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Acoustics — Determination of sound power levels of noise sources — Requirements for the performance and calibration of reference sound sources

Acoustique — Détermination des niveaux de puissance acoustique émis par les sources de bruit — Prescriptions relatives aux performances et à l'étalonnage des sources sonores de référence

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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Annex A of this International Standard is for information only.

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Introduction

Reference sound sources are used extensively in "comparison methods" for determining the noise emissions of stationary sound sources. A reference sound source, of known sound power output, is used to establish the numerical relationship between the sound power level of a source, in a given location in a given acoustical environment, and the space- and time-average sound pressure level at a set of microphone positions. Once that relationship is established, it is straightforward to measure the average sound pressure level produced by an "unknown source" and to compute the sound power level produced by that source.

This International Standard defines key performance characteristics of reference sound sources and specifies procedures for their calibration.

This International Standard supplements a series of International Standards, the ISO 3740[1] series, that describes various methods for determining the sound power levels of machines and equipment. This series specifies the acoustical requirements for measurements that are appropriate for different test environments.

Six International Standards in the ISO 3740 series include procedures in which a reference sound source is used: ISO 3741, ISO 3742, ISO 3743, ISO 3744, ISO 3746 and ISO 3747. ISO 3740 gives guidelines for the use of all the International Standards in the series.

It should be noted in ISO 3744 and ISO 3747 that a reference sound source may be used in environments other than a free field over a reflecting plane. In such environments, the sound power and mode of

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1) ISO 3740:1980, *Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards and for the preparation of noise test codes*

ISO 3741:1988, *Acoustics — Determination of sound power levels of noise sources — Precision methods for broad-band sources in reverberation rooms*

ISO 3742:1988, *Acoustics — Determination of sound power levels of noise sources — Precision methods for discrete-frequency and narrow-band sources in reverberation rooms*

ISO 3743:1988, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for special reverberation test rooms*

ISO 3744:1981, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane*

ISO 3745:1977, *Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms*

ISO 3746:1979, *Acoustics — Determination of sound power levels of noise sources — Survey method*

ISO 3747:1987, *Acoustics — Determination of sound power levels of noise sources — Survey method using a reference sound source.*

acoustic radiation may differ from the basic calibration data which are determined with the reference sound source mounted directly on the reflecting plane of a hemi-anechoic room. At the request of users, manufacturers of reference sound sources should provide information about the magnitude of the changes in such environments.

Several types of reference sound source are described in annex A.

NOTE 1 In addition to being useful for determining sound power levels by the comparison method, reference sound sources may be used for qualification tests on an acoustic environment and to estimate the influence of an acoustic environment on the sound pressure levels produced by one or more sound sources located in that environment.

Acoustics — Determination of sound power levels of noise sources — Requirements for the performance and calibration of reference sound sources

1 Scope

1.1 General

This International Standard specifies the essential acoustical performance requirements of reference sound sources.

It specifies procedures for calibrating a sound source intended for use as a reference sound source in terms of its sound power levels in octave and one-third octave bands and with frequency weighting A.

To achieve uniform and accurate results, this International Standard requires that the calibration be performed in the acoustic environment provided by a hemi-anechoic room, i.e. a free field over a reflecting plane. The reference sound source operates on the reflecting plane and radiates sound into the free field above the plane.

It specifies the detailed procedures necessary to achieve the estimated calibration uncertainty given in table 1.

This International Standard applies to a sound source which is manufactured for use as a reference sound source.

1.2 Measurement uncertainty

Calibration of a reference sound source, when carried out in accordance with this International Standard, is expressed in terms of the sound power level of the source while it is radiating into an acoustic free field above a reflecting plane. Determination of the sound power levels of a reference sound source, when made in accordance with this International Standard in several laboratories, tends to result in standard deviations which are equal to or less than those given in table 1. The standard deviations of table 1 take into account the cumulative effects of all causes of measurement uncertainty. The A-weighted sound power level is determined with a standard deviation of less than 1 dB.

Table 1 — Estimated standard deviation of sound power level calibrations of reference sound sources in hemi-anechoic rooms

Octave band centre frequency	One-third octave band centre frequency	Standard deviation
Hz	Hz	dB
125	100 to 160	1
250 to 4 000	200 to 5 000	0,5
8 000	6 300 to 10 000	1

NOTES

2 The standard deviations listed in table 1 are measures of the uncertainties associated with the test methods defined in this International Standard. If a particular reference sound source were to be transported to each of a large number of laboratories, and if, at each laboratory, the sound power of that source were measured in accordance with the provisions of this International Standard, the standard deviation, as a function of frequency, of these many sound power determinations could be calculated.

3 If a similar round robin series of measurements were to be carried out on each of a large number of other reference sound sources, this procedure would correspond to the random selection of a sound source and the random selection of a laboratory. It is not these standard deviations that have been estimated and are listed in table 1. The uncertainties given in table 1 apply only to the particular source that is being calibrated. The calibration of a particular reference sound source does not apply to another reference sound source of the same design and manufacture unless statistical data are available to specify the additional uncertainty introduced by product variability.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3745:1977, *Acoustics — Determination of sound power levels of noise sources — Precision methods for anechoic and semi-anechoic rooms.*

IEC 651:1979, *Sound level meters.*

3 Definitions

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

3.1 free field over a reflecting plane: Sound field in a homogeneous, isotropic medium produced by a source in the half-space above a rigid reflecting plane surface on which the source is located.

3.2 hemi-anechoic room: 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. For the purposes of this International Standard, a test room with a hard floor meeting the requirements of ISO 3745.

3.3 surface sound pressure: The sound pressure averaged on a mean-square basis (square root of the squared value) in time, and in space (i.e., over all microphone positions on the measurement surface).

3.4 surface sound pressure level, $\bar{L}_p$, 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 frequency weighting or the width of the frequency band used is indicated; for example, A-weighted surface sound pressure level, octave-band surface sound pressure level, one-third octave-band surface pressure level, etc. The reference sound pressure is 20 μPa.

3.5 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 frequency weighting or the width of the frequency band used is indicated; for example, A-weighted sound power level, octave-band sound power level, one-third octave band sound power level, etc. The reference sound power is 1 pW ($= 10^{-12}$ W).

3.6 measurement surface: Hypothetical surface enveloping the source on which the measuring points are located. For the purposes of this International Standard, the measurement surface is a hemisphere.

3.7 far field: That portion of the radiation field of a sound source in which the sound pressure level decreases by 3 dB for each doubling of the area of the measurement surface. This attenuation rate 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 sound pressure is proportional to the total acoustic power radiated by the source.

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

3.9 directivity index (free field over a reflecting plane), N_{DI}: The directivity index, in decibels, of the source when radiating into a free field over a reflecting plane, as calculated from measurements in a hemi-anechoic room by the equation

$$N_{DI} = L_{pi} - \bar{L}_p + 3$$

where L_{pi} is the sound pressure level, in decibels, as measured in the far field of the source in the particular direction in which N_{DI} is desired and $\bar{L}_p$ is the surface sound pressure level, at the same distance, averaged over the hemispherical measurement surface, using the procedures given in clause E.2 of ISO 3745:1977.

3.10 frequency range of interest: For general purposes, the octave bands with midband frequencies from 125 Hz to 8 000 Hz or the one-third octave bands with midband frequencies from 100 Hz to 10 000 Hz.

4 Performance requirements

4.1 Stability of the sound power output

The reference sound source shall be designed and constructed so that the sound power level in each one-third octave band over the frequency range of interest can readily be maintained to within ±0,5 dB of the level that was determined by calibration of a given unit.

The manufacturer of the reference sound source shall state the range of variation of the source of electrical or mechanical power (for example, the supply voltage) within which the sound power level in any one-third octave band within the frequency range of interest shall not vary by more than ±0,3 dB. The manufacturer shall provide proce-

dures to adjust the sound power levels produced by the reference sound source for the influence of larger variations in the source of electrical voltage or mechanical power.

NOTE 4 The sound power level of a reference sound source may depend upon the atmospheric pressure and the air temperature. For use at extreme temperatures or altitudes, the manufacturer should supply appropriate corrections, and their uncertainties, for the influence of air temperature and atmospheric pressure on sound power level.

4.2 Total broad-band sound power level

Because of the many diverse uses of reference sound sources, no specific requirements are placed upon the total broad-band sound power level produced by a reference sound source. However, if the total broad-band sound power level is reported, the corresponding frequency range shall also be reported.

4.3 Spectral characteristics

The reference sound source shall produce broad-band steady sound over the frequency range in which it is intended for use, preferably for one-third octave midband frequencies between 100 Hz and 10 000 Hz. Over this frequency range, all the one-third octave-band sound power levels, when measured in a hemi-anechoic room in conformity with the requirements of clause 5, shall be within a range of 12 dB. Under these same measuring conditions, and over this same frequency range, the sound power level in each one-third octave band shall not deviate by more than ± 3 dB from the sound power level in the adjacent one-third octave bands.

For some purposes, it may be desirable for special sound sources to meet these criteria over a more limited frequency range or for a different spectrum shape. If a reference sound source does not comply with the requirements of this International Standard over the frequency range from 100 Hz to 10 000 Hz, the manufacturer shall state the one-third octave-band sound power levels of the reference sound source, and also state that the frequency response of the reference sound source does not comply with this International Standard.

4.4 Directivity index

The highest value of the directivity index of the source, N_{DI}, in any one-third octave band with midband frequency between 100 Hz and 10 000 Hz, shall not exceed 9 dB (i.e. 6 dB greater than the 3 dB directivity index for uniform hemispherical radiation) when measured in a hemi-anechoic room complying with clause 5.

If the discrete array of 5.3.1 is used, the highest value of the directivity index for each one-third octave band shall be computed from the largest of the measured sound pressure levels for that frequency band. If one of the traversing arrays of 5.3 is used, the highest sound pressure level (with the measuring instrument set for "slow" response) for each one-third octave band during the traverse shall be recorded and used to compute the highest value of the directivity index.

4.5 Mechanical characteristics

Annex A gives guidelines for the mechanical characteristics of various types of reference sound sources.

4.6 Recalibration

The manufacturer shall recommend the maximum time interval between successive calibrations. During this interval, changes in the sound power levels of the reference sound source shall not exceed the limits given in 4.1.

NOTE 5 In order to determine whether or not recalibration of a reference sound source is necessary during the recommended maximum time interval, one-third octave-band sound pressure levels should be measured occasionally at one or more fixed reference points (for example, at time intervals and locations recommended by the manufacturer) with the source operating at a specific location in a hemi-anechoic environment. If, after using manufacturer-specified procedures to adjust the measured sound pressure levels to constant environmental conditions when necessary, changes in any one-third octave band sound pressure level exceed the limits of 4.1, recalibration of the reference sound source may be necessary.

5 Calibration of reference sound source

5.1 Installation and operation

The source to be calibrated shall be placed on the reflecting plane and oriented as in normal usage. It shall be operated in accordance with the manufacturer's instructions.

The essential characteristics of the source of mechanical or electrical power (for example line voltage and frequency) and the relevant operating parameters of the reference sound source (for example rotational speed of an aerodynamic source) shall be recorded.

NOTE 6 It may be necessary to use auxiliary equipment to measure the relevant operating parameters (for example, a stroboscope to determine rotational speed).

The reference sound source shall be in a stable operating condition before any measurements (either acoustic or of operating parameters) are made.

5.2 Test environment

Calibrations made in accordance with this International Standard shall be carried out indoors in a hemi-anechoic room that meets or exceeds the qualification requirements of annex A of ISO 3745:1977. The floor of the hemi-anechoic room shall extend at least 1 m in each horizontal direction beyond the projection of the measurement surface onto the floor. Because the environmental conditions cannot be controlled, outdoor measurements are not permitted by this International Standard.

During the calibration measurements, the temperature in the hemi-anechoic room shall be maintained between 10 °C and 30 °C with a maximum variation of ± 3 °C during any individual calibration. The relative humidity shall be maintained between 30 % and 80 %.

The background noise level in each one-third octave band over the frequency range from 100 Hz to 10 000 Hz shall be at least 15 dB below the one-third octave band sound pressure level produced by the reference sound source at all microphone positions.

5.3 Microphone positions

A hemispherical measurement surface with a radius of at least 2 m shall be used. It shall be centred on the projection of the centre of the radiating surface of the sound source (as defined by the manufacturer) onto the reflecting plane. One of the sets of microphone positions given in 5.3.1 to 5.3.4 shall be used.

5.3.1 Discrete position array

If discrete microphone positions are selected, the array given in annex C of ISO 3745:1977 shall be used. The ten-microphone array shall be rotated through 30° about a vertical axis that is perpendicular to the floor of the test room and passes through the centre of the radiating surface of the sound source (as defined by the manufacturer), and the measurements shall be repeated. Alternatively, instead of using the rotated array, nine additional microphone positions may be chosen to be added to the ten-microphone array, so that sound pressure level measurements are made at 19 different positions.

5.3.2 Circular paths

If the microphones are traversed through circular paths around the vertical axis of the measurement surface (analogous to the paths shown in annex D of ISO 3745:1977), at least ten microphone heights shall be used, corresponding to $z = 0{,}05r$; $0{,}15r$; $0{,}25r$; $0{,}35r$; $0{,}45r$; $0{,}55r$; $0{,}65r$; $0{,}75r$; $0{,}85r$ and $0{,}95r$, where r is the 2 m radius of the hemispherical measurement surface.

5.3.3 Meridional paths

If the microphones are traversed along meridional paths, as shown in annex F of ISO 3745:1977, at least eight traverses at 45° increments around the vertical axis of the measurement surface shall be used. If the traverses are made at a constant angular speed, a sine potentiometer (or its electrical or mathematical equivalent) shall be used to obtain proper weighting for the surface area associated with the time required for the microphone to traverse a given arc length. If the traverse is conducted such that the microphone moves at a constant vertical speed (i.e. the angular speed is inversely proportional to the sine of the angle between the angular position of the microphone and the vertical axis of the measurement surface), no area weighting shall be applied.

5.3.4 Spiral path

If the microphone is traversed along one meridional path as in 5.3.3 , and simultaneously traversed through circular paths as in 5.3.2, thus forming a spiral path around the vertical axis of the measurement surface, an integral number of at least five circular paths shall be used. Alternatively, a spiral path may be generated by slowly rotating the reference sound source at a constant rotational speed through one complete turn while traversing the microphone along a meridional path. Area weighting as in 5.3.3 shall be used, if required.

5.4 Measurements

Sound pressure levels shall be measured in accordance with ISO 3745.

One-third octave-band sound pressure levels shall be measured. Octave-band and A-weighted sound pressure levels may be measured directly or calculated, on a mean-square sound pressure basis, from the one-third octave-band data. The A-weighting as a function of frequency shall comply with IEC 651.

5.5 Calculations

One-third octave-band surface sound pressure levels shall be calculated in accordance with ISO 3745. If octave-band and A-weighted sound pressure levels are measured directly, corresponding surface sound pressure levels shall also be computed.

One-third octave-band, octave-band, and A-weighted sound power levels shall be calculated in accordance with ISO 3745 from the measured (or calculated) surface sound pressure levels.

The highest value of the directivity index of the source, N_{DI}, shall be calculated for each one-third octave band.

6 Information to be recorded

The information to be recorded shall be as specified in clause 9 of ISO 3745:1977. For calibration of a reference sound source in accordance with clause 5, measured sound pressure levels and calculated surface sound pressure and sound power levels shall be recorded at least to the nearest 0,1 dB.

7 Information to be reported

7.1 General

General information to be reported shall be as specified in clause 10 of ISO 3745:1977.

7.2 Calibration of an individual reference sound source (in accordance with clause 5)

The report shall indicate whether or not the calibration has been carried out in full conformity with the procedures of this International Standard. The report shall also indicate whether or not the spectral uniformity complies with 4.3 and whether or not the directivity index complies with 4.4.

The sound power levels for octave bands having midband frequencies from 125 Hz to 8 000 Hz, for one-third octave bands having midband frequencies from 100 Hz to 10 000 Hz, and for A-weighting shall be reported to the nearest 0,1 dB. The report shall state that the sound power levels are in decibels (reference: 1 pW).

The highest value of the directivity index of the source for one-third octave bands having midband frequencies from 100 Hz to 10 000 Hz shall be reported to the nearest 0,5 dB. For each frequency, the direction corresponding to the maximum directivity index shall be reported.

The temperature, relative humidity and barometric pressure at the time of calibration shall be reported. If adjustments to specified environmental conditions (see 4.1) are made, such adjustments and their method of determination shall be reported.

The essential characteristics of the source of electrical or mechanical power and the relevant operating parameters of the reference sound source (see 5.1) shall be reported.