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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

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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

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

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:

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

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:

$$D_\mathrm{S}(r) = 10\,\lg \frac{\sum_j 10^{\left(D_j(r) + L_{W\mathrm{mach}\,j}\right)/10}}{\sum_j 10^{L_{W\mathrm{mach}\,j}/10}}\ \mathrm{dB} \tag{3}$$

where

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

$L_{W\mathrm{mach}\,j}$ 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:

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

where

j is the number of the octave band;

D_Norm is the value of D for the frequency-normalized spatial sound distribution curve;

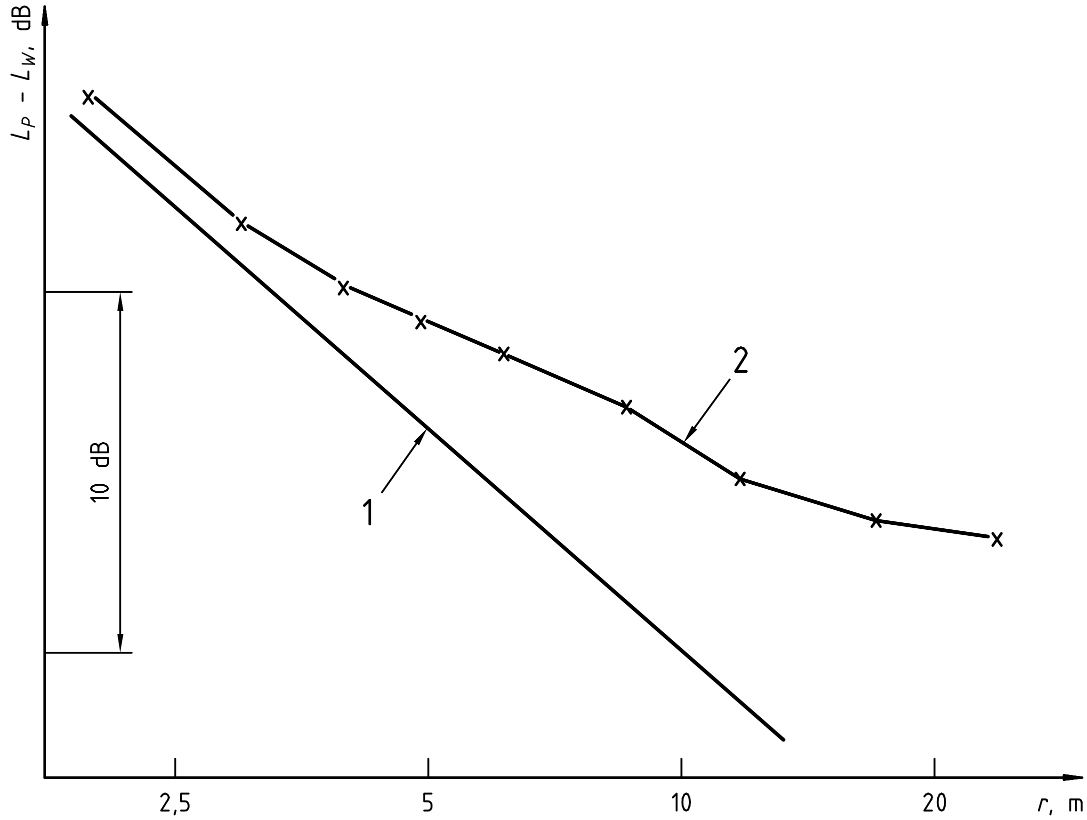
P_j is given in Table 1.

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.

5.3 Measurement path and points

5.3.1 Measurement path

The measurement path shall be parallel to the floor and begin on the source. The last measurement point on the path shall be located at a minimum distance of 1,5 m from any wall or large reflecting object. A larger distance is recommended.

Preferred path heights are 1,55 m (so simulating a person standing up) and 1,2 m (so simulating a person seated). Any other path height is acceptable as long as the path remains parallel to the floor and its value is recorded and reported.

The path shall be such that there is no obstacle on the floor below it. If this condition cannot be met, this shall be recorded and reported together with the precise location of the obstacle(s) with respect to the measurement path.

The path shall be oriented along a free line of sight from the source, if possible, and it shall be clear of any large reflecting structures to a distance of at least 1,5 m to either side. Otherwise, a different path or height of the path above floor level shall be chosen. If possible, measurements shall be carried out along a second preferably orthogonal path.

5.3.2 Measurement points

The measurement points shall be distributed on the measurement path. Possible distributions of microphone positions along a path are many. It is recommended to choose one of the following distributions:

— 1 m, 2 m, 3 m, ... , 10 m, 12 m, 14 m, ... , 20 m, 24 m, 28 m, ... , 40 m, 48 m, 56 m, ... (constant increment within each range and logarithmically growing increment from one range to the next);

— 2 m, 3 m, 4 m, 6 m, 8 m, 12 m, 16 m, 24 m, 32 m, 48 m, 64 m, ...

The number of measurement positions in a given distribution is a minimum number. More measurement positions may be added. Continuous recording of the sound pressure level versus distance, when practical, provides the best possible description of the spatial sound distribution.

The distances indicated in the above distributions are from the acoustical centre of the source to the microphone. For sources whose acoustical centre is on the floor, Table 3 relates the above distance to the horizontal distance for the two microphone heights given in 5.3.1.

Table 3 — Correspondence between the distance *r* from a microphone to the acoustical centre of the source and the horizontal distance, for a sound source whose acoustical centre is on the floor

Values in metres

Distance to acoustical centre of source	2	3	4	5	6	7	8	9	10
Horizontal distance for a path height of 1,2 m	1,60	2,75	3,82	4,85	5,88	6,90	7,91	8,92	9,93
Horizontal distance for a path height of 1,55 m	1,26	2,57	3,69	4,75	5,80	6,83	7,85	8,87	9,88

NOTE The horizontal distance is rounded to the nearest centimetre. From a distance of 10 m, these two distances may be taken as equal.

NOTE 1 The 1-m position of the first recommended distribution is not possible if the acoustical centre of the sound source is on the floor.

NOTE 2 When the room is large enough, there can be several possibilities regarding the choice of paths. Two of them are of special relevance depending on the purpose of the measurements, as follows.

a) Determination of several spatial sound distribution curves along the longitudinal and lateral axis of the room in different contiguous zones of it, e.g. when the purpose is evaluation of the acoustical performance of the room (see clause 6) in the middle region in each of these zones. This is of particular interest in the case of large workrooms whose acoustical performance varies from one zone to another due to spatial variations of the room architecture and/or sound absorption properties.

b) Determination of one spatial sound distribution curve for the room along its longitudinal axis and one along its lateral axis. This is of particular interest in the case of large workrooms with homogeneous architecture and absorbing properties for which it is desired to know the acoustical performance.

5.4 Measurement procedure

If possible, measurements shall be carried out with all machines, ventilation system, high-pressure pipework leading through the room, etc. being inoperative except for the sound source used for the test.

The sound source used for the test shall fulfil the requirements of 5.1 and shall be positioned precisely with its acoustical centre as specified in 5.1.3.

The room under test shall be under its normal operating conditions (normal fittings in terms of type, volume and location in the room; doors and windows closed if this corresponds to the normal operating conditions).

It shall be verified that the requirements regarding background noise given in 5.1.4 are met. If necessary, background noise corrections shall be made according to 5.1.4.

With the sound source used for the test in operation, the sound pressure level shall be measured at the discrete points located on the measurement path(s), as specified in 5.3, for the six octave bands from 125 Hz to 4 000 Hz.

The overall measurement time may be kept short (so that there is only a short interruption of activity of the workroom) by the use of recording equipment. In this case, the signal shall be recorded without any frequency filtering and the spectral analysis shall be performed later in the laboratory for each measurement point. The dynamic behaviour of the recording equipment shall be taken into account. As a rule, it is recommended to use a pre-amplifier with calibrated decibel ranges.

If several locations of the source used for the test fulfil the requirements of this International Standard and if the purpose of the test is the evaluation of the acoustical performance of the room (see clause 6), the location retained shall be, if possible, in the zone of the room where the noisiest machines are or will be located.

NOTE For a given workroom, results of the measurements described above can be influenced by the type and sound power uncertainty of the sound source used for the test, and by the position and direction of the measurement path. The specifications given in this International Standard ensure that the uncertainty of the measurement method is kept within an acceptable range. Quantitative information on the accuracy of the measurement method cannot presently be given.

However, the following maximum values of the uncertainty for A-weighted levels could be expected for tests carried out under repeatability conditions (same source, same height and orientation of the source, same path, same height of the measurement path, same number and position of microphones, same instrumentation, same operator, unchanged acoustical environment):

$\pm$ 0,3 dB for DL_2, and

$\pm$ 2 dB for DL_f.

5.5 Representation of the measured data

The spatial sound distribution curve shall be drawn into a diagram as shown in Figure 1. The distance drawn on the abscissa is the distance from the microphone to the acoustical centre of the source. Values of D shall be tabulated as shown in Table 4. If it is desired to determine the spatial sound distribution curve for a specified sound power spectrum S (see 4.2.2) and/or a frequency-normalized spatial sound distribution curve (see 4.2.3), then the corresponding values of D shall also be plotted and tabulated.

6 Parametric description of the measured spatial sound distribution curve in view of evaluation of the acoustical performance of workrooms

6.1 General

One of the main purposes of the measurement of spatial sound distribution curves is evaluation of the acoustical performance of a workroom. This is based on the derivation from the spatial sound distribution curve of specific parameters, namely the rate of spatial decay of sound pressure levels per distance doubling (see 3.5) and the excess of sound pressure level with respect to a free field (see 3.6). These parameters are normally determined in three distance ranges from the source.

6.2 Distance ranges

The following distance ranges shall be distinguished when evaluating a spatial sound distribution curve and the related characteristics (see Figure 2).

a) The near region: this region ranges from 1 m to distance d_1. In this region, the spatial sound distribution curve is dominated by the direct sound from the source used for the test. The position of the source used for the test in relation to near reflecting surfaces or surfaces limiting the radiation to a certain solid angle (e.g. source in a corner or in a part of the room with a low ceiling) has a considerable influence on the sound distribution in that range. This region is used for evaluation of the acoustical properties of small rooms.

b) The middle region: this region ranges from distance d_1 to distance d_2. It is recommended, whenever possible, to go up to 24 m. The middle region is of particular importance for characterizing the acoustical performance of a room for health and safety aspects.

c) The far region: this region starts from distance d_2. In this region, the sound distribution is strongly influenced by reflecting and scattering surfaces (of machines or other fittings) in the room. This region is also important for the acoustical evaluation of workplaces far away from the source, under health and safety aspects.

Typical values for d_1 and d_2 are 5 m and 16 m, respectively. If, in order to take account of room dimensions and depending on the purpose of the test, other values are used, they shall be recorded and reported.

Distances shall be measured from the acoustical centre of the sound source used for the test.

6.3 Determination of the rate of spatial decay of sound pressure levels per distance doubling, DL_2

The rate of spatial decay of sound pressure levels per distance doubling, DL_2, in the range [r_n, r_m] of values of r and for a given octave band j, is calculated from the values of D at microphone positions i (see 4.2.2) using the following equation:

$$DL_2 = -0{,}3 \frac{z\sum_{i=n}^{m}\left[D_i \lg\left(\frac{r_i}{r_0}\right)\right] - \sum_{i=n}^{m} D_i \sum_{i=n}^{m} \lg\left(\frac{r_i}{r_0}\right)}{z\sum_{i=n}^{m}\left[\lg\left(\frac{r_i}{r_0}\right)\right]^2 - \left[\sum_{i=n}^{m} \lg\left(\frac{r_i}{r_0}\right)\right]^2} \text{ dB} \qquad (5)$$

where

$z = m - n + 1$

D_i is given by equation (1), or equation (B.1) if the correction defined in annex B is used.

If the value of DL_2 is to be determined only in octave bands, the sound power level of the source used for the test need not be known. However, all other specifications regarding the sound source given in 5.1 shall be fulfilled.

The rate of spatial decay of sound pressure levels per distance doubling over the distance range $[r_n, r_m]$, for the frequency-normalized spectrum defined in 4.2.3, is obtained using equation (5) with D_i replaced by the value of D given by equation (4).

6.4 Determination of the excess of sound pressure level with respect to a reference sound distribution curve, DL_f

6.4.1 General

In each distance range, the excess of sound pressure level can be characterized in two different ways that are both of practical interest: first, by means of an average value; and second, by means of its value at a specified distance.

The excess of sound pressure level shall be determined from measurements carried out using a sound source complying with 5.1.

6.4.2 Value of the excess of sound pressure level over a distance range $[r_n, r_m]$ and in a given octave band

The excess of sound pressure level with respect to a free field (or a hemi-free field) at a given distance from the source and in a given octave band is given by:

$$DL_f = D - D_{ref} \tag{6}$$

where

D is given by equation (1), or equation (B.1) if the correction defined in annex B is used;

D_{ref} is given by equation (2).

The average value, $DL_f(r_n, r_m)$, of DL_f as given by equation (6), over the distance range limited by microphone positions $i = n$ and $i = m$ located at distances r_n and r_m from the sound source and for a given octave band, is given by:

$$DL_f\left(r_n, r_m\right) = \frac{\sum_{i=n+1}^{m}\left[\left(DL_{f_i} + DL_{f_{i-1}}\right)\lg\left(\frac{r_i}{r_{i-1}}\right)\right]}{2\lg\left(\frac{r_m}{r_n}\right)}\ \text{dB} \tag{7}$$

6.4.3 Value DL'_{fr} of DL_f at a specified distance r and for a given octave band

The value, DL'_{fr}, of DL_f in a given octave band at a conventional distance r from the source is useful for describing the sound distribution curve in each distance range, as illustrated in Figure 2. DL'_{fr} is the height of the regression line over the free-field line, at distance r and for the given octave band. Conventional distances retained for the purpose of this International Standard are 4 m for the near region, 10 m for the middle region and 30 m for the far region. DL'_{fr} shall be calculated using equation (8):

$$DL'_{fr} = \left(\sum_{i=n}^{m}\frac{D_i}{z}\right) + 20\lg\left(\frac{r}{r_0}\right)\text{dB} + \left[\frac{DL_2\left(r_n, r_m\right)}{\lg 2}\right]\left[\left(\sum_{i=n}^{m}\frac{\lg\left(r_i / r_0\right)}{z}\right) - \lg\left(\frac{r}{r_0}\right)\right] + 11\,\text{dB} \tag{8}$$

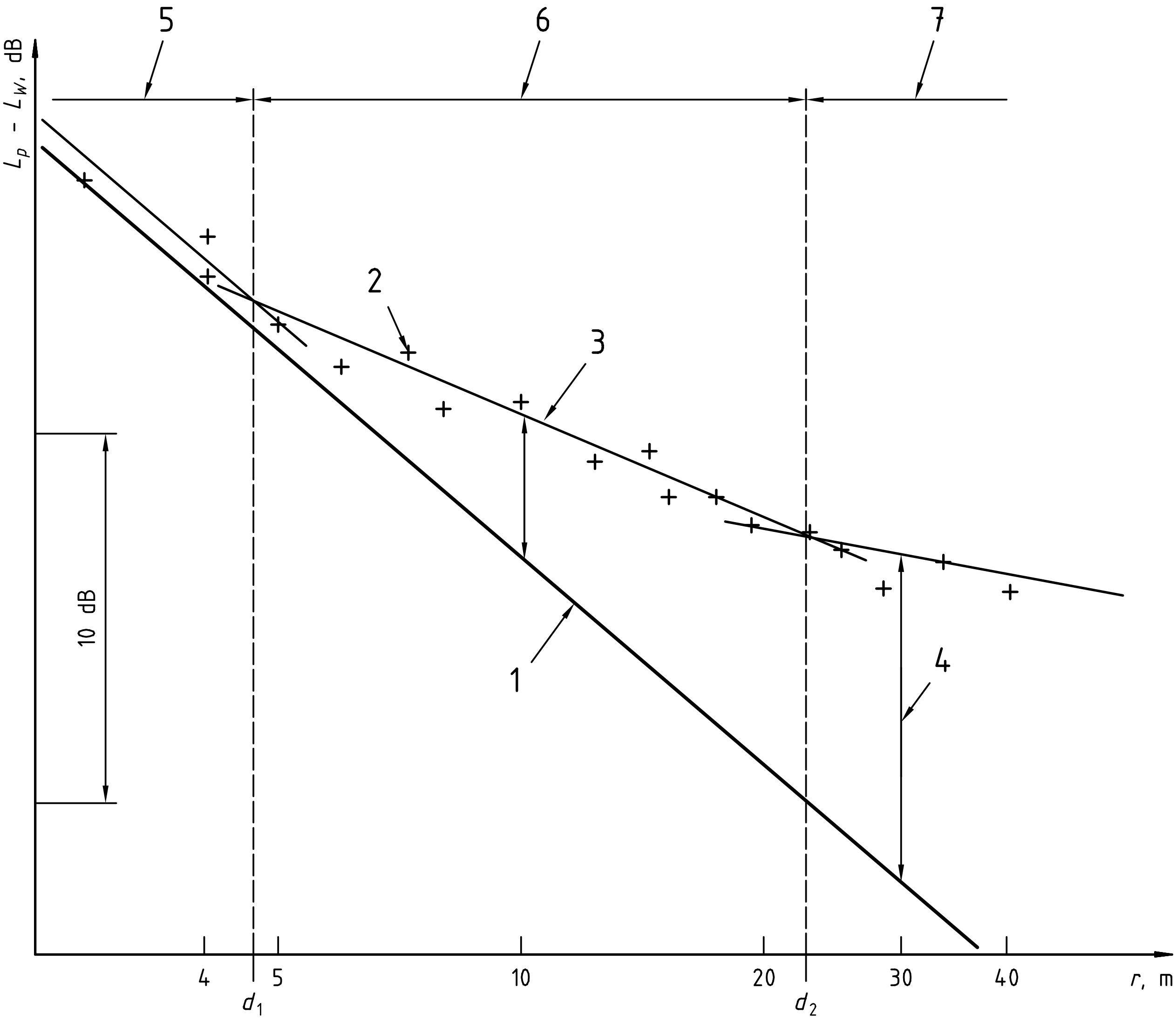
where

$z = m - n + 1$;

r_i is the distance to the sound source from the microphone position i within the distance range $[r_n, r_m]$;

D_i is given by equation (1), or equation (B.1) if the experimental reference curve defined in annex B is used;

r_0 is the reference distance (= 1 m).



Key

1 Free-field sound distribution curve
2 Measurement point
3 Regression line for the middle region
4 Excess of sound pressure level in the 1 000 Hz octave band at the specified distances of 4 m, 10 m and 30 m
5 Near region
6 Middle region
7 Far region

r Distance from the source

Figure 2 — Illustration for the 1 000 Hz octave band of the parametric description of a spatial sound distribution curve using three portions of straight lines (regression lines of slope DL_2) bounded by distances d_1 and d_2 and the excess of sound pressure level at the three specified distances

6.5 Evaluation of measured data

Evaluation of the measured data shall be done from the spatial sound distribution curve represented as indicated in 5.5.

Values of DL_2, DL_f and DL'_{fr} for each path and each distance range of interest among those defined in 6.2 shall be derived from the measured data using equations (5), (7) and (8) respectively.

When two orthogonal measurement paths are used and, depending on the purpose of the measurements, the two so-obtained spatial sound distribution curves may be considered and evaluated separately or merged into one average curve (arithmetic average of levels).

Values of DL_2 and DL_f shall at least be determined for the middle region. This determination shall at least be made with d_1 = 5 m and d_2 = 16 m if data comparison at the international level is intended.

In order to avoid confusion between the values of DL_2, DL_f and DL'_{fr} in the three regions, the specific following notation shall be used:

— $DL_{2,F}(r_n;r_m)$ and $DL_{f,F}(r_n;r_m)$ for the average sound pressure decay per distance doubling and for the average excess of sound pressure level, respectively, over the distance range limited by distances r_n and r_m, where F is the value of the centre frequency, in hertz, of the octave band considered;

— $DL'_{f,F,r}$ for the excess of sound pressure level at the specified distance r, where F is the value of the centre frequency, in hertz, of the octave band considered.

EXAMPLES

$DL_{2,1\,000}(1;5)$ is the average value of DL_2 in the octave band of 1 000 Hz for a near region ranging from 1 m to 5 m.

$DL_{f,4\,000}(24;100)$ is the average value of DL_f in the octave band of 4 000 Hz for a far region ranging from 24 m to 100 m.

$DL'_{f,2\,000,10}$ is the excess of sound pressure level in the octave band of 2 000 Hz, at the specified distance of 10 m.

The indication of the frequency band shall be replaced by subscript S or Norm if DL_2 and/or DL_f and/or DL'_{fr} are determined for a specific spectrum (see 4.2.2) or for the normalized frequency spectrum (see 4.2.3), respectively.

7 Information to be recorded and reported

For measurements according to this International Standard, the following information shall be recorded and reported:

a) a description of the sound source used for the test including its directivity characteristics; height of the acoustical centre of the source above the floor;

b) a description of the measurement instrumentation used;

c) a description of the room (shape, dimensions, fitting) and clear identification of the path(s) and the position(s) in the room of the source used for the test (both shown preferably on a scaled top view of the room);

d) for each path, the number of measurement points and their positions;

e) an indication of the type of data aimed at;

f) spatial sound distribution curves in octave bands;

g) the spatial sound distribution curve for a given sound power spectrum (in which case this spectrum shall be recorded in a table or a diagram);

h) the frequency-normalized spatial sound distribution curve;

i) the experimental reference curve for correcting according to the method of annex B if this correction is made;

j) background noise levels, especially at the measurement points far from the source used for the test and, if relevant, indication of the measurement points at which a background noise correction has been applied and the magnitude of it;

k) the measured data;

l) if the purpose of the test is the evaluation of the acoustical performance of a workroom, calculated values of DL_f (value over a distance range and/or value at a specified distance) and DL_2, for each path and, at least, for the middle region; the values of d_1 and d_2 used;

m) the statement that the determination was made in accordance with this International Standard; if relevant, any deviations from the requirements of this International Standard shall be recorded and reported with justifications;

n) the person responsible for the measurements and calculations;

o) the time and date of the measurements.

Regarding item a), the directivity characteristics of the sound source used for the test need not be reported.

Spatial sound distribution curves for each path shall be reported in tabular (see Table 4) or graphical (see Figure 1) form.

Table 4 — Example of tabular form for reporting spatial sound distribution data

Distance from microphone to acoustical centre of the source m	**Octave-band centre frequency** Hz						**Reference curve used** (see 4.2.1 and annex B)
	125	250	500	1 000	2 000	4 000	
	$L_p - L_W$, dB						

Annex A
(normative)

Performance requirements for the sound source to be used for the test

A.1 Directivity of the source

The sound source used for the test shall be as omnidirectional as possible. Directional characteristics of the sound source shall be measured in one-third-octave frequency bands in accordance with the following method, based on ISO 140-3:1995, 1.3.

Measurements shall be carried out in an appropriate environment as indicated in 5.1.2, Table 2 . Approximate free-field or hemi-free-field conditions, indoors or outdoors, are acceptable if the influence of reflections from obstacles and surfaces (other than the floor for an approximate hemi-free field) is less than 0,2 dB in the frequency range of interest.

For a test of the directional radiation of a source operating above the floor, the following “gliding” procedure, applied in each one-third-octave frequency band of the frequency band of interest, shall be used:

— install the source in a free field on a rotating table;

— set the microphone at 1,5 m from the acoustical centre of the source;

— with the source driven by a wide-band noise and slowly rotated, measure the sound pressure levels, with time-weighting F, in steps of 1°;

— calculate the mean sound pressure level over the 0° to 360° range, L_{360};

— calculate the mean sound pressure levels, $L_{30,i}$, over the ranges 0° to 30°, 1° to 31°, 2° to 32°, etc.

The directivity indices are:

$$\mathrm{DI}_i = L_{30,i} - L_{360} \tag{A.1}$$

Uniform omnidrectional radiation shall be assumed if the DI values are within ± 2 dB in the one-third-octave frequency bands from 100 Hz to 630 Hz. In the one-third-octave frequency bands of 630 Hz to 1 000 Hz, the range of DI values increases linearly from ± 2 dB to ± 8 dB. It is ± 8 dB for the one-third-octave frequency bands of 1 000 Hz to 5 000 Hz.

For sources operating with their acoustical centre on the floor, directional characteristics shall be measured over a hemisphere with the source set on the reflecting surface, using either the “gliding” method described above or a discrete point method.

Only sound sources whose directional characteristics have been measured in one-third-octave bands in the frequency range 100 Hz to 5 000 Hz and which fulfil the following criteria in that range shall be used. The maximum absolute value of the directivity index of the source in one-third-octave bands, as defined above, shall not exceed 8 dB.

The fulfilment of the above criteria may be assured by appropriate means, for example by allowing the sound source to rotate. If the sound source is rotated, any measured value of DI shall be an average over at least one revolution of the source system.

Considering that the source used for the test is not perfectly omnidirectional, in order to improve the repeatability of the measurements and to ensure consistency of the results between possible repeated sets of measurements in a given room, the source shall be marked so that its orientation with respect to the measurement path can be controlled and kept unchanged.

A.2 Sound power level difference between adjacent frequency bands

The sound power level of the source in each one-third-octave band in the frequency range 100 Hz to 5 000 Hz shall not deviate by more than 8 dB from the sound power level in the adjacent one-third-octave bands.

A.3 Overall sound power level

There is no requirement for the overall value of the sound power level in one-third-octave bands.

A.4 Stability over time

It shall be ensured that the sound power of the sound source system (which in the case of a loudspeaker system includes a generator and a power amplifier) is constant over time. When a loudspeaker system is used, it is recommended

— to use a power amplifier with temperature compensation and stabilized voltage,

— to use a generator with volume adjustment in discrete steps defined by resistors, or with stops at discrete volume settings, rather than a generator with continuous volume adjustment, and

— to check the stability with temperature of the loudspeakers used.

The variation of the sound power level of the source, determined under repeatability conditions, shall not exceed ± 1 dB in the one-third-octave bands from 100 Hz to 160 Hz, and ± 0,5 dB in the one-third-octave bands from 200 Hz to 5 000 Hz.

The short-term stability of the sound power shall be checked by measuring the sound pressure level at a fixed point 1 m from the source or at the first measurement position, just before and just after the measurement of the spatial sound distribution curve. The level difference in each octave band shall not exceed ± 1 dB for the measurement to be valid.

Annex B
(normative)

Correction of measured sound distribution curves to account for differences in ground reflections and source directivity

Experience shows that in rooms with a low value of DL_f the actual sound distribution curve in a free field over a reflecting plane of the particular sound source used influences the sound distribution curve of the workroom to be tested due to the effects of ground reflections and source directivity.

The experimental reference curve is the spatial sound distribution curve measured in a free field over a reflecting plane, without any other reflecting or scattering objects. The reflecting plane shall fulfil the requirements of ISO 3744:1994, annex A. The measurement shall be carried out with the sound source to be used for characterizing the workroom under test. The orientation of the sound source, the heights of the sound source and of the microphone, together with the distances from the source to the microphones, shall be at least the same as those to be used for characterizing the workroom under test.

This measured reference curve may be used for correcting the values of D_j measured in the workroom. Corrected values of D_j , $D_{\text{corr}\,j}$, are given by:

$$D_{\text{corr}j}(r) = 10\lg\left[10^{D_j(r)/10} - 10^{D_{\text{meas,ref}\,j}(r)/10} + 10^{D_{\text{floor,ref}}(r)/10}\right]\text{dB} \quad \text{(B.1)}$$

where

$D_j(r)$ is given by equation (1);

$D_{\text{meas,ref}\,j}(r)$ is taken from the measured reference curve defined above;

$D_{\text{floor,ref}}(r)$ is given by the following equation:

$$D_{\text{floor,ref}}(r) = D_{\text{ref}}(r) + 10\lg\left(1 + \frac{r^2}{r^2 + 4h_S h_P}\right)\text{dB} \quad \text{(B.2)}$$

where

$D_{\text{ref}}(r)$ is given by equation (2);

h_S is the height of the source;

h_P is the height of the path.

If the height of the sound source is the same as that of the path, equation (B.2) reduces to:

$$D_{\text{floor,ref}}(r) = D_{\text{ref}}(r) + 10\lg\left(1 + \frac{r^2}{r^2 + 4h_S^2}\right)\text{dB} \quad \text{(B.3)}$$

If the sound source is located on the floor, $h_S = 0$ and equation (B.2) reduces to:

$$D_{\text{floor,ref}}(r) = D_{\text{ref}}(r) + 3\ \text{dB} \quad \text{(B.4)}$$

Annex C
(informative)

Example of use of this International Standard

C.1 General

In the example chosen

— the source used for the test has its acoustical centre on the floor,

— the experimental reference curve of the sound source is known and used for correcting the values measured in the workroom,

— the workroom is new and the activity to take place in it is not well defined so that no particular frequency spectrum is known, and

— the reason for measuring the spatial sound distribution curve is determination of the rate of spatial decay per distance doubling and of the excess of sound pressure level, in octave bands and for the A-weighted pink-noise reference frequency spectrum.

C.2 Data concerning the workroom and measurement path chosen

See Figure C.1 and Table C.1.

The workroom has the following characteristics:

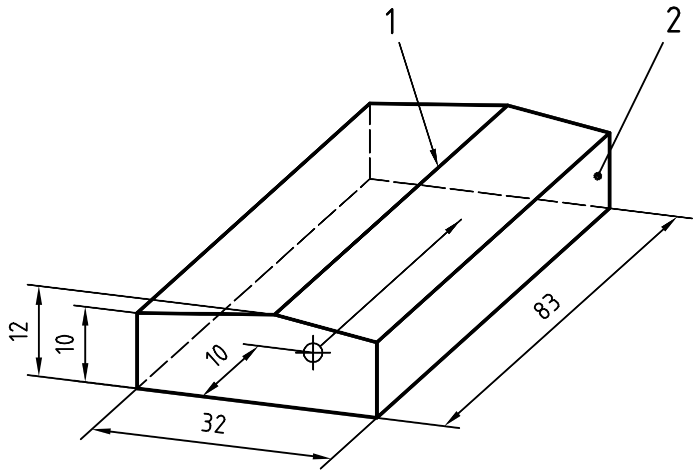
— shape: rectangular hall; large shipyard workroom;

— dimensions: 83 m × 32 m × 11 m;

— nature of walls: see drawing (special feature: chequered sound-absorbing treatment);

— fittings: moderately fitted hall.

Dimensions in millimetres



Key

1 Roof: fibrocement and 50 % chequered sound-absorbing panels
2 Walls: metal skin and 50 % chequered sound-absorbing panels

○ Source

Figure C.1 — Sketch showing the workroom with the location of the sound source and the measurement path in the room

Table C.1 — Measurement path: Location of microphones

Microphone number	1	2	3	4	5	6	7	8	9	10	11
Distance from microphone to acoustical centre of the source, m	2	3	4	5	6	8	12	16	24	32	48

C.3 Sound source used for test

See Table C.2 and Figure C.2.

The sound source has the following characteristics:

— type: CIMPO - INRS (electromechanical);

— make: INRS;

— date of latest calibration: December 1995.

Table C.2 — Sound power spectrum in octave bands and A-weighted sound power level of the source used

	Octave-band centre frequency, Hz						A
	125	250	500	1 000	2 000	4 000	
L_W, dB	97,6	98,6	102,2	110,8	111,2	107,4	115,7

Performance characteristics of the source fulfil the requirements of ISO 14257, i.e.:

— maximum directivity index: 4,4 dB;

— maximum sound power level difference of adjacent one-third-octave bands: 6,5 dB;

— stability over time conforming to A.4 of ISO 14257:2001. OK.

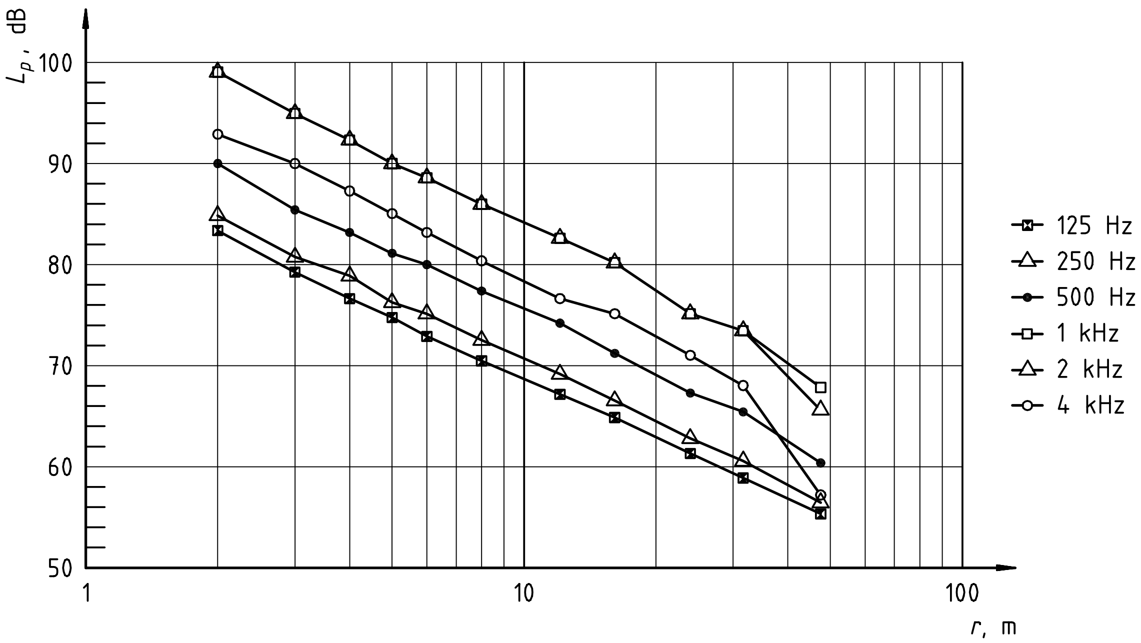


Figure C.2 — Experimental reference spatial sound distribution curves of the source measured in a free field over a reflecting plane (see annex B), to be used for correcting the sound distribution values measured in the workroom, for each octave band

Table C.3 — Sound pressure levels in octave bands at the microphone positions on the path, taken from experimental reference spatial sound distribution curves of the source used for the test, measured in a free field over a reflecting plane (see annex B)

Distance from microphone to acoustical centre of source, m	**Sound pressure levels**, dB					
	Octave-band centre frequency, Hz					
	125	250	500	1 000	2 000	4 000
2	83,4	84,8	89,7	98,8	99,2	92,8
3	79,8	80,9	85,5	94,7	94,8	90,2
4	76,9	78,8	83,2	92,3	92,2	87,3
5	74,9	76,4	81,4	90,3	90,1	85,0
6	73,2	75,1	80,0	88,7	88,6	83,2
8	70,7	72,5	77,5	86,1	85,9	80,4
12	67,3	69,1	74,1	82,6	82,6	76,8
16	65,1	66,6	71,2	79,8	80,1	75,2
24	61,5	62,8	67,4	75,7	75,3	71,0
32	59,1	60,5	65,3	73,7	73,4	68,0
48	55,6	56,5	60,4	67,8	65,7	57,3

C.4 Sound distribution values and curves

Sound distribution values are shown in Tables C.4 to C.6 and distribution curves are shown in Figure C.3.

Table C.4 — Sound pressure levels in octave bands measured in the room under test with the sound source in operation (corrected for background noise)

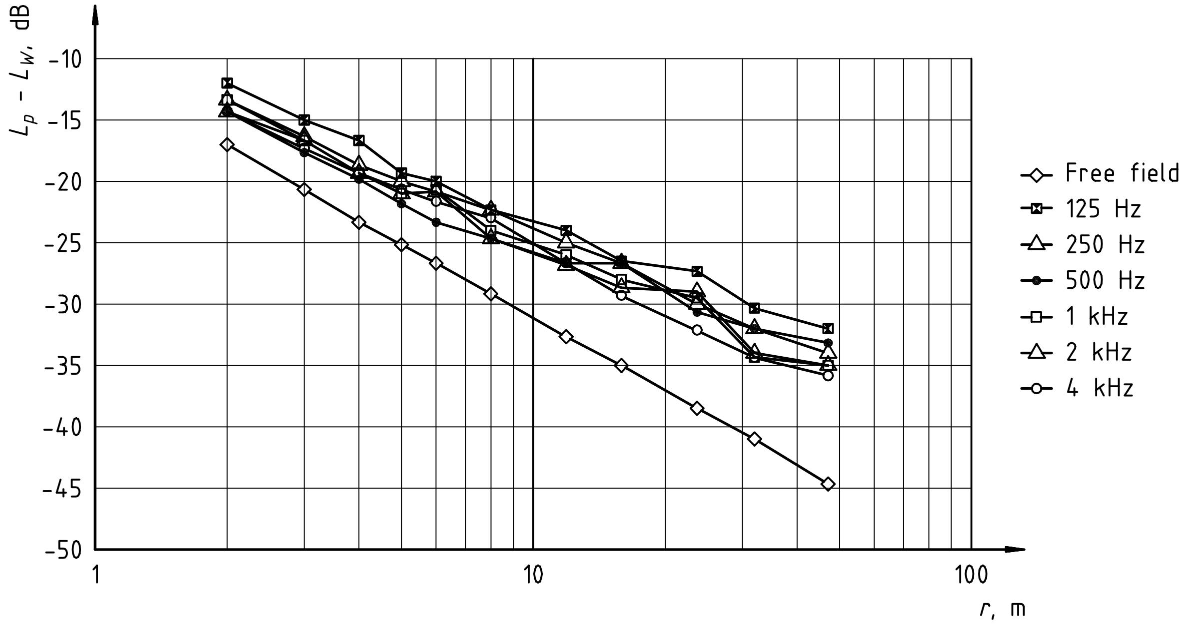
Distance from the microphone to the acoustical centre of the source, m	**Sound pressure levels**, dB					
	Octave-band centre frequency, Hz					
	125	250	500	1 000	2 000	4 000
2	85,7	84,9	89,8	98,9	99,7	93,8
3	82,5	81,9	85,7	95,1	96,0	91,2
4	80,8	79,6	83,6	93,0	93,5	88,3
5	78,3	77,8	81,8	92,0	92,2	86,8
6	77,1	77,9	80,5	91,0	91,0	85,7
8	75,4	74,3	78,8	87,9	89,6	84,3
12	73,7	72,1	76,8	85,8	86,6	80,4
16	71,3	70,3	76,3	83,5	85,0	78,1
24	70,4	69,8	72,0	81,5	81,1	74,9
32	67,3	65,0	70,5	77,0	79,4	72,5
48	65,7	63,5	69,1	75,6	76,7	70,5

Table C.5 — Values of $D = L_p - L_W$, in octave bands (corrected for background noise)

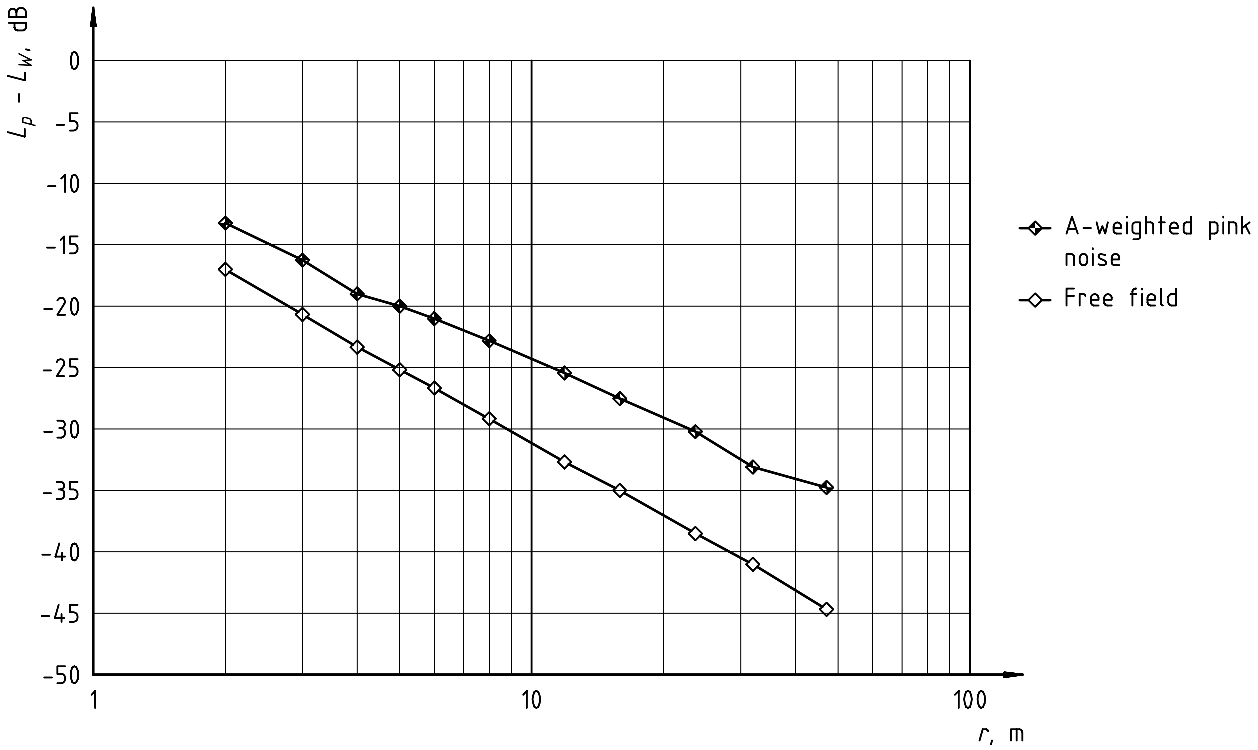
Distance from the microphone to the acoustical centre of the source, m	**Values of D**, dB					
	Octave-band centre frequency, Hz					
	125	250	500	1 000	2 000	4 000
2	–11,9	–13,7	–12,4	–11,9	–11,5	–13,6
3	–15,1	–16,7	–16,5	–15,7	–15,2	–16,2
4	–16,8	–19	–18,6	–17,8	–17,7	–19,1
5	–19,3	–20,8	–20,4	–18,8	–19	–20,6
6	–20,5	–20,7	–21,7	–19,8	–20,2	–21,7
8	–22,2	–24,3	–23,4	–22,9	–21,6	–23,1
12	–23,9	–26,5	–25,4	–25	–24,6	–27,0
16	–26,3	–28,3	–25,9	–27,3	–26,2	–29,3
24	–27,2	–28,8	–30,2	–29,3	–30,1	–32,5
32	–30,3	–33,6	–31,7	–33,8	–31,8	–34,9
48	–31,9	–35,1	–33,1	–35,2	–34,5	–36,9

Table C.6 — Values of $D = L_p - L_W$, in octave bands and for the A-weighted pink-noise reference spectrum, corrected for background noise and using the experimental reference curves of the source (measured in free field over a reflecting plane)

Distance from the microphone to the acoustical centre of the source, m	**Values of D**, dB						**Values of D for the A-weighted pink-noise reference spectrum**, dB
	Octave-band centre frequency, Hz						
	125	250	500	1 000	2 000	4 000	
2	–11,8	–13,9	–13,9	–13,8	–13,3	–13,1	–13,4
3	–14,9	–16,5	–17,3	–16,9	–16,1	–16,4	–16,5
4	–16,5	–19,2	–19,6	–19,1	–18,4	–19,0	–18,9
5	–19,0	–20,7	–21,4	–19,8	–19,5	–20,3	–20,0
6	–20,1	–20,7	–22,8	–20,6	–20,7	–21,3	–21,1
8	–21,9	–24,3	–24,4	–23,8	–21,9	–22,7	–22,8
12	–23,7	–26,5	–26,1	–25,6	–25,0	–26,5	–25,7
16	–26,2	–28,3	–26,2	–27,7	–26,5	–29,2	–27,5
24	–27,1	–28,7	–30,4	–29,4	–30,0	–32,2	–30,4
32	–30,2	–33,6	–32,0	–34,2	–31,9	–34,4	–33,1
48	–31,9	–35,0	–33,1	–34,9	–34,0	–35,8	–34,6



a)



b)

Figure C.3 — $L_p - L_W$ sound distribution curves in octave bands and for the A-weighted pink-noise reference spectrum, corrected for background noise and using the experimental reference curves of the source (measured in free field over a reflecting plane)

C.5 Rates of spatial decay of sound pressure levels per distance doubling

See Tables C.7 and C.8.

Table C.7 — Values of the spatial decay, DL_2, of sound pressure levels per distance doubling in octave bands, for each distance range

Distance range	**Values of** DL_2, dB					
	Octave-band centre frequency, Hz					
	125	250	500	1 000	2 000	4 000
Near range: 2 m to 5 m	5,2	5,2	5,7	4,6	4,8	5,5
Middle range: 5 m to 24 m	3,7	4,0	3,5	4,4	4,5	5,4
Far range: 24 m to 48 m	4,6	6,0	2,6	5,2	4,0	3,6

Table C.8 — Values of the spatial decay, DL_2, of sound pressure levels per distance doubling for the A-weighted pink-noise reference spectrum and for each distance range

Distance range	**Spatial decay of sound pressure levels per distance doubling for the A-weighted pink-noise reference spectrum**, dB
Near range: 2 m to 5 m	5,1
Middle range: 5 m to 24 m	4,6
Far range: 24 m to 48 m	4,1

C.6 Excess of sound pressure level

See Tables C.9 to C.12.

Table C.9 — Values of the excess of sound pressure level, DL_f, in octave bands for each distance range

Distance range	**Values of** DL_f, dB					
	Octave-band centre frequency, Hz					
	125	250	500	1 000	2 000	4 000
Near range: 2 m to 5 m	5,6	3,8	4,3	5,2	5,4	4,0
Middle range: 5 m to 24 m	8,1	6,3	6,9	7,3	7,8	5,6
Far range: 24 m to 48 m	11,5	8,6	9,8	8,3	9,4	6,6

Table C.10 — Values of the excess of sound pressure level, DL_f, for the A-weighted pink-noise reference spectrum and for each distance range

Distance range	Excess of sound pressure level for the A-weighted pink-noise reference spectrum, dB
Near range: 2 m to 5 m	4,8
Middle range: 5 m to 24 m	7,0
Far range: 24 m to 48 m	8,5

Table C.11 — Values of the excess of sound pressure level, DL'_{fr}, in octave bands, at 4 m, 10 m and 30 m from the source

Distance from the source, m	Values of DL'_{fr}, dB					
	Octave-band centre frequency, Hz					
	125	250	500	1 000	2 000	4 000
4	6,2	4,0	4,4	5,2	5,3	3,9
10	7,8	5,4	6,4	6,9	7,7	5,8
30	10,6	7,4	9,3	7,2	9,2	6,1

Table C.12 — Values of the excess of sound pressure level, DL'_{fr}, for the A-weighted pink-noise reference spectrum, at 4 m, 10 m and 30 m from the source

Distance from the source, m	Excess of sound pressure level for the A-weighted pink-noise reference spectrum dB
4	4,8
10	6,8
30	8,0

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