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→ S31-012-3

ISO TC 43/SC 2 N 0890

Date: 2007-06-18

ISO/CD 3382-3

ISO TC 43/SC 2/WG

Secretariat: DIN

Acoustics — Measurement of room acoustic parameters — Part 3: Open plan spaces

Acoustique — Mesurage des paramètres acoustiques des salles — Partie 3: Espaces ouvertes

Document type: International Standard
Document subtype:
Document stage: (30) Committee
Document language: E

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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.

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The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3382-3 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

ISO 3382 consists of the following parts, under the general title *Acoustics — Measurement of room acoustic parameters*:

— *Part 1: Performance spaces;*

— *Part 2: Reverberation time in ordinary rooms.*

— *Part 3: Open plan spaces.*

Introduction

In open plan spaces, its occupants are affected by activities surrounding them. One cause of disturbance is lack of speech privacy. The concept of speech privacy relates to the degree of speech disturbance perceived by two individuals who are not in conversation with each other. Speech can be intrusive for the listener, whereas for the speaker, it can be desirable to avoid involuntary spread of speech of personal character.

A successful design of open plan spaces includes careful consideration of the layout of the working positions. Other factors affecting the acoustical performance of open plan spaces are sound absorption, screen height, background noise and room dimensions. The reverberation time of a room used to be regarded as the predominant indicator of its acoustical properties. However, there is reasonable agreement that other types of measurements such as rate of spatial decay of sound pressure levels, speech transmission index and background noise levels are needed for a more complete evaluation of the performance of open plan spaces.

This International Standard specifies parameters that can be used as indicators describing the general acoustical performance of open plan spaces. The focus is set on reaching good speech privacy between working stations. Measurement methods are presented. Measurements are recommended to be performed when the space is furnished as it strongly affects the result, but measurements are also possible in unfurnished rooms.

Acoustics — Measurement of room acoustic parameters — Part 3: Open plan spaces

1 Scope

This International Standard specifies methods for the measurement of room acoustic properties in open plan spaces, with or without furnishing. It describes measurement procedures, the apparatus needed, the coverage required, and the method for evaluating the data and presenting the test report.

The measurement results can be used to evaluate room acoustic properties in various open plan spaces, such as in open plan schools, call centres, open plan offices of different sizes. This standard is not meant for ordinary rooms, concert halls and other performance spaces.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14257, *Acoustics — Measurement and parametric description of spatial sound distribution curve in workrooms for evaluation of their acoustical performance*

ISO 16032, *Acoustics - Measurement of sound pressure level from service equipment in buildings - Engineering method*

IEC 60268-16, *Sound system equipment – Objective rating of speech intelligibility by speech transmission index*

IEC 61672, *Sound level meters*

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

3 Terms and definitions

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

3.1
actual privacy radius
r_{act}
distance where the measured speech level, L_{speech}, is of the same level as the measured background noise, L_{Aeq}

3.2
frequency range
the frequency range is for measurement of spatial sound distribution curve 250 Hz to 4 000 Hz and for background noise 63 Hz to 8 000 Hz

3.3
privacy radius
r_P
distance where the A-weighted speech level is of the same level as an A-weighted background noise level of 40 dB, assuming the A-weighted speech level at 1 m distance is 60 dB

3.4
speech level
level of speech calculated from frequency weighted pink noise

NOTE The weighting is based on values for speech peaks for males, Table 1 in ASTM E 1130-02, applying band importance from ANSI S3.5-1969, Table 4, A-weighting, and thereafter normalizing the spectrum.

3.5
speech transmission index
STI
physical quantity representing the transmission quality of speech with respect to intelligibility

3.6
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 characterise 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).

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

NOTE 3 In this standard the spatial distribution curve for A-weighted speech is studied, hence, the corresponding measures are herein called DL_{2S} and DL_{fS}.

4 Recommended parameters

In this International Standard, when evaluating the acoustical performance of open plan spaces, the focus is set on privacy parameters. The recommended parameters are:

— Rate of spatial decay of sound pressure levels per distance doubling, DL_{2S}

— Excess of sound pressure level, DL_{fS}

— Privacy radius, r_P

— Sound transmission index, *STI*

— Background noise L_{Aeq}

NOTE Background noise in open plan spaces in general can consist of noise from installations, traffic and occupant's activities. In this standard background noise from installations is mainly considered. However, in cases where it is judged that the measurement conditions provide relevant results, noise from traffic and occupant's activities can be included.

5 Measurement conditions

5.1 General

In this International Standard methods to measure speech transmission index, rate of spatial decay of sound pressure levels and background noise in open plan rooms are presented. The measurement conditions in the following standards are applicable with the modifications stated in the following clauses.

Measurement of spatial sound distribution curves	ISO 14257
Measurement of speech transmission index	IEC 60268-16
Measurement of background noise	ISO 16032

NOTE Background noise is also measured when measuring the spatial sound distribution curve and the speech transmission index. Measurement of background noise shall then follow ISO 14257 and IEC 60268-16 respectively.

5.2 Equipment

5.2.1 Sound sources

In all measurements an omnidirectional sound source producing pink noise shall be used. The requirements given in ISO 14257 for the omnidirectional sound source shall be fulfilled for measurements to be in accordance with this International Standard. Calibration and verification of the sound power of the source is performed as in ISO 14257, with the sound source positioned at the height of 1,2 m.

NOTE If *STI*-values are needed for an evaluation of speech intelligibility, measurements should be made according to IEC 60268-16.

5.2.2 Measurement and instrumentation

Sound pressure levels in each octave band and at each microphone position shall be measured using a sound level meter meeting the requirements for a class 1 measurement given in IEC 61672. 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 positions

5.3.1 General

For each parameter, the number of measurement positions of the sound source and microphone is specified in Table 1.

The acoustical centre of the sound source shall be located at a working position, at the height 1,2 m (so simulating a person seated). The microphone shall be located at a, for the space, typical working position, 1,2 m above the floor, unless a more realistic position is simulated using the height 1,55 m (so simulating a person standing).

Table 1 — Summary of minimum number of positions

Measurement of	Number
Spatial sound distribution curve	
Source positions	≥ 1
Number of measurement positions in furnished rooms in each source position	≥ 6
STI	
Source positions	≥ 2
Source-microphone combinations	≥ 3
Background noise	
Measurement positions	≥ 6

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5.3.2 Furnished rooms

In measurement of spatial sound distribution curve, the microphone positions shall be spread out as evenly in the region as possible, preferentially at logarithmically growing increment, i.e. 2 m, 4 m, 8 m, 16 m, ..., but not necessarily along a line; the number of microphone positions given in Table 1 shall also be fulfilled. The distance between the source or microphone and any screen between the source and the microphone shall not be less than 1 m. The distance between a measurement point and any wall shall be at least 1,5 m. Supplementary measurements where the source is positioned in an aisle can also be made.

5.3.3 Unfurnished rooms

The measurements are recommended to be performed in furnished rooms as the furniture strongly affects the result. In unfurnished rooms, the sound source shall be located in a normal position according to the use of the room. Spatial distribution curves are measured along a line at distances as above. When two or more lines are measured, the angle alfa, as defined in Figure 1, shall be fulfilled between at least two of the lines. Symmetric positions of source and microphone should be avoided.

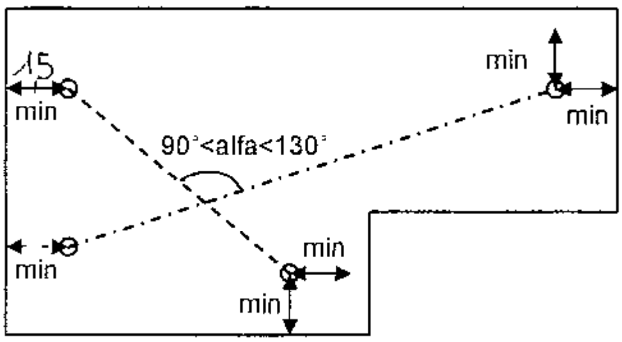


Figure 1 — Example of defining measurement paths in unfurnished rooms.

6 Evaluation of measured data

6.1 Spatial sound distribution curve

The spatial sound distribution curve shall be determined as in ISO 14257, using the frequency weighted speech spectrum, P_S, given in table 2. The normalized spatial sound distribution curve relative to frequency weighted speech is calculated from octave-band data, D_j, according to the equation:

$$D_S(r) = 10\lg\left(\sum_j 10^{(D_j(r)-P_{jS})/10}\right) \text{ dB} \tag{1}$$

where

$D_S(r)$ is the value of D for the A-weighted speech normalized spatial sound distribution curve, at position r,

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

P_{jS} is given in table 2.

Table 2 — Values of P_S for the frequency weighted speech spectrum

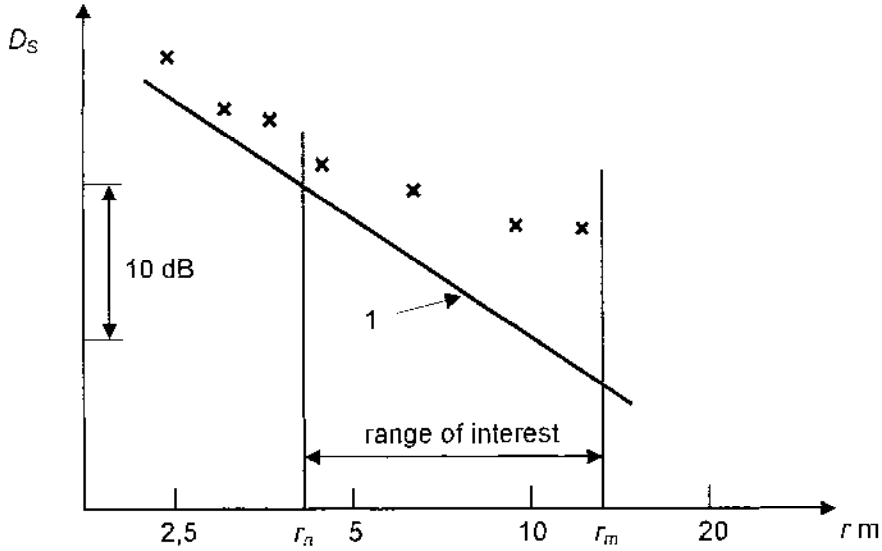
Octave band j, centre frequency in Hz	250	500	1000	2000	4000
Subscript j	1	2	3	4	5
P_{jS} [a]	-15.5	-3.3	-5.3	-8.0	-12.6

[a] The values are calculated based on values for speech peaks for males, table 1 in ASTM E 1130-02, applying band importance from ANSI S3.5-1969, table 4, A-weighting, and thereafter normalizing the spectrum, see annex B.

The spatial sound distribution curve based on $D_S(r)$ shall be drawn into a diagram as in ISO 14257. The slope of the curve can vary in different distance ranges. Identify the range of interest, $[r_n, r_m]$, in the diagram, see Figure 2. The rate of spatial decay of sound pressure levels per distance doubling, DL_{2S}, over the distance range $[r_n, r_m]$ is thereafter obtained using the equation (5) in ISO 14257 with D_i replaced by D_S given by Equation (1).

The excess of sound pressure level, DL_{fS}, is in this standard evaluated over the distance range $[r_n, r_m]$ following 6.4.2 in ISO 14257 with D replaced by D_S given by Equation (1).

The spatial sound distribution curves may be considered and evaluated separately or merged into one average curve when more than one position of the sound source is used.



Key

1 Free-field sound distribution curve

× Measurement points

r Distance from the source to the receiver (logarithmic scale)

Figure 3 — Example of a spatial sound distribution curve where the range if interest is identified

6.2 Privacy radius

Privacy radius is given by the distance where the A-weighted speech normalized sound pressure level equals 40 dB assuming the speech level at 1 m distance is 60 dB. When the slope of the sound distribution curve is constant the privacy radius can be calculated from the rate of spatial decay of sound pressure levels per distance doubling according to the equation:

$$r_{\mathrm{p}} = 10^{\frac{20 \lg 2}{DL_{2S}}} \ \mathrm{m} \qquad (2)$$

where

DL_{2S} is the rate of spatial decay of sound pressure levels per distance doubling for the range of interest $[r_n, r_m]$;

To calculate the privacy radius when the slope of the sound distribution curve varies, see appendix A.

NOTE Dependent on whether the speaker raise or lower his/her voice, the A-weighted speech level could be higher and lower than 60 dB at 1 m distance. The actual level of the background noise also affects the privacy radius. The privacy radius can be calculated for the actual speech level and actual background noise according to the equation:

$$r_{\mathrm{Pact}} = 10^{\frac{(L_{\mathrm{speech}} - L_{\mathrm{b}}) \lg 2}{DL_{2S}}} \ \mathrm{m} \qquad (3)$$

where

L_{speech} is the actual A-weighted speech level at 1 m distance in dB,

L_{b} is the actual A-weighted background noise level in the open plan space in dB.

6.3 *STI*

STI is evaluated and presented according to IEC 60268-16 for each source-receiver combination.

6.4 Background noise

The background noise level is evaluated as in ISO 16032.

7 Statement of result

The test report shall state that the measurements were made in conformity with this International Standard. Any exceptions to this standard shall be noted. The report shall include:

a) the name and place of the room tested;

b) a sketch plan of the room, with an indication of the scale and, if relevant, a section of the room;

c) the volume of the room;

d) the condition of the room (furniture, screens, ceiling treatment, number of persons present etc.);

e) the type of sound source and its directivity characteristics;

f) a description of the sound signal used;

g) details of the source and microphone positions, shown on a plan together with an indication of the heights of the positions. Any screens between the source and microphone shall be specified on the plan; the size shall be given in the report;

h) the description of measuring apparatus and the microphones;

i) spatial sound distribution curve(s) using $D_S(r)$ where the range of interest $[r_n, r_m]$ is indicated;

j) a table with the measuring results (see Table 3);

k) background noise levels in spatial sound distribution measurements, 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;

l) background noise levels in speech transmission index measurements;

m) the date of measurement and name of the measuring organisation.

Table 3 — Example of tabular form for reporting measurement results

DL_{2S} in dB, $[r_n, r_m]$	
DL_{fS} in dB, $[r_n, r_m]$	
r_P in m	
STI, source no. – receiver no.	
STI, source no. – receiver no.	
STI, source no. – receiver no.	
Background noise, L_{Ceq} in dB	

Annex A
(normative)

Privacy radius in case of varying slope of spatial sound distribution curve

In case of varying slope of spatial sound distribution curve the equation 2 is changed to:

$$r_{\mathrm{P}} = 10^{\frac{1}{DL_{2\mathrm{S}}}\left(20\lg 2-\left(DL_{2\mathrm{S}n}-DL_{2\mathrm{S}}\right)\lg r_n\right)}\ \mathrm{m} \tag{A.1}$$

where

$DL_{2\mathrm{S}}$ is the rate of spatial decay of sound pressure levels per distance doubling for the range of interest $[r_n, r_{\mathrm{m}}]$;

$DL_{2\mathrm{S}n}$ is the rate of spatial decay of sound pressure levels per distance doubling for the range $[1, r_n]$ obtained as $DL_{2\mathrm{S}}$ above;

When $r_{\mathrm{P}} > r_{\mathrm{m}}$ and there is enough data to calculate the $DL_{2\mathrm{S}}$ for $r > r_m$ an improved estimation for r_{P} is received by following equation:

$$r_{\mathrm{P}} = 10^{\frac{1}{DL_{2\mathrm{S}}}\left(20\lg 2-\left(DL_{2\mathrm{S}n}-DL_{2\mathrm{S}}\right)\lg r_n-\left(DL_{2\mathrm{S}m}-DL_{2\mathrm{S}}\right)\lg r_m\right)}\ \mathrm{m} \tag{A.2}$$

where

$DL_{2\mathrm{S}m}$ is the rate of spatial decay of sound pressure levels per distance doubling for the range $[r_m, r > r_{\mathrm{m}}]$ obtained as $DL_{2\mathrm{S}}$ above;

Additional measurement positions are needed in a region when the region includes less than three microphone positions.

NOTE When the actual privacy radius is sought as in equation (3). the equations are changed to

$$r_{\mathrm{P,act}} = 10^{\frac{1}{DL_{2\mathrm{S}}}\left(\left(L_{\mathrm{S,4m}}-L_{\mathrm{S}}\right)\lg 2-\left(DL_{2\mathrm{S}n}-DL_{2\mathrm{S}}\right)\lg r_n\right)}$$

$$r_{\mathrm{P,act}} = 10^{\frac{1}{DL_{2\mathrm{S}}}\left(\left(L_{\mathrm{S,4m}}-L_{\mathrm{S}}\right)\lg 2-\left(DL_{2\mathrm{S}n}-DL_{2\mathrm{S}}\right)\lg r_n-\left(DL_{2\mathrm{S}m}-DL_{2\mathrm{S}}\right)\lg r_m\right)}$$

Annex B
(informative)

Frequency weighted speech spectrum

Table B.1 — Values of P_S for the frequency weighted speech spectrum

Octave band j, centre frequency, Hz	250	500	1000	2000	4000
Subscript j	1	2	3	4	5
Speech peaks for males, L_{male} [a]	67,1	69,8	63,1	58,8	55,3
Band importance, W_i [b]	0,0617	0,1671	0,2373	0,2648	0,2142
$10\lg W_i$	-12,1	-7,8	-6,2	-5,8	-6,7
A-weighting	-8,6	-3,2	0	1,2	1
L_{male}-$10\lg W_i$+A-weighting	46,7	58,9	56,9	54,2	49,6
P_{jS} [c]	-15,5	-3,3	-5,3	-8,0	-12,6

[a] The values are the corresponding octave band values based on values for speech peaks for males, table 1 in ASTM E 1130-02

[b] Band importance from ANSI S3.5-1969, table 4

[c] The result after normalizing the spectrum

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