (see Clause 5.4.3).

NOTE: An example of an instrument employing such averaging is a sound level meter fulfilling at least the requirements for a Type 2 instrument in accordance with AS 1259, with the time-weighting characteristic 'S'. For noise which is impulsive in character, see Appendix 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 Appendix E.

3.2 THE MICROPHONE AND ITS ASSOCIATED CABLE. A capacitor 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 complied with by a microphone of a standardized sound level meter complying with the requirements for a Type 2 instrument in accordance with AS 1259, 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 (e.g. wind noise) or electrical noise (e.g. noise from gears, flexing cables, or sliding contacts) that could interfere with the measurements.

3.3 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 2 instrument in AS 1259.

3.4 WEIGHTING NETWORK, FREQUENCY ANALYSER. An A-weighting network complying with the requirements for a Type 2 sound level meter in accordance with AS 1259, and an octave band or one-third octave band filter set complying with AS Z41 shall be used. The centre frequencies of the frequency bands shall correspond to those of AS 2533.

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

3.5 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.

SECTION 4. INSTALLATION AND OPERATION OF SOURCE

4.1 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 Section gives general recommendations concerning the installation and operation of sources. Reference should be made to specific test methods for more detailed information concerning installation and operation of specific classes of sources, e.g. 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.

4.2 SOURCE POSITION. 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 positioning 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 Clause 5.1.

The source shall be placed at a sufficient distance from any reflecting wall or ceiling or any reflecting object so that the requirements given in Appendix A are complied with on the measurement surface.

NOTE: The typical installation conditions for some sources involve two reflecting surfaces, e.g. 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 microphone arrays should be based on the general requirements of this standard and specified in specific test codes for such sources.

4.3 SOURCE MOUNTING. Many small sound sources, e.g. 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 of 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.

4.4 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 Clause 4.1) shall be placed outside the test environment.

4.5 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) above).

(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, e.g. temperature, humidity, device speed. 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.

SECTION 5. SOUND PRESSURE LEVELS ON MEASUREMENT SURFACE

5.1 MEASUREMENT SURFACE.

5.1.1 Reference surface and measurement surface. To facilitate the positioning of the microphones, 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. In the defining of 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 methods 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.

5.1.2 Coordinate system and definition of distance d_o. The position 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 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 coordinate system to one of the upper corners of the reference box:

$$d_o = [(0.5l_1)^2 + (0.5l_2)^2 + l_3^2]^{1/2}$$

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

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

(a) A hemispherical surface of radius r.

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

(c) 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, e.g. machines of the same type, the use of the same shape of measurement surface is recommended. The specific test method 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.

5.1.4 Selection of measurement surface.

5.1.4.1 *General.* Where environmental conditions permit, use of the hemispherical measurement surface is usually preferred. Where measurements are to be made close to the source because of adverse environmental conditions or other constraints, either a rectangular parallelepiped or 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.

5.1.4.2 *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 4 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 Appendix A of this standard cannot be complied with; such large values of the radii may not be used.

5.1.4.3 *Parallelepiped and conformal measurement surfaces.* If a hemispherical measurement surface is not selected, either a rectangular parallelepiped or 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 Appendix A of this standard are complied with.

5.1.4.4 *Additional considerations concerning choice of measurement surface.* For machines usually mounted and/or to be measured in rooms or spaces under unfavourable acoustical conditions, e.g. 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.

5.1.5 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 Figs B1 and B2 in Appendix B. Fig. B2 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 Figs B1 and B2 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.

5.1.6 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 Fig. C1 in Appendix C. The area S of the measurement surface is given by the following equation:

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

where

$$a = 0.5l_1 + d$$
$$b = 0.5l_2 + d$$
$$c = l_3, + d$$

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

Fig. C1 prescribes the sites of nine key microphone positions.

5.1.7 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 Fig. D1 in Appendix D) . The eight key microphone positions are shown in Fig. D2 in Appendix D.

The area S of the measurement surface is given approximately by the following equation:

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

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

5.2 ADDITIONAL MICROPHONE POSITIONS ON MEASUREMENT SURFACE.

5.2.1 General. In Clause 5.1, 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 Clause 5.3 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;

(b) if any dimension of the reference box is larger than $2d$;

(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, e.g. the openings of an otherwise enclosed machine.

If condition (a) or condition (b) exists, additional microphone positions defined in Clause 5.2.2 shall be used. If condition (c) or condition (d) exists, additional measurement positions on the measurement surface in the region of high noise radiation shall be used (see Clause 5.2.4).

5.2.2 Positions of additional microphones.

5.2.2.1 *Hemispherical measurement surface.* For the microphone array on the hemisphere, an additional 10-point array is defined by rotating the original array of Fig. B2 through 180 degrees 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 10 to 20.

5.2.2.2 *Rectangular parallelepiped.* For the rectangular parallelepiped array, the additional microphone positions are shown in Fig. C1 in Appendix C. The total number of microphone positions is increased from 9 to 17.

5.2.2.3 *Conformal surface.* For the conformal surface, the additional microphone positions are shown in Fig. D2 in Appendix D. The total number of microphone positions is increased from 8 to 16.

5.2.3 Sufficiency of number of microphone positions. In general, the key microphone positions defined in Clauses 5.2.2.1, 5.2.2.2 and 5.2.2.3 are sufficient for the purposes of measurements obtained according to this standard. The only exception is for very large sources, i.e. those for which the characteristic distance d_o 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.

5.2.4 Additional localized microphone positions on measurement surface. If condition (c) or condition (d) of Clause 5.2.1 exists, 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 AS 1217.6, Clause 5.7.1.2 (unequal areas), for the determination of L_W shall be used.

5.3 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 determined according to the calculation procedures of Section 6 do not deviate by more than 1 dB from those determined from measurements over the entire measurement surface.

5.4 CONDITIONS OF MEASUREMENT.

5.4.1 General. Environmental conditions may have an adverse effect on the microphone used for the measurements. Such conditions, e.g. 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 positioning of the microphone. The microphone shall always be oriented so that the angle of incidence of the sound waves is that for which the microphone is calibrated.

The sound pressure level shall be observed over a typical period of operation of the source. Readings of the sound pressure level (corresponding to the level of the mean-square sound pressure) shall be taken at each measurement point with A-weighting and for each frequency band within the frequency range of interest. The instrumentation used must comply with the requirements of Section 3.

The following data shall be obtained:

(a) The A-weighted sound pressure levels and band pressure levels during operation of the source under test.

(b) The A-weighted sound pressure levels and band pressure levels produced by the background noise.

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

5.4.2 Measurements with sound level meter. If the indicating meter of a sound level meter is used, the time-weighting 'S' characteristic shall be used. Where the fluctuations of the indicating pointer on the sound level meter are less than ± 3 dB using the time-weighting 'S' characteristic, the noise is considered to be steady for the purposes of this standard, and the level is taken to be the average of the maximum and minimum levels during the period of observation. If the meter fluctuations during the period of observation are greater than ± 3 dB, the noise is considered non-steady and one of the instrumentation systems described in Appendix E shall be used.

For the detection of impulsive noise an additional measurement with the time-weighting characteristic 'I' of the sound level meter shall be performed. The procedure of Appendix F shall be used.

5.4.3 Measurements with RC-smoothing or integrating systems. If RC-smoothing is used, the time constant τ_A should be long enough to obtain an estimate of the r.m.s. level during the period of observation with a precision of ±0.5 dB.

If true integration is used, it is necessary that the integration time be equal to the period of observation.

For time-varying noise, it is important to specify carefully the period of observation, and this will usually depend on the purpose of the measurements. For example, if the machine has two particular modes of operation having different noise levels, it may be necessary to select a period of observation for each mode.

5.4.4 Corrections for background noise. The measured sound pressure levels shall be corrected for background noise according to Table 5.1.

TABLE 5.1
CORRECTIONS FOR BACKGROUND NOISE

Difference between sound pressure level measured with sound source operating and background sound pressure level alone dB	Corrections to be subtracted from sound pressure level measured with sound source operating to obtain sound pressure level due to sound source alone dB
<6	Measurements invalid
6	1.0
7	1.0
8	1.0
9	0.5
10	0.5
>10	0.0

SECTION 6. CALCULATION OF SURFACE SOUND PRESSURE LEVEL, SOUND POWER LEVEL, AND DIRECTIVITY FACTOR

6.1 CALCULATION OF SOUND PRESSURE LEVEL AVERAGED OVER THE MEASUREMENT SURFACE. For the A-weighted sound pressure level and the level in each frequency band of interest, an average sound pressure level over the measurement surface L_{pm} is calculated from the measured sound pressure levels L_{pi} (after corrections for background noise are applied according to Clause 5.4.4, if necessary) by using the following equation:

$$\bar{L}_{pm} = 10 \log \left[\frac{1}{N} \sum_{i=1}^{n} 10^{0.1L_{pi}} \right] \quad \text{.... (1)}$$

where

$\bar{L}_{pm}$ = sound pressure level averaged over the measurement surface, in decibels (Reference: 20 μPa)

L_{pi} = A-weighted or band pressure level resulting from the ith measurement, in decibels (Reference: 20 μPa)

N = total number of measurements.

Note: Where the range of values of L_{pi} does not exceed 5 dB, a simple arithmetic average will differ by not more than 0.7 dB from the value calculated using the energy average, formula (1).

6.2 CALCULATION OF SURFACE SOUND PRESSURE LEVEL. The surface sound pressure level L_{pf} shall be obtained by correcting the value of L_{pm} for reflected sound to approximate the average value of the sound pressure level which would be obtained under free-field conditions, by using the following equation:

$$\bar{L}_{pf} = \bar{L}_{pm} - K \quad \text{.... (2)}$$

where

L_{pm} = surface sound pressure level, in decibels (Reference: 20 μPa)

K = mean value of the environmental correction over the measurement surface, in decibels.

For the purposes of this standard, the maximum allowable range of the environmental correction, K, is -2 dB to +2 dB.

NOTE: The environmental correction K accounts for the influence of a non-ideal environment, e.g. the presence of sound absorption or reflected sound. It typically ranges from -2 dB (for measurements outdoors with absorbing ground) to + 10 dB (for measurements indoors in highly reverberant rooms). The procedures given in Appendix A are used to calculate the value of the environmental correction.

6.3 CALCULATION OF SOUND POWER LEVEL. The sound power level characterizing the noise emitted by the source shall be calculated from the following equation:

$$L_W = \bar{L}_{pf} + 10 \log (S/So) \quad \text{.... (3)}$$

where

L_W = A-weighted or band power level of the source, in decibels (Reference: 1 pW)

$\bar{L}_{Pf}$ = surface sound pressure level determined according to Clause 6.2, in decibels (Reference: 20 μPa)

S = area of the measurement surface, in square metres

So = 1 m^2

6.4 CALCULATION OF DIRECTIVITY INDEX AND DIRECTIVITY FACTOR. If required, values of the directivity index and directivity factor may be calculated using the procedures of Appendix G.

SECTION 7. INFORMATION TO BE RECORDED

7.1 GENERAL. The following information, where applicable, shall be compiled and recorded for all measurements made according to this standard.

7.2 SOUND SOURCE UNDER TEST. The following shall be recorded:

(a) Description of the sound source under test (including its dimensions and the dimensions of the reference box).

(b) Operating conditions.

(c) Mounting conditions.

(d) Position of sound source in test environment.

(e) If the test object has multiple noise sources, a description of the source(s) in operation during the measurements.

7.3 ACOUSTIC ENVIRONMENT. The following shall be recorded:

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

(b) Acoustical qualification of test environment according to Appendix A.

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

(d) Wind speed and direction.

(e) Sound power output of the reference sound source, if used.

7.4 INSTRUMENTATION. The following shall be recorded:

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

(b) Bandwidth of frequency analyser.

(c) Frequency response of instrumentation system.

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

(e) Characteristics of windscreen (if any).

7.5 ACOUSTICAL DATA. The following shall be recorded:

(a) The shape of the measurement surface, the measurement distance, the site and orientation of microphone positions or paths.

(b) The area S of the measurement surface.

(c) The corrections, in decibels, if any, applied in each frequency band for the frequency response of the microphone, frequency response of the filter in the passband, background noise, etc.

(d) The environmental correction K calculated according to one of the procedures of Appendix A.

(e) The surface sound pressure level $\overline{L}_{pf}$, in decibels, expressed in terms of a weighted level (with A, or other weighting) and in terms of a level in each frequency band of interest; reference 20 μPa.

(f) The sound power level L_W, in decibels, calculated from the surface sound pressure level for A-weighting (or other weighting) and for all frequency bands used; reference 1 pW.

(g) Remarks on subjective impression of noise (audible discrete tones, impulsive character, spectral content, temporal characteristics, etc).

(h) If measured, the difference between time-weighting '*I*' and time-weighting '*S*' readings of the sound pressure level at the selected microphone positions (see Appendix F).

(j) The date and time when the measurements were performed.

7.6 INFORMATION TO BE REPORTED. The report shall contain the statement that the sound power levels have been obtained in full compliance with this standard. The report shall state that these sound power levels are given in decibels re 1 pW.

Only those data recorded according to the requirements of Section 7 and which are required for the purpose of the measurements shall be reported.

APPENDIX A

QUALIFICATION PROCEDURES FOR THE ACOUSTIC ENVIRONMENT

A1 GENERAL. An environment providing a free field over a reflecting plane shall be used for measurements made according to this standard. This environment may be a hemi-anechoic room, an outdoor space or an ordinary room if the requirements given below are complied with.

The test room shall be large enough and, if possible, free from reflecting objects with the exception of the reflecting plane. The test room shall provide a measurement surface that lies —

(a) inside a sound field that is free of undesired sound reflection from the room boundaries; and

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

For open test sites which consist of a hard, flat ground surface such as asphalt or concrete and with no sound-reflecting obstacles within a distance from the source equal to 3 times the greatest distance from the source centre to the lower measurement points, it may be assumed that the environmental correction K is less than or equal to 0.5 dB and is, therefore, negligible.

NOTE: An obstacle in the proximity of the source may be considered to be sound reflecting if its width, e.g. diameter of a pole or supporting member, exceeds 10 percent of its distance from the reference box.

The environmental correction K may also be assumed to be negligible for indoor environments which are laboratory anechoic rooms complying with the requirements of Appendix A of AS 1217.6.

The evaluation of environmental influences is performed by selecting one of two alternative procedures used to determine the magnitude of the environmental correction K. These procedures are used to determine if any undesired environmental influences are present and to qualify a given measurement surface for an actual source under test according to this standard.

The first qualification test (absolute comparison test, see Paragraph A3) is carried out with a reference sound source. The second qualification test (reverberation test, see Paragraph A4) may be used if the source under test cannot be moved or if its dimensions are large. This test requires measurements of reverberation time.

The free-field qualification on a given measurement surface is satisfied by a given test room if the ratio of the sound absorption A of the room to the area S of the measurement surface is sufficiently large. In general, ratios $A/S > 10$ require no environmental corrections. For ratios A/S between 10 and 6, an environmental correction K can be determined according to the procedures given in this Appendix. In this case, K is usually smaller than 2 dB. For ratios $A/S < 6$, the room correction factor K may exceed 2 dB and cause greater uncertainty for the sound power level determinations than those given in Table 1.1. In such cases, a smaller measurement surface, a better environment or a measurement according to the survey method (see AS 1217.7) should be chosen. The reflecting plane should comply with the requirements given in Paragraph A2.1. For outdoor measurements, additional precautions given in Paragraph A2.2 should be considered.

A2 ENVIRONMENTAL CONDITIONS.

A2.1 Properties of reflecting plane.

A2.1.1 *General.* Measurements may be made in one of the following environments:

(a) Over a reflecting plane outdoors.

(b) In a test room with one reflecting surface.

(c) In a test room with sound absorptive surfaces in which a reflecting plane is present.

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

A2.1.2 *Shape and size.* The reflecting plane should extend at least $\lambda/2$ beyond the projection of the measurement surface on the plane for the lowest frequency of the frequency range of interest.

A2.1.3 *Absorption coefficient.* The reference plane should have acoustical characteristics approximating those of a perfect acoustical reflector over the frequency range of interest. For indoor measurements, a concrete floor is usually satisfactory. For outdoor measurements, a concrete or a smooth sealed asphalt surface should be satisfactory.

A2.2 Precautions for outdoor measurements. Care should be taken to minimize the effects of adverse meteorological conditions, e.g. 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.

A3 ABSOLUTE COMPARISON TEST.

A3.1 Procedure. A reference sound source with characteristics that comply with ISO 6926 shall be mounted in the test environment in essentially the same position as that of the source under test. The sound power level of the reference sound source is determined according to the procedures of Sections 5 and 6 without the environmental correction K, i.e. K is initially assumed equal to zero. The same measurement surface is used as during the measurements of the source under test. The environmental correction K is given by the following equation:

$$K = L_W - L_{Wr}$$

where

L_W = calculated A-weighted or band power level of the reference sound source using procedures of Sections 5 and 6 (with $K = 0$ in equation (2)), in decibels (Reference: 1 pW)

L_{Wr} = nameplate A-weighted or band power level of the reference sound source, in decibels (Reference: 1 pW)

A3.2 Positions of reference sound source in test environment.

A3.2.1 *Source can be removed from test site*. The reference sound source is to be positioned on the reflecting plane, independent of the height of the machine. One single position is sufficient, even when very large machines are to be tested, provided that the ratio of the length of the machine under test to its width is not greater than 2. If the ratio is greater than 2, the reference sound source shall be operated on the floor at four points. Assuming the projection of the machine under test on the floor to be approximately rectangular in shape, the four points are positioned at the middle point of the sides of the rectangle. To obtain L_W the surface sound pressure level L_{pf} shall be calculated with the reference sound source positioned at each of the four points on the floor. At each point on the measurement surface, the sound pressure level shall be averaged for the four source positions on a mean-square basis, i.e. using equation (1) in Clause 6.1.

A3.2.2 *Source cannot be removed from test site*. The reference sound source is to be positioned on the upper surface of the machine which should preferably be acoustically reflective. This method should not be applied if the machine has highly absorptive surfaces, e.g. textile machines. In this case, the procedure of Paragraph A4 should be followed.

A3.3 Qualification requirements. For the measurement surface in a given test environment to be satisfactory for measurements according to the requirements of this standard, the environmental correction K must be numerically less than or equal to 2 dB. If the environmental correction K exceeds 2 dB, either a smaller measuring surface or a better test environment is required. The procedure shall be repeated. Alternatively, procedures using a reference sound source may be used or the guidelines given in AS 1217.7 may be followed to determine the sound power levels of the source under test.

NOTE: Measurement procedures using a reference sound source, may yield sound power levels within the limits for the measurement uncertainty specified in Clause 1.4 of this standard, even for values $K > 2$.

A4 REVERBERATION TEST.

A4.1 Test procedure. This test procedure is applicable to rooms that are approximately cubical in shape.

The environmental correction K is obtained from the following equation:

$$K = 10 \log \left(1 + \frac{4}{A/S}\right)$$

The value of K may be obtained from Fig. A1 by entering the abscissa with the appropriate value of A/S. The area S of the measurement surface is calculated according to the requirements given in Clause 5.1.

The total sound absorption A of the test room is determined from measurements of the reverberation time of the test room in octave bands for the entire frequency range of interest (see AS 1045).

The value of A is then—

$$A = 0.16(V/T)$$

where

V = volume of the test room, in cubic metres

T = reverberation time of the test room in octave band, in seconds.

A4.2 Qualification requirements. For the measurement surface in a test room to be satisfactory for measurements according to this standard, the ratio A to S should exceed 6, i.e. $A/S > 6$.

If the above requirement cannot be complied with, a new measurement surface shall be chosen. The new measurement surface should have a smaller total area, but still lie outside the near field (see Clause 1.4). Alternatively, the ratio A/S may be increased by introducing additional sound-absorptive materials into the test room and then redetermining the value of the ratio A/S under the new conditions.

If the requirements of this Paragraph cannot be complied with for any measurement surface which lies outside the near field of the source under test, the particular environment chosen cannot be used for measurements on the source under test according to the requirements of this standard. A new test environment must be selected or it must be assumed that the uncertainties may exceed the values given in Table 1.1.

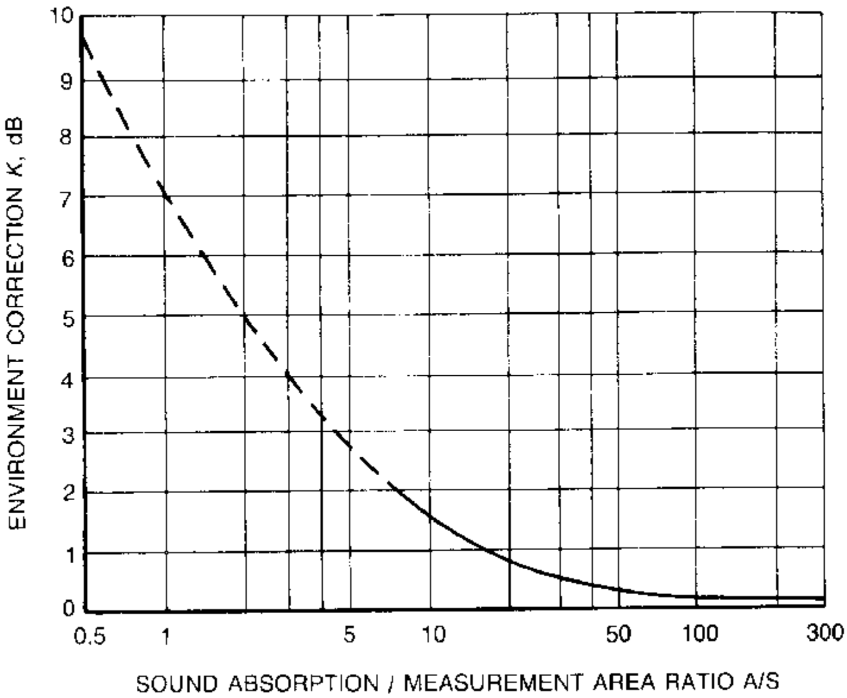

Fig. A1. ENVIRONMENTAL CORRECTION

APPENDIX B

MICROPHONE ARRAY ON THE HEMISPHERE

The positions of ten points associated with equal areas on the surface of a hemisphere of radius r are numbered from 1 to 10 in Figs B1 and B2. The Cartesian coordinates (x, y, z) with the origin centred on the vertical projection of the centre of the reference box on the reflecting plane are also given in tabular form in Table B2. The additional points on the hemisphere are numbered from 11 to 20 in the same figure.

NOTES:

1. The overhead position (No 10) may be deleted for safety reasons, if it can be shown by preliminary investigation that the exclusion of the overhead position does not influence the calculated sound power level of the source by more than 1.0 dB. If this position is deleted, positions 1 to 9 must remain.
2. If the source emits predominant pure tones, strong interference effects may occur if several microphone positions are placed at the same height above the reflecting plane. In such cases, the use of a microphone array with the coordinates given in Table B1 is recommended.

TABLE B1
COORDINATES OF MICROPHONE ARRAY FOR PURE SOUNDS

No	$\frac{x}{r}$	$\frac{y}{r}$	$\frac{z}{r}$
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

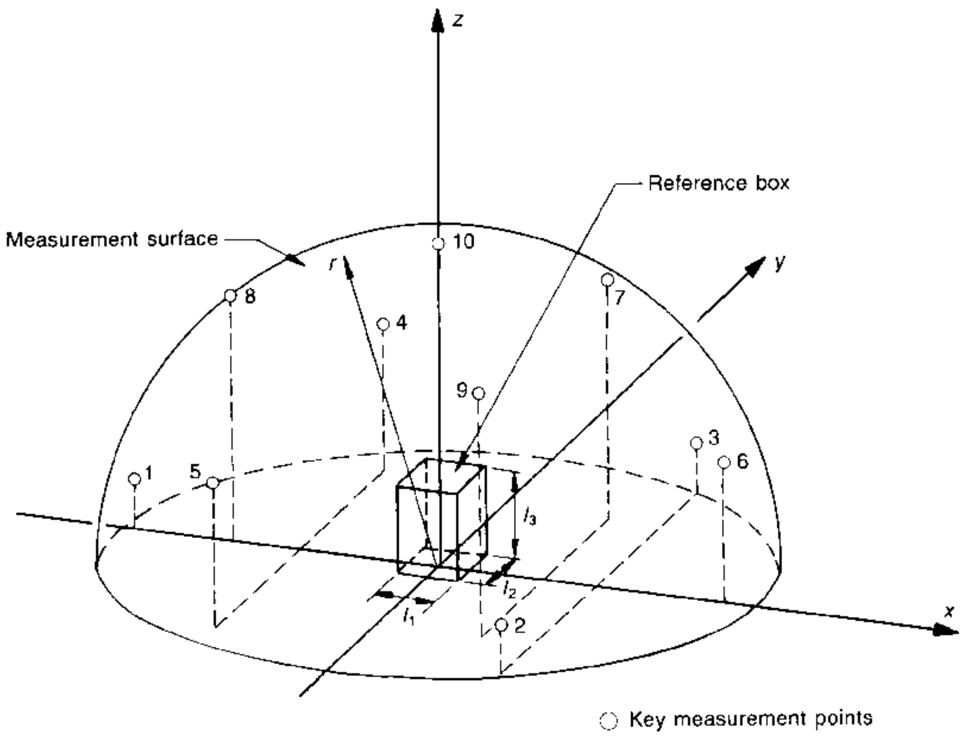

Fig. B1. HEMISPHERICAL MEASUREMENT SURFACE — KEY MEASUREMENT POINTS

TABLE B2
COORDINATES OF KEY MEASUREMENT POINTS

No	$\frac{x}{r}$	$\frac{y}{r}$	$\frac{z}{r}$
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

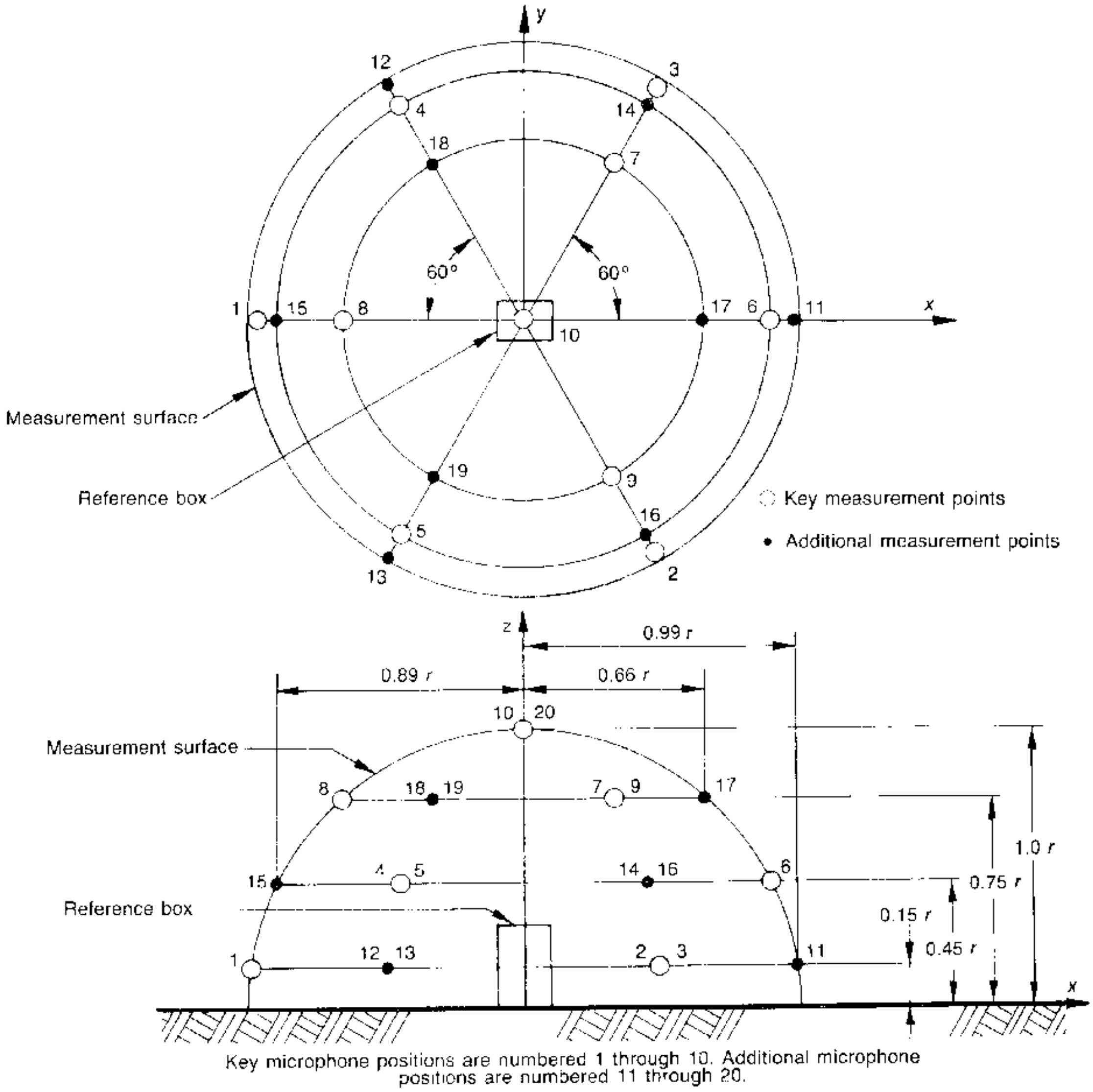

Fig. B2. MICROPHONE ARRAY ON THE HEMISPHERE

APPENDIX C

MICROPHONE ARRAY ON THE PARALLELEPIPED MEASURING SURFACE

The coordinates of the key measurement points given in Table C1 and Fig. C1 are determined by the following:

$a = 0.5l_1 + d$

$b = 0.5l_2 + d$

$c = l_3 + d$

$h = C \times c$

where

l_1, l_2 and l_3 = dimensions of the reference box

d = measurement distance, normally 1 m.

The height h shall be chosen uniformly for a series of similar sources. The minimum height of the microphone above the reflecting plane shall be 0.15 m.

For specific kinds of sound sources, the constant C or the height h may be specified in the appropriate test method as one of the following values:

C = 0.5 (In the absence of specifications, C = 0.5 shall be used.)

C = $0.5l_3/c$ (the centre of the source)

h = shaft height for rotating machines

h = 1.20 m

NOTES:

1. The overhead position (No 9) may be deleted for safety reasons, if it can be shown by preliminary investigation that the exclusion of the overhead position does not influence the calculated sound power level of the source by more than 1.0 dB. If this position is deleted, positions 1 to 8 must remain.
2. The number of measurement points may be reduced to five (Nos 1, 2, 3, 4, 9 of Fig. C1) if the surface sound pressure level so determined does not deviate by more than 1.0 dB from that determined from measurements at the nine key measurement points of Fig. C1 (see Clause 5.3).

TABLE C1
COORDINATES OF KEY MEASUREMENT POINTS

No	*x*	*y*	*z*
1	*a*	0	*h*
2	0	*b*	*h*
3	-*a*	0	*h*
4	0	-*b*	*h*
5	*a*	*b*	*c*
6	-*a*	*b*	*c*
7	-*a*	-*b*	*c*
8	*a*	-*b*	*c*
9	0	0	*c*

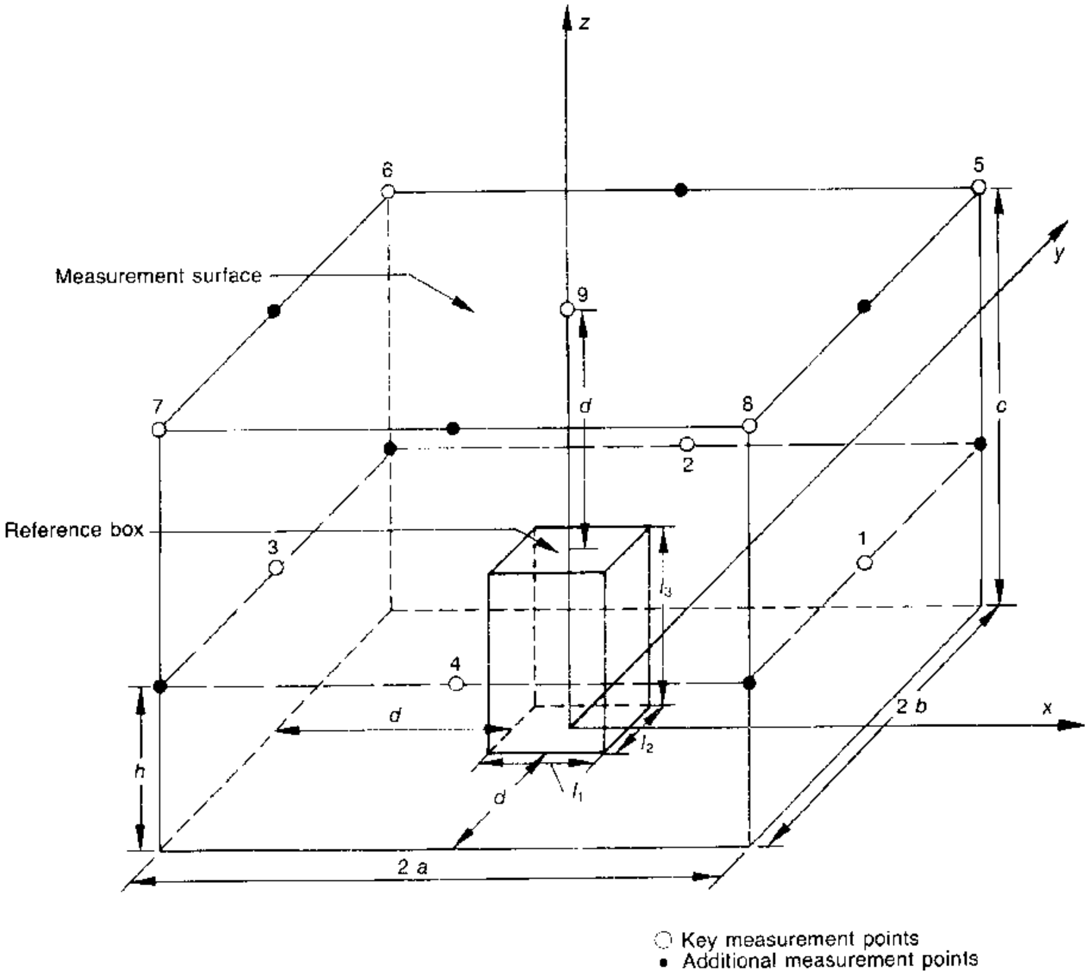

Fig. C1. MICROPHONE ARRAY ON THE PARALLELEPIPED

APPENDIX D

MICROPHONE ARRAY ON THE CONFORMAL MEASUREMENT SURFACE

The coordinates of the microphone positions given in Table D1 and Fig. D2 are determined by the following:

$a = 0.5l_1 + d$

$b = 0.5l_2 + d$

$c = l_3 + d$

$h_1 = 0.25(b + c - d)$

$h_2 = 0.75(b + c - d) \leq c$

$b_1 = 0.5(b + c - d) \leq b$

where

d = measurement distance, normally 1 m.

The minimum height of the microphone above the ground shall be 0.15 m.

The additional points on the conformal surface are numbered from 9 to 16 on Fig. D2.

TABLE D1
COORDINATES OF KEY MEASUREMENT POINTS

No	x	y	z
1	a	0	h_1
2	0	b	h_1
3	$-a$	0	h_1
4	0	$-b$	h_1
5	$a/2$	b_1	h_2
6	$-a/2$	b_1	h_2
7	$-a/2$	$-b_1$	h_2
8	$a/2$	$-b_1$	h_2

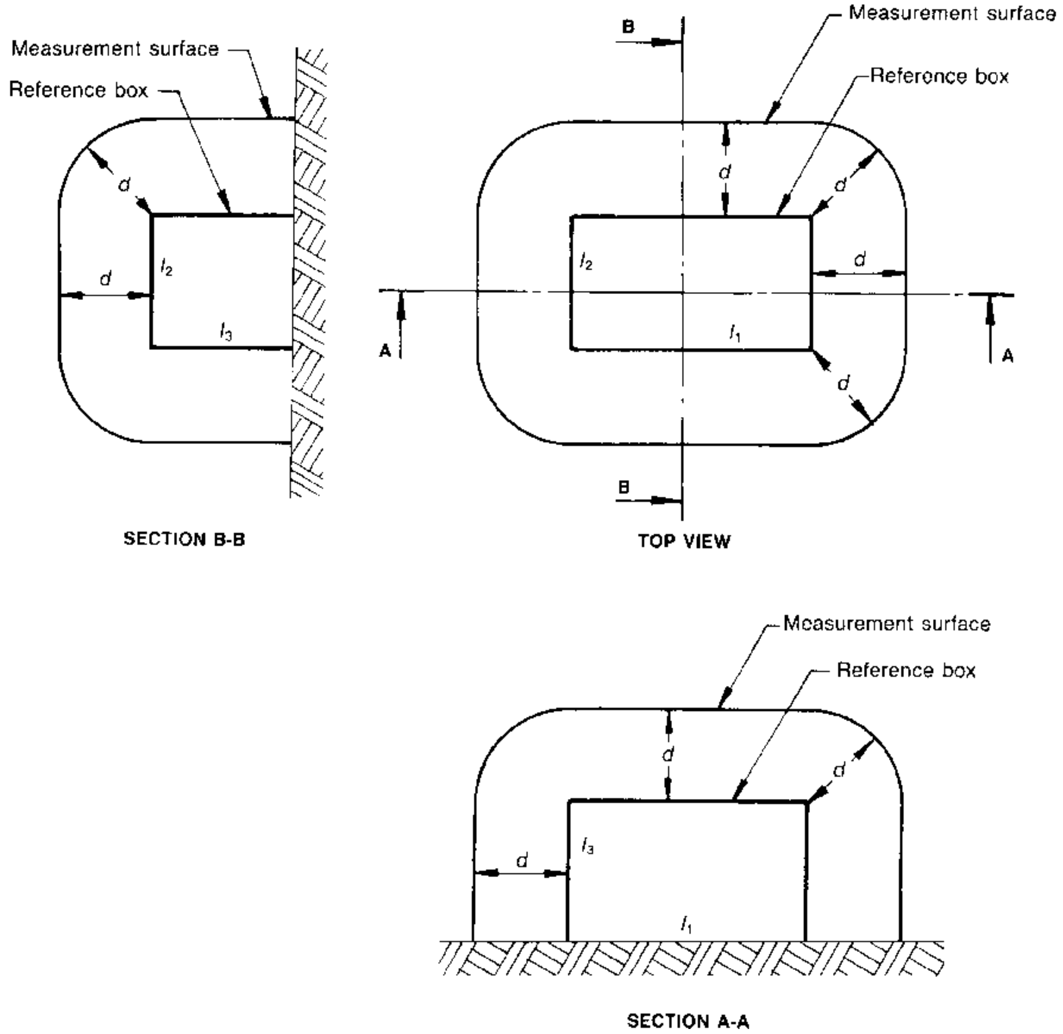

Fig. D1 CONFORMAL SURFACE AT A DISTANCE *d* FROM REFERENCE BOX

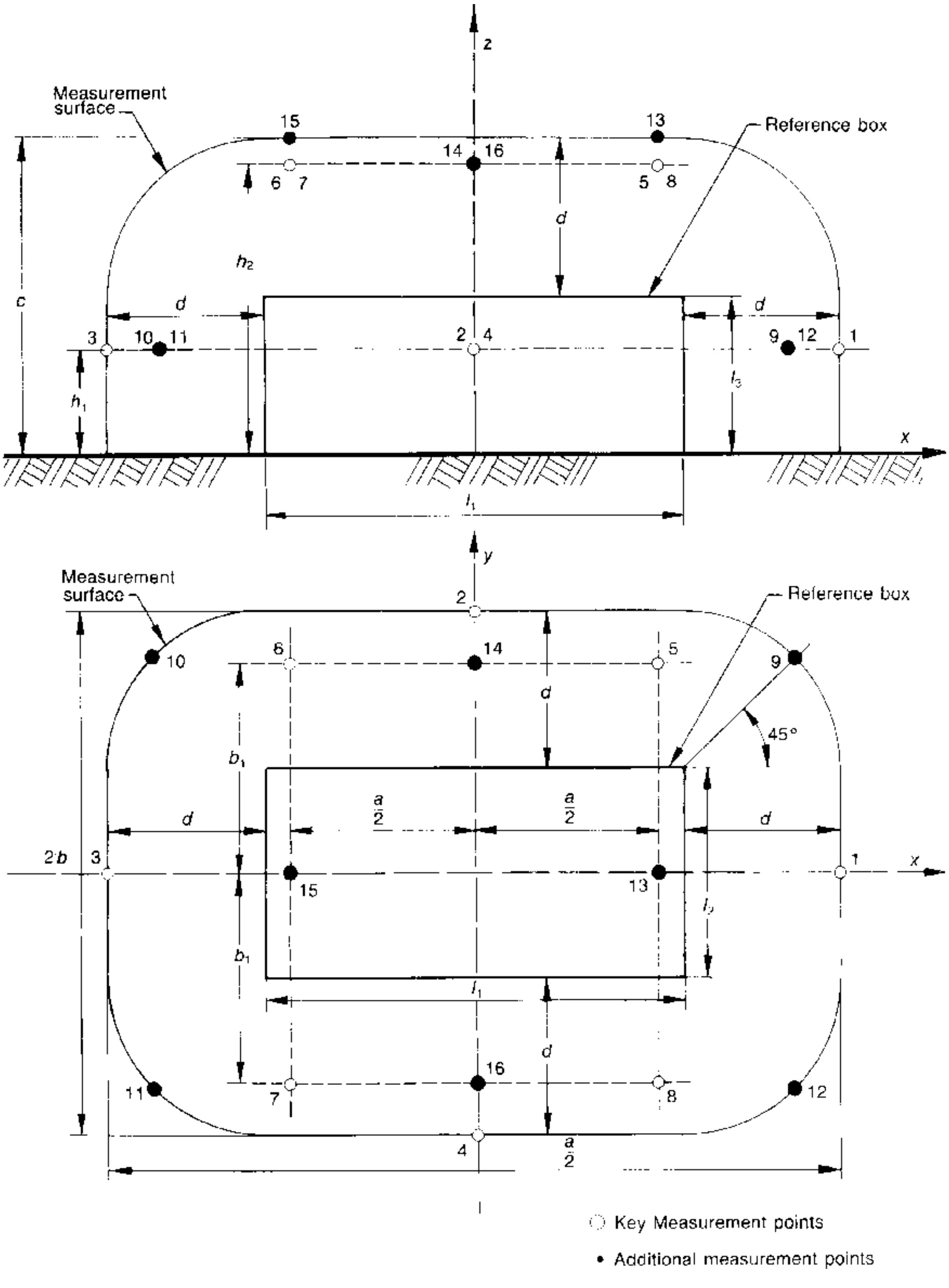

Fig. D2. MICROPHONE ARRAY ON THE CONFORMAL SURFACE

APPENDIX E

EXAMPLES OF SUITABLE INSTRUMENTATION SYSTEMS

E1 GENERAL. Basically, the instrumentation system consists of a microphone, an amplifier with filters, a squaring and averaging circuit and an indicating device. There are several methods of processing or conditioning the filter outputs that may be used to obtain an estimate of the mean-square value of the output. These include use of detection equivalent to RC-smoothing, integration of the squared value of the filter outputs and digital methods. Some general aspects are described below.

E2 RC-SMOOTHING, SOUND LEVEL METER. Many analogue devices, including the sound level meter according to AS 1259, employ RC-smoothing.

For the sound level meter set on time-weighting characteristic '*S*', the average value of the meter deflection approximates the mean-square sound pressure level if the fluctuations are less than 5 dB.

The microphone on the sound level meter shall have a uniform frequency response at the angle of incidence specified by the manufacturer. A capacitor microphone with a diameter of 13 mm will be suitable for this purpose. The microphone and its associated pre-amplifier (if any) shall be placed in the test room and connected with the sound level meter by a cable that complies with the requirements of Clause 3.2. The system shall be calibrated with the cable inserted between pre-amplifier and sound level meter.

The sound level meter and the observer shall be placed in a room adjacent to the test room. The meter shall be set on time-weighting characteristic '*S*' and the readings taken as described in Clause 5.4.2.

Other analogue devices can provide smoothing with longer time-constants and shall be used if the fluctuations exceed 5 dB.

E3 ANALOGUE INTEGRATORS. Another approach to r.m.s. detection is the 'true' analogue integrator that computes (approximately) the integral.

$$e_{rms} = \left[\frac{1}{T}\int_o^T e_o^2(t)\ dt\right]^{1/2}$$

where $e_o(t)$ is the filter output. The square and square roots are usually accomplished by non-linear analogue elements. The integral may be computed either by conversion of $e_o(t)$ to a current and accumulation of charge on a capacitor, or by counting the number of cycles in a signal whose frequency is proportional to $e_o(t)$.

E4 DIGITAL SYSTEMS. The r.m.s. value of the filter outputs may be determined by sampling, conversion to digital values, squaring and accumulating the results. The sampling rate can be either —

(a) high compared with highest frequency present in the filter output; or

(b) relatively low compared with the highest frequency present so that the resulting samples are (approximately) statistically independent.

In either case, the output of the detector after a specified time-interval should be within 3 percent of the true r.m.s. value of the time function for all frequencies within the frequency range of interest.

E5 LEVEL RECORDERS. A level recorder may be used either as a squaring, averaging and indicating device or exclusively as an indicating device.

In the first case, the time-constant of the instrumentation system is determined by the writing speed of the level recorder. Since the level recorder is a complicated electromechanical system, a simple rule for the determination of the resulting time-constant cannot be given. It is advisable to consult the manufacturer in this matter.

If the level recorder is used for indication only, the recorder will normally be set for recording of the d.c. output of a preceding squaring and averaging device, the time-constant of which will determine the resulting time-constant of the instrumentation system.

In both cases, the average value obtained will be an acceptable approximation to the r.m.s. value only if the pen fluctuations are less than 5 dB.

APPENDIX F

GUIDELINES FOR THE DETECTION OF IMPULSIVE NOISE

In many cases, comparison of the readings of a sound level meter on time-weighting characteristic '*S*' with that of the sound level meter on time-weighting characteristic '*I*' (according to AS 1259) may be helpful in determining whether or not the noise contains important impulsive components. For this purpose, the comparison is made at one or more of the microphone positions, the 'A' frequency weighting is applied and the period of observation at each position shall be at least 3 s with both time-weighting characteristics. At least the mean value of the differences between the readings at the chosen microphone position is to be given in the test report.

APPENDIX G

CALCULATION OF DIRECTIVITY INDEX AND DIRECTIVITY FACTOR USING HEMISPHERICAL MICROPHONE ARRAY

The presence of a hard reflecting plane modifies the directivity pattern of a source. The directivity index and directivity factor may be obtained by considering the reflecting plane to be part of the source. The directivity index *DI* of the source may then be calculated, in decibels, from measurements in a free field above a reflecting plane by using the following equation:

$$DI = L_{pi} - \bar{L}_{pf} + 3 \qquad \text{.... (3)}$$

where

L_{pi} = sound pressure level measured in the particular direction in which *DI* is desired, at a distance *r* metres from the centre of the hemispherical measurement surface, in decibels (Reference: 20 μPa)

$\bar{L}_{pf}$ = surface sound pressure level over the hemispherical measurement surface of radius *r*, in decibels (Reference: 20 μPa)

NOTE: In the report of the measurements, it may be sufficient to include only the highest value of *DI* and the direction in which it occurs. The directivity factor *Q* of the source, in a given direction, may be determined from the following equation:

$$Q = 10^{0.1DI} \qquad \text{.... (4)}$$

where

DI = directivity index in the same direction obtained from equation (3) in decibels.

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