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Acoustics — Measurement and parametric description of spatial sound distribution curves in workrooms for evaluation of their acoustical performance

Acoustique — Mesurage et description paramétrique des courbes de décroissance sonore spatiale dans les locaux de travail en vue de l'évaluation de leur performance acoustique

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established 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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 14257 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

Annexes A and B form a normative part of this International Standard. Annex C is for information only.

Introduction

According to ISO 11690-1, the spatial sound distribution in a workroom is described by a curve characterizing the sound pressure level from a point source with a known sound power level, and with steady emission and omnidirectional sound radiation as a function of the distance from the source. This International Standard specifies a method for the determination of that spatial sound distribution curve, and for the derivation of two characteristics (rate of spatial decay of sound pressure levels per distance doubling and excess of sound pressure level) for the room in question.

Data obtained using this International Standard are of use for the following:

— acoustical qualification of a room with respect to noise control;

— determination of appropriate positions of a machine and of work stations in a room;

— assessment of the necessity to increase the sound absorption in the room;

— qualitative estimation of the potential performance of screens installed in the room;

— calculation of the noise-immission levels to be expected when machines with known emission are operated at specified positions in the room.

Acoustics — Measurement and parametric description of spatial sound distribution curves in workrooms for evaluation of their acoustical performance

1 Scope

This International Standard specifies a method for measuring the spatial sound distribution curve(s) of a given workroom. A method is given for determining, from the measured data, two descriptors of the acoustical performance of a workroom regarding noise control: i.e. the excess of sound pressure level with respect to a free field, and the sound pressure level decay per distance doubling.

This International Standard does not deal with assessment of the acoustical quality with respect to speech communication or other psychological factors.

This International Standard is applicable to workrooms of any shape and any dimensions provided that the number of microphone positions allows the regression calculation to be performed.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 3741, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for reverberation rooms*

ISO 3744:1994, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane*

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

ISO 6926, *Acoustics — Requirements for the performance and calibration of reference sound sources used for the determination of sound power levels*

IEC 60651, *Sound level meters*

IEC 60804, *Integrating-averaging sound level meters*

IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters*

3 Terms and definitions

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

3.1
sound pressure level
L_p
ten times the logarithm to the base 10 of the ratio of the square of the sound pressure, p, radiated by a sound source to the square of the reference sound pressure (p_0 = 20 µPa)

NOTE 1 The sound pressure level is expressed in decibels.

NOTE 2 The frequency weighting or the width of the frequency band used, and the time weighting (S, F or I, see IEC 60651), should be indicated.

3.2
sound power level
L_W
ten times the logarithm to the base 10 of the ratio of the sound power radiated by a sound source to the reference sound power ($P_0 = 10^{-12}$ W)

NOTE 1 The sound power level is expressed in decibels.

NOTE 2 The frequency weighting or the width of the frequency band used should be indicated. For example, the A-weighted sound power level is L_{WA}.

3.3
spatial sound distribution curve
curve which shows how the sound pressure level from a reference sound source decreases when the distance to the source increases

NOTE 1 Such curves are frequency dependent and characterize the acoustic properties of rooms. In some cases, several spatial sound distribution curves are necessary to characterize a room.

From this curve and for a given range of distances from the source, two main quantities are determined:

— the rate of spatial decay of sound pressure levels per distance doubling (DL_2), and

— the excess of sound pressure level (DL_f).

Three distance ranges are normally of interest: near, middle and far regions. These two quantities (DL_2 and DL_f) are useful for assessing the acoustic quality of a room.

NOTE 2 Adapted from ISO 11690-1:1996, definition 3.4.11.

3.4
sound distribution value
$D_j(r)$
difference, in decibels, between the sound pressure level, in a given octave band and at a microphone position located at a given distance from the reference sound source, and the sound power level of the reference sound source in the same octave band, as given by

$$D_j(r) = L_{pj}(r) - L_{Wj} \quad (1)$$

where

L_{Wj} is the sound power level of the reference sound source used for the test;

L_{pj} is the sound pressure level at each measurement point located at a distance r from the sound source;

j is the number of the octave band.

NOTE The sound distribution value for a given sound power spectrum can be calculated according to equation (3).

3.5
rate of spatial decay of sound pressure levels per distance doubling
DL_2
slope, in decibels per distance doubling, of the spatial sound distribution curve for a given range of distances

3.6
excess of sound pressure level
DL_f
average difference, in decibels, over a given distance range, between the spatial sound distribution curve of the room and the spatial sound distribution curve for a free field

NOTE The spatial sound distribution curve for a free field falls off with 6 dB per distance doubling.

4 Sound distribution in a room

4.1 General

For basic information on sound propagation in a room and on the spatial sound distribution curves, see ISO 11690-1, ISO/TR 11690-3 and other references in the Bibliography.

4.2 Spatial sound distribution curves

4.2.1 Reference spatial sound distribution curve

The reference curve is the spatial sound distribution curve which would occur in a free field, without any reflecting surfaces or scattering objects. At each microphone position, values D_{ref} for this curve are given by the following equation:

$$D_{ref}(r) = 10\ \lg\left(\frac{r_0^2}{4\pi r^2}\right) \text{dB} = \left(20\ \lg\frac{r_0}{r} - 11\right) \text{dB} \qquad (2)$$

where

r is the distance, in metres, between the sound source and the measurement point considered;

r_0 is the reference distance (= 1 m).

Experience shows that ground reflections and the directivity of the source influence the measured sound distribution curve if the influence of the room is low, such as in very large rooms and/or in rooms with highly absorbent boundary surfaces. This may be taken into account by applying the correction method described in annex B.

It is recommended to draw the reference curve in all diagrams showing spatial sound distribution curves (see Figure 1).

4.2.2 Spatial sound distribution curves in frequency bands and for a given frequency spectrum

For the purposes of this International Standard, spatial sound distribution curves are measured in octave bands.

NOTE In narrower frequency bands (such as one-third-octave bands), interference effects can occur. These can affect spatial sound distribution curves in a complex manner so that extensive experience is required for correct interpretation. Thus, such measurements are not recommended.

The spatial sound distribution curve in a given octave band and on a given path is determined from equation (1).

The sound distribution curve for a given octave band j is the diagram of the sound distribution values $D_j(r)$ where a logarithmic scale is used for r (see Figure 1).

For practical purposes, there is often particular interest in the spatial sound distribution curve for a given sound power spectrum, e.g. the spectrum of a specific machine. This curve is determined from octave-band data according to the following equation that gives the value, D_S, of D at distance r:

$$D_S(r) = 10 \lg \frac{\sum_j 10^{\left(D_j(r)+L_{W\text{mach}\,j}\right)/10}}{\sum_j 10^{L_{W\text{mach}\,j}/10}} \text{ dB} \qquad (3)$$

where

$D_j(r)$ is the value of D in octave band j, at position r;

$L_{W\text{mach}\,j}$ is the value of the sound power level of the machine in octave band j.

4.2.3 Frequency-normalized spatial sound distribution curve

If the frequency spectra of the sound power of the machines that operate or will operate in the workroom under test are not known, it is often sufficient and useful to determine the spatial sound distribution curve(s) of the workroom under test for a normalized frequency spectrum. The normalized frequency spectrum for the purpose of this International Standard is A-weighted pink noise so that the frequency-normalized spatial sound distribution curve relative to this particular spectrum is calculated from octave-band data, D_j, according to the equation:

$$D_{\text{Norm}} = 10 \lg \left(\sum_j 10^{\left(D_j + P_j\right)/10} \right) \text{ dB} - 6{,}2 \text{ dB} \qquad (4)$$

where

j is the number of the octave band;

D_{Norm} is the value of D for the frequency-normalized spatial sound distribution curve;

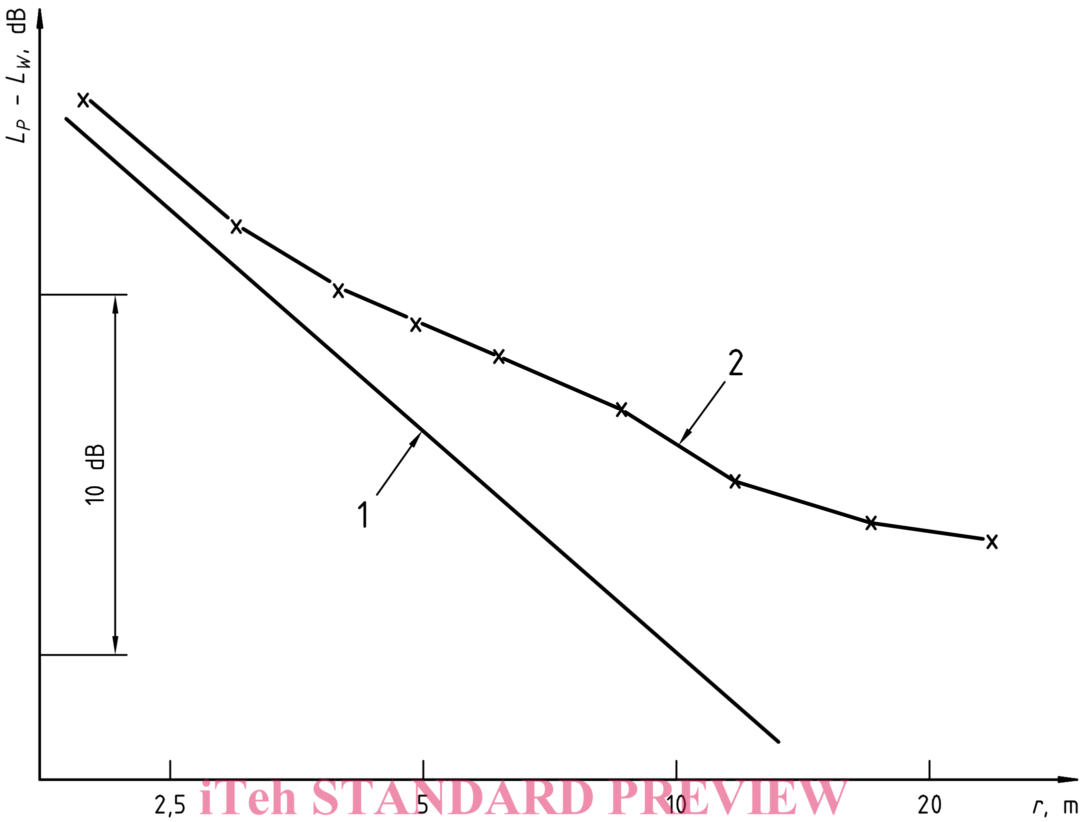
P_j is given in Table 1.

Table 1 — Values of P_j for the frequency-normalized spatial sound distribution curve

Octave band j, **centre frequency**, Hz	**125**	**250**	**500**	**1 000**	**2 000**	**4 000**
Subscript j	1	2	3	4	5	6
P_j, dB	– 16,1	– 8,6	– 3,2	0	1,2	1

NOTE A-weighted pink noise has been retained as a normalized frequency spectrum because the range of frequency spectra met in practice is so large that the use of an average industrial frequency spectrum can imply that a frequency-normalized spatial sound distribution curve is meaningful for all possible industrial situations, which is not true.

For special purposes, such as optimizing the sound absorption in a room, a specific spectrum may be used.



Key

1 Free-field sound distribution curve
2 Spatial sound distribution curve

x Measurement points
r Distance from the source to the receiver (logarithmic scale)

Figure 1 — Representation of a spatial sound distribution curve

5 Measurement of the spatial sound distribution curve

5.1 Specifications regarding the sound source used for the test

5.1.1 Performance requirements to be met by the source

Part of the requirements for reference sound sources according to ISO 6926 are more stringent than necessary for the purposes of this International Standard. Some characteristics of the reference sound source, however, must meet more stringent requirements for measurements to be in accordance with this International Standard. Annex A therefore specifies the requirements for a reference sound source for the purposes of this International Standard.

5.1.2 Calibration and verification of the sound power of the source

The sound source shall be calibrated in octave and one-third-octave frequency bands in accordance with ISO 6926. Table 2 indicates the acoustical environments to be used for sound power and directivity determinations, depending on the position of the source in normal use, for calibration and verification purposes. The method for determining the directional characteristics of the sound source is specified in annex A. Checks shall be done in octave bands. Intervals between checks depend on experience gathered with the source system used.

Table 2 — Appropriate environments for the determination of the sound power of the source for calibration and verification purposes

Height above floor of acoustical centre of sound source in normal use	Appropriate environments for determination of sound power	Appropriate environments for determination of directional characteristics
0,5 m or less	Reverberation room (see ISO 3741) or hemi-anechoic room (see ISO 3745)	Hemi-anechoic room (see ISO 3745)
More than 0,5 m	Reverberation room (see ISO 3741) or anechoic room (see ISO 3745)	Anechoic room (see ISO 3745)

If the source system is used rather frequently, it is recommended to determine its sound power level in octave bands every 3 months or more frequently until there are at least six individual measurement results. Later on, time intervals between checks may be longer.

NOTE The purpose of the determination of the spatial sound distribution curve may not require knowledge of the sound power level of the source. This is the case, for example, when the acoustical performance of a workroom (see clause 6) is evaluated using only the rate of spatial decay of sound pressure levels per distance doubling (see 3.5).

5.1.3 Location of the source

For measurement of the spatial sound distribution curve, the acoustical centre of the sound source shall be located

— either as close as possible to the floor, or

— at a height above the floor of more than 0,5 m.

A source is considered as being close to the floor if its acoustical centre is at a height less than or equal to 0,5 m.

The acoustical centre of the source shall be located at least 3 m away from any wall and any reflecting object other than the floor. If this requirement cannot be fulfilled because of the room dimensions, the distance used for the test shall be recorded and reported.

5.1.4 Sound power versus background noise

The sound power of the source shall be such that, for all distances and for all octave bands for which the spatial sound distribution curve is to be measured, the sound pressure level due to the source is at least 10 dB higher than the background noise from other sources. If, at a given measurement point and in a given octave band, the sound pressure level, when the source used for the test is in operation, is less than 10 dB but more than 6 dB higher than background noise, a background noise correction determined as specified in ISO 3744 shall be made.

5.2 Measurement instrumentation

Sound pressure levels in each octave band and at each microphone position shall be measured using a class 1 sound level meter in compliance with IEC 60651 or a class 1 integrating-averaging sound level meter in compliance with IEC 60804. The microphone shall be omnidirectional (taking into account any supplementary equipment connected to it). Octave-band filters shall comply with IEC 61260.

If the signal is recorded (using, for example, analog or digital recorders) for off-line processing, it shall be ensured that the instrumentation as a whole complies with the above-mentioned requirements.