INTERNATIONAL STANDARD ISO 3745

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Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit — Méthodes de laboratoire pour les salles anéchoïque et semi-anéchoïque

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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 3745 was developed by Technical Committee ISO/TC 43, *Acoustics*, and was circulated to the member bodies in May 1975.

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

Austria	Ireland	South Africa, Rep. of
Belgium	Israel	Sweden
Canada	Italy	Switzerland
Czechoslovakia	Japan	Turkey
Denmark	Netherlands	United Kingdom
Finland	New Zealand	U.S.A.
France	Norway	U.S.S.R.
Germany	Poland	
Hungary	Romania	

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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Annexes

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Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms

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 the basic documents.

Guidelines for making these decisions 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	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	Special reverberant test room		Steady, broad-band narrow-band, discrete-frequency	A-weighted and in octave bands	Other weighted sound power levels
3744	Engineering	Outdoors or in large room	Largest dimension less than 15,0 m	Any	A-weighted and in one-third octave or octave bands	Directivity information and sound pressure levels as a function of time; other weighted sound power levels
3745	Precision	Anechoic or semi-anechoic room	Preferably less than 0,5 % of test room volume	Any		
3746	Survey	No special test environment	No restrictions : limited only by available test environment	Steady, broad-band, narrow-band, discrete-frequency	A-weighted	Sound pressure levels as a function of time; other weighted sound power levels

* See clause 2.

0.2 SYNOPSIS OF ISO 3745

Applicability

Test environment

Free field (anechoic room) or free field over a reflecting plane (semi-anechoic room).

Type of source

Device, machine, component, subassembly.

Size of noise source

Volume of the source preferably less than 0,5 % of test room volume.

Character of noise radiated by the source

All types.

Accuracy

Precision (standard deviation for determining sound power levels for 1 kHz octave band is less than or equal to 0,5 dB for anechoic rooms and less than or equal to 1,0 dB for semi-anechoic rooms).

Quantities to be measured

Sound pressure levels (weighted and in frequency bands) over a prescribed surface.

Quantities to be calculated

Weighted sound power level (A 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 in detail two laboratory methods for determining the sound power radiated by a device, machine, component or subassembly using a laboratory anechoic room having prescribed acoustical characteristics. While other methods could be used to measure the noise emitted by machinery and equipment, the methods specified in this International Standard are particularly useful for rating the sound output of sources which produce steady noise and for which directivity information on the source may be desired.

The methods specified in this International Standard yield physical data that may be used for the following purposes :

1) rating apparatus according to its sound power output;

2) establishing sound control measures;

3) predicting the sound pressure levels produced by a device in a given enclosure or environment.

Techniques for utilizing the physical data for these special purposes are not included in this International Standard.

The determination of the sound power radiated by a sound source in a completely free field or in a free field above a reflecting plane is based on the premise that the reverberant field produced by the source is negligible and that the total radiated power is obtained from the mean-square sound pressure averaged in time and in space over a hypothetical sphere or hemisphere surrounding the source. The radius of the sphere or hemisphere is chosen so that its surface is in the far radiation field of the source.

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 two laboratory methods for determining the sound power level of a source. It gives requirements for the test room, as well as the source location, operating conditions and instrumentation. Techniques are specified for obtaining an estimate of the surface sound pressure level from which the weighted sound power level of the source as well as the sound power level in octave or one-third octave bands may be calculated. It is intended to prescribe techniques for acoustical measurements that may be used in test codes for particular types of equipment.

1.2 Field of application

1.2.1 *Types of noise*

This International Standard applies to sources which produce sound that is uniformly distributed in frequency over the frequency range of interest and is relatively steady for at least 30 s. The spectrum of the sound may also include prominent discrete-frequency components or narrow bands of noise. The procedures specified in this International Standard may also be applied to sources that emit 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. (See annex I for guidelines on the detection of impulsive noise.)

1.2.2 *Size of source*

This International Standard applies primarily to small sound sources, i.e. sources whose volumes are preferably less than 0,5 % of the volume of the test room used for the measurements. This restriction is necessary to ensure that the hypothetical sphere or hemisphere surrounding the sources lies in the far radiation field of the source.

1.3 Measurement uncertainty

Measurements made in conformity with this International Standard tend to result in standard deviations which are equal to or less than those given in tables 2 and 3. The standard deviations of tables 2 and 3 reflect the cumulative effects of all causes of measurement uncertainty, excluding variations in the sound power of the source from test to test.

The major cause of uncertainty in determining sound power in an anechoic room is the spatial irregularity of the sound field due to the directivity of the source. In a semi-anechoic room, the spatial irregularity may be increased due to the superposition of the sound field of the actual source and that of the image source. The directivity pattern of a source located above a reflecting plane is generally more complicated than that of the same source in a free field. Moreover, the near field extends to greater distance, and the radius of the test hemispheres is usually larger than the radius of the test sphere that would be required in a free field. The smallest uncertainty in determining sound power levels occurs when measurements are made in a free field. For this reason, if no other constraints are present, the free-field environment is preferred for laboratory measurements. However, it is difficult to make measurements on some classes of equipment under truly free-field conditions. Some sound sources are too large to fit into existing anechoic rooms, some are too heavy to be suspended in the centre of these rooms and others are normally supported by or associated with a hard, reflecting surface. For these reasons, the free field above a reflecting plane is a laboratory environment that is useful for measurements on many different types of equipment.

An anechoic room provides the preferred environment for measurements with the smallest uncertainty. However, reasonable accuracy can be obtained in a semi-anechoic room provided the precautions specified in this International Standard are observed.

TABLE 2 — **Uncertainty in determining sound power levels of sound sources in anechoic rooms**

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

TABLE 3 — **Uncertainty in determining sound power levels of sound sources in semi-anechoic rooms**

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

2 REFERENCES

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

ISO/R 354, *Measurement of absorption coefficients in a reverberation room.*

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

ISO 3740, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic International 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 3744, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane.*

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

IEC Publication 50(08), *International electrotechnical vocabulary — Electro-acoustics.*

IEC Publication 179, *Precision sound level meters.*

IEC Publication 179A, First supplement to Publication 179, *Additional characteristics for the measurement of impulsive sounds.*

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

3 DEFINITIONS

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

3.1 free sound field : A field in a homogeneous, isotropic medium free of boundaries.

3.2 free field over a reflecting plane : A field in a homogeneous, isotropic medium in the half-space above an infinite, rigid plane surface.

3.3 anechoic room : A test room whose surfaces absorb essentially all of 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 and also averaged over the measurement surface using the averaging procedures specified in clause 7.

3.6 surface sound pressure level, $\overline{L_p}$, in decibels : 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, L_W, in decibels : Ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power. The weighting network or the width of the frequency band used shall be indicated; for example, A-weighted sound power level, octave band power level, one-third octave band 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 40 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. For the purposes of this International Standard, the measurement surface is usually a sphere or hemisphere of radius r.

3.10 far field : That portion of the radiation field of a noise source in which the sound pressure level decreases by 3 dB for each doubling of the area of the measurement surface. This is equivalent to a decrease of 6 dB for each doubling of the distance from a point source.

In the far field, the mean-square pressure is proportional to the total acoustic power radiated by the source.

NOTE — For most practical sources, the far field begins at a distance from the source which may be significantly less than $2a$, where a is the largest dimension of the source.

3.11 near field : That portion of the radiation field of a noise source which lies between the source and the far field.

3.12 volume of source under test : The volume of the whole object under test.

4 TEST ROOM REQUIREMENTS

4.1 General

The test room shall be large enough and shall have a sufficiently high value of the total sound absorption to provide an adequate free field for all frequency bands within the frequency range of interest and for each measurement surface selected. For guidance on the design of anechoic rooms, refer to annex G.

4.1.1 *Criterion for room adequacy*

The adequacy of the test room for measurements according to this International Standard shall be established using the procedures of annex A.

4.1.2 *Criterion for background noise*

At the microphone positions, the background sound pressure level including any noise due to the motion of the microphone shall be at least 6 dB and preferably more than 12 dB below the sound pressure level to be measured in each frequency band within the frequency range of interest.

4.2 Room volume

In order to make measurements in the far radiation field of the source, it is recommended that the volume of the test room be at least 200 times greater than the volume of the source whose sound power level is to be determined.

4.3 Criteria for temperature and humidity

The air absorption in the test room varies with temperature and humidity, particularly at frequencies above 1 000 Hz. For measurements according to this International Standard the temperature and the relative humidity shall be controlled during the sound pressure level measurements and held to as nearly constant values as practicable.

4.4 Criteria for the reflecting plane

The reflecting plane on which the source is located shall extend at least to the measurement surface. The sound absorption coefficient of the reflecting plane shall not exceed 0,06.

5 INSTRUMENTATION

5.1 General

The instrumentation shall be designed to measure the level of the mean-square sound pressure with A-weighting or in octave or one-third octave bands, 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 7.3) and computing the average value according to 7.7.

NOTE — For establishing the presence of impulsive noise, the "impulse" meter characteristics according to IEC Publication 179A shall be used in addition.

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.

NOTE — An example of an instrument employing such averaging is a sound level meter that meets the requirements of IEC Publication 179 with a "slow" meter characteristic.

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 annexes H and I.

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. A 13 mm (1/2 in) microphone is recommended.

The microphone and its associated cable shall be chosen so that their sensitivity does not change over the temperature range encountered in 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 in table 4.

TABLE 4 — **Relative tolerances for the instrumentation system**

Frequency	Tolerance limits
Hz	dB
80	± 1,5
100 to 4 000	± 1,0
5 000 to 8 000	± 1,5
10 000	± 2,0
12 500	± 3,0

5.4 Weighting network, frequency analyser

An A-weighting network meeting the tolerances of IEC Publication 179 and an octave band or one-third octave band filter set meeting the requirements of IEC Publication 225 shall be used. The centre frequencies of the frequency bands shall correspond to those of ISO 266.

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

5.5 Calibration

Before each series of measurements, an acoustical calibrator with an accuracy of ± 0,2 dB shall be applied to the microphone for calibration of the entire measuring system at one or more frequencies over the frequency range of interest. The calibrator shall be checked annually to verify that its output has not changed. In addition, an electrical calibration of the instrumentation system over the entire frequency range of interest shall be performed periodically, at least at intervals of 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 types of sources (for example, rotating electrical machines).

6.2 Installation of source

Whenever a typical condition of mounting exists for the source, that condition shall be used or simulated, if practicable. Sources which are normally supported by or associated with a hard surface shall be installed in a semi-anechoic room (free field above a reflecting plane).

6.2.1 *Method of mounting*

Many small sound sources (for example, ballasts for fluorescent lamps, electric clocks, etc.), although themselves poor radiators of low-frequency sound, may, as a result of the method of mounting, produce marked increases in 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. However, such resilient mounts shall not be used if the device under test is not resiliently mounted in typical field installations. In this case, the mounting base shall have a sufficiently high impedance to prevent it from vibrating and radiating sound excessively.

6.3 Choice of method

The following considerations dictate the method that shall be used for determinations of sound power according to the requirements of this International Standard.

6.3.1 *Plane reflecting surfaces*

When a source is mounted near a reflecting plane, the power it radiates may differ appreciably from the power it radiates into free space. If such a mounting is typical of field installations, the device under test shall be installed in a semi-anechoic room (free field above a reflecting plane) located with respect to the hard floor as in typical field installations. The reflecting plane is considered to be a part of the source.

6.3.2 *Free-field environment*

If the source under test is not usually mounted over a reflecting plane, or if no typical condition of mounting exists, the source shall be placed near the centre of an anechoic room.

NOTE — Equipment normally operated on a table or stand shall be so mounted during the tests. Either an anechoic or a semi-anechoic room may be used.

6.4 Auxiliary equipment

Care shall be taken to ensure that any electrical conduits, piping or air ducts connected to the equipment do not radiate significant amounts of sound energy into the test room. If practicable, all auxiliary equipment necessary for the operation of the device under test shall be located outside the test room and the test room shall be cleared of all objects which may interfere with the measurements.

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 :

1) device under normal load operating at normal speed;

2) device under full load (if different from 1));

3) device under no load (idling);

4) device under operating condition corresponding to maximum sound generation.

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 DETERMINATION OF MEAN-SQUARE PRESSURE

7.1 General

An anechoic room provides the preferred environment for measurements with the smallest uncertainty (see table 2). However, reasonable accuracy can be obtained in a semi-anechoic room provided the precautions specified in this International Standard are observed (see table 3).

7.2 Measurement surface

7.2.1 *Radius of test sphere*

For measurements in an anechoic room, the hypothetical sphere which is used to determine the space average of the mean-square sound pressure should preferably be centered on the acoustic centre of the sound source. As the location of the acoustic centre is frequently unknown, the centre chosen (for example, the geometric centre of the source) shall be clearly stated in the test report. The radius of the test sphere shall be equal to or greater than twice the major source dimension, and not less than 1 m. No microphone position shal be used which lies outside the region qualified for measurements according to annex A.

7.2.2 *Radius of test hemisphere*

For measurements in a semi-anechoic room, the hypothetical hemisphere shall be centered on the projection on the floor of the centre selected according to 7.2.1. The radius of the test hemisphere shall be equal to or greater than twice the major source dimension, or four times the average distance of the source from the reflecting plane, whichever is the larger, and not less than 1 m. No microphone position shall be used which lies outside the region qualified for measurements according to annex A.

NOTE — If a test hemisphere cannot be used, a measurement surface defined by a constant distance, *d* (i.e. the measurement distance) from the radiating surface of the source may be used. The measurement distance, *d*, should not be less than 1 m.

7.3 Microphone positions

7.3.1 *General*

To obtain the average value of the mean-square pressure on the surface of the test sphere (or hemisphere), one of the three following methods shall be used :

1) An array of fixed microphone positions is used, the positions being distributed over the surface of the test sphere (or hemisphere).

NOTE — Either a single microphone may be moved from one position to the next sequentially or a number of fixed microphones may be used and their outputs sampled sequentially.

2) The microphone is moved along multiple parallel circular paths regularly spaced on the test sphere (or hemisphere).

3) The single microphone is moved along multiple meridional arcs regularly spaced on the test sphere (or hemisphere).

7.3.2 *Fixed microphone positions*

7.3.2.1 TEST SPHERE (FOR MEASUREMENTS IN A FREE FIELD)

The array of 20 microphone positions shown in annex B shall be used. In general, the number of measurement points is sufficient if the difference, in decibels, between the highest and lowest sound pressure levels measured in any frequency band of interest is numerically less than half the number of measurement points. If this requirement is not satisfied using the 20-point array of annex B, an additional 20-point array may be defined by rotating the original array of annex B by 180° about the **z**-axis. (The top and bottom points on the **z**-axis of the new array are coincident with the top and bottom points of the original array.) The 40 points on the two arrays are associated with equal areas on the surface of the test sphere of annex B.

NOTES

1 If the requirement on the sufficiency of the number of measurement points is not satisfied by the 40 points on the two arrays, a detailed investigation may be necessary of the sound pressure levels over a restricted area of the sphere where "beaming" from a highly directional source may be observed. This detailed investigation is necessary to determine the highest and lowest values of the sound pressure level in the frequency band of interest. If this procedure is followed, the microphone positions will usually not be associated with equal areas on the surface of the test sphere and proper allowance must be made (see 7.7.1.2).

2 For sources which are essentially non-directional, the use of fewer microphone positions (for example, 8 or 12) may not result in higher uncertainties than those given in table 2.

7.3.2.2 TEST HEMISPHERE (FOR MEASUREMENTS IN A FREE FIELD OVER A REFLECTING PLANE)

The array of 10 microphone positions shown in annex C shall be used. In general, the number of measurement points is sufficient if the difference in decibels between the highest and lowest sound pressure levels measured in any frequency band of interest is numerically less than half the number of measurement points. If this requirement is not satisfied using the 10-point array of annex C, an additional 10-point array may be defined by rotating the original array of annex C by 180° about the **z**-axis. (The top point on the **z**-axis of the new array is coincident with the top point of the original array.) The 20 points on the two arrays are associated with equal areas on the surface of the test hemisphere of annex C.

NOTES

1 If the requirement on the sufficiency of the number of measurement points is not satisfied by the 20 points on the two arrays, a detailed investigation may be necessary of the sound pressure levels over a restricted area of the hemisphere where "beaming" from a highly directional source may be observed. This detailed investigation is necessary to determine the highest and lowest values of the sound pressure level in the frequency bands of interest. If this procedure is followed, the microphone positions will usually not be associated with equal areas on the surface of the test hemisphere and proper allowance must be made (see 7.7.1.2).

2 To reduce errors due to interference effects caused by reflections from the plane, no fewer than the 10 microphone positions prescribed in annex C shall be used even if the source is essentially non-directional and broad-band in character.

7.3.3 *Coaxial circular paths in parallel planes*

For measurements in a free field over a reflecting plane, the sound pressure level is averaged in space and time by moving a single microphone successively along at least five circular paths as shown in annex D. The annular areas of the hemisphere associated with each circular path are equal. The microphone is traversed at constant speed using a turntable.

For measurements in a completely free field, five additional circular paths are used which are the mirror images of those shown in annex D.

NOTE — To avoid errors due to interference effects caused by reflections from the plane, no fewer than the five circular paths prescribed in annex D shall be used in a free field above a reflecting plane even if the source is essentially non-directional and broad-band in character.

7.3.4 *Meridional arc traverses*

A third alternative method for averaging the mean-square pressure over the surface of the test sphere or hemisphere uses a single microphone, traversed along a semi-circular arc about a horizontal axis through the centre of the source. The microphone output is squared and averaged by electronic means, giving suitable weight to the surface areas of the sphere. For measurements in a free field over a reflecting plane, the arc is only a quarter-circle in length; the axis about which the microphone rotates lies in the reflecting plane as shown in annex F. At least eight such microphone traverses at equal increments of azimuth angle around the source shall be used. This may be accomplished by rotating the source.