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Acoustics — Measurement of room acoustic parameters —

Part 3: Open plan offices

Acoustique — Mesurage des paramètres acoustiques des salles —

Partie 3: Bureaux ouverts

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 126, *Acoustic properties of building products and buildings*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 3382-3:2012), which has been technically revised. The main changes compared to the previous edition are as follows:

— new single-number quantity, comfort distance, added, and privacy distance removed;

— sole use of omnidirectional sound source in all measurement phases emphasized;

— definitions (Clause 3), measurement conditions (Clause 4), and determination of single-number values (Clause 5) clarified;

— use of impulse response method better described and a new Annex B added;

— Clause 6 “Precision” and an informative Annex D were added;

— STI is determined in conformity with IEC 60268-16 using weighting factors α and β for male gender;

A list of all parts in the ISO 3382 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Open-plan office is a large and open office space where large number of occupants can simultaneously work in well-defined workstations. Both flexible offices and activity-based offices often involve spaces that resemble open-plan offices. Open working areas, which can be considered as open-plan offices, can also be found in many libraries, hospital wards, industrial workplaces, and schools.

Noise and lack of speech privacy are among the largest contributors to environmental dissatisfaction in open-plan offices[1]. Colleagues' speech is the main source of office noise. Inadequate room acoustic design of the office is one reason to the perception of noise and lack of speech privacy. Distraction due to colleagues' speech weakens the ability to concentrate and reduces work performance, especially in tasks requiring cognitive resources. Insufficient speech privacy prevents confidential conversations. Several experimental studies suggest that distraction can be reduced by reducing speech intelligibility[2][3]. A large field survey supports that reduced speech intelligibility is associated with reduced noise disturbance[4]. According to Reference [4], many of the single-number quantities described in this standard are associated with the perceived noise disturbance in open-plan offices.

The outcomes of this method describe the acoustic performance of the open-plan office in a standardized condition where a single occupant is speaking with normal speech effort[5]. The background sound caused by building appliances or sound masking system is considered in the measurements. The measurements are conducted in an unoccupied open-plan office because the method concerns the permanent building properties and stable room acoustic conditions as well as ISO 3382-1 and ISO 3382-2. The activity sound caused by the occupants does not belong to the scope of this standard, although the level of activity sound can be significantly larger than the level of background sound.

The method uses omnidirectional sound source to provide reproducible results between measurement operators. Furthermore, the speaking direction of occupant in the office workstation is not always known nor constant in time. The use of directional sound sources would lead into different results between measurement operators due to different choices of source direction and source directivities.

Room acoustic quality can be affected by the amount and positioning of wall and ceiling sound absorption materials, room geometry, workstations, screens, other furniture, floor coverings, and background sound level (e.g., masking sound). Presentation of acoustic design guidelines is beyond the scope of this document because literature gives sufficient advice how to reach good room acoustic quality[5][6][7].

Acoustics — Measurement of room acoustic parameters —

Part 3:
Open plan offices

1 Scope

This document specifies a method for the measurement of room acoustic parameters in unoccupied open-plan offices. It specifies measurement procedures, the apparatus needed, the coverage required, the method for evaluating the data, and the presentation of the test report.

This document describes a group of single-number quantities indicating the room acoustic performance of an open-plan office in a condition when one person is speaking. They focus on spatial decay of speech while the quantities in ISO 3382-2 focus on temporal decay of sound.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 3382-1, *Acoustics — Measurement of room acoustic parameters — Part 1: Performance spaces*

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

IEC 60942, *Electroacoustics — Sound calibrators*

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

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
omnidirectional sound source
OSS
sound source which radiates sound evenly to all directions

3.2
spatial decay rate of speech
$D_{2,S}$
rate of spatial decay of A-weighted sound pressure level (SPL) of speech per distance doubling in decibels

Note 1 to entry: $D_{2,S}$ describes how fast the A-weighted SPL of speech attenuates in the open-plan office when the distance to OSS increases. Large value means strong room acoustic attenuation. In free field, $D_{2,S}$ = 6 dB.

3.3
speech level at 4 m distance
$L_{p,A,S,4m}$
A-weighted SPL of speech in decibels at the distance of 4,0 m from the middle point of the OSS

Note 1 to entry: Distance between nearby workstations is usually less than 4,0 m. Small value means strong room acoustic attenuation near the OSS.

3.4
comfort distance
r_C
shortest distance from the middle point of the OSS where the A-weighted SPL of speech is lower than 45 dB

Note 1 to entry: Comfort distance reduces with increasing $D_{2,S}$ and decreasing $L_{p,A,S,4m}$.

3.5
background noise level
$L_{p,B}$
unweighted SPL of background noise in decibels at the workstations along the measurement path during working hours when occupants are absent

3.6
speech transmission index
STI
quantity describing the transmission quality of speech from speaker to listener

Note 1 to entry: STI is based on IEC 60268-16.

3.7
distraction distance
r_D
shortest distance from the middle point of the OSS where the STI is lower than 0,50

Note 1 to entry: Distraction distance reduces with decreasing r_C and increasing $L_{p,B}$. Smaller values are associated with higher levels of speech privacy. Annex A gives a psychological reasoning of distraction distance.

3.8
workstation
furniture ensemble containing at least one chair and one table having a minimum size of 70 cm x 70 cm

Note 1 to entry: Workstation can also contain other components, such as table-mounted or floor-mounted screens, storage units, display units, or luminaires.

3.9
sound masking system
centralized or networked electronic system used to produce spatially constant background sound in the workstation area

4 Measurement conditions

4.1 Equipment

4.1.1 Sound source, OSS shall be used in all measurements. The requirements given in ISO 3382-1 for the OSS within 125 Hz to 4 000 Hz shall be fulfilled for measurements to be in accordance with this document.

NOTE There are no requirements for the 8 000 Hz octave band.

4.1.2 Microphone, SPLs in each octave band and at each microphone position shall be measured using a sound level meter meeting the requirements of IEC 61672-1, class 1. The microphone shall be omnidirectional considering any supplementary equipment connected to it.

4.1.3 Analyser, the octave-band filters of the analyser or analysis software shall comply with IEC 61260. If the signal is recorded, the recording device shall have the characteristics described in ISO 3382-1.

4.1.4 Calibrator, the acoustical sensitivity of the measurement system shall be checked using a sound calibrator that complies with IEC 60942. This is done both before and after each measurement series. The results of the calibration checks shall be documented. A difference of more than 0,5 dB between calibration checks shall be an argument to repeat measurements. It is recommended that the calibration is checked when batteries of the measurement equipment or open-plan office is changed.

4.2 Measurement procedure

4.2.1 Measurement conditions

Measurements can be conducted in open-plan offices of any kind and with any configuration of ceiling absorbers, wall absorbers, sound masking systems, floor coverings, fixed partitions, workstations, screens, storage units, and other furniture, whether they are fixed or mobile. The results are valid only to the specified configuration which prevails during the measurement. Therefore, it is mandatory to report the abovementioned configurations along with the measurement results.

Background noise means all continuous or non-transient sounds, which are present during normal working hours and are not caused by the occupants. Such sounds are, e.g., heating, ventilation, and air conditioning (HVAC) devices, environmental noise caused by sources outside the building, and electronic sound masking system.

The HVAC devices shall operate on the same power as during typical working hours. If the office is equipped with a sound masking system, it shall be switched on during the measurement. Sound masking shall operate at the same level and with the same spectrum as during typical working hours. Adaptive masking systems can be tested separately for minimum and maximum levels. Appliances such as refrigerators, printers, coffee machines, radios, and video projectors shall be shut down if they increase the background noise level in any measurement position. Windows and balcony doors shall be closed. Occupants shall not be present in the workstations involving measurement positions or OSS.

If the table heights are electrically adjustable, the tabletop height shall be set to (75 ± 5) cm from the floor corresponding to the tabletop height of a sitting occupant. The setting shall be made in the workstations located along the measurement path and in the workstation containing the OSS.

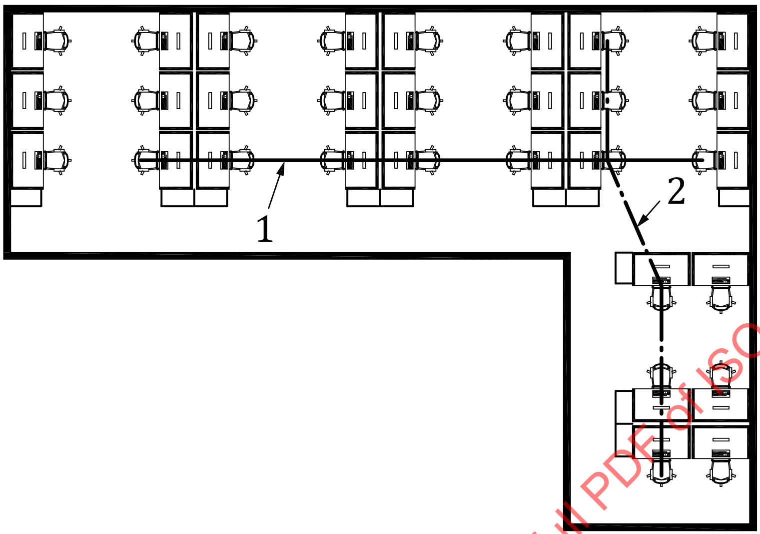
4.2.2 Acoustic zones and measurement paths

Acoustic zone means an area in the open-plan office, where the absorption treatment, room height, and workstation layout are similar. Open-plan office can contain one or several acoustic zones. If the open-plan office contains two or more acoustic zones, the measurements should be conducted in each of them. Separate results are reported for each acoustic zone, where measurements have been conducted.

At least two separate measurement paths shall be used per acoustic zone. If only one measurement path is possible in a zone, measurements shall be conducted in both directions along this measurement path.

4.2.3 Source and microphone positions

The measurements shall be conducted along a straightest possible path which crosses over workstations, as shown in Figure 1.



Key

1 straight measurement path

2 non-straight measurement path

Figure 1 — Example of a straight and a non-straight measurement path in an open-plan office, where workstations and other furniture are present
(position of the OSS is in the end of a path)

If the acoustic zone contains high piece of furniture (such as screens, dividers, or storage units being higher than 1,20 m) between workstations, the measurement path should be chosen in such a way that there is such a high piece of furniture between the OSS and the first measurement position.

The OSS is located at the workstation at the end of the path. The OSS shall be located at the position of a sitting occupant's head in a workstation. The middle point of the OSS shall be at the height of 1,20 m above the floor. The distance between the middle point of the OSS and a nearest table shall be at least 0,40 m. The distance between the middle point of the OSS and nearest wall of the room shall be at least 1,00 m. Discrepancy from this requirement shall be mentioned in the report.

All workstations along the measurement path shall be measured and considered in the analysis. The number of measurement positions on a path shall be at least four. In other words, measurements according to this standard are only possible if measurement path involves at least five consecutive workstations. The preferred number of successive measurement positions on the path is six to ten. Measurement positions locating farther than 16 m from OSS are not necessary, but they can facilitate the determination of r_D, if it is larger than 16 m.

The reference position shall be located at the distance of 1,00 m from the middle point of the OSS without any separating obstacles, such as a screen, between the OSS and the microphone. The reference position can locate in another direction than the measurement path if an obstacle prevents the abovementioned condition. The reference position is not a measurement position affecting the reported single-number values. It enables a post check of the actual sound power level of the OSS. The value at the reference position can be shown in spatial decay curves of both A-weighted SPL of speech and STI to provide additional information about the acoustic conditions at short conversation distance.

The actual measurement positions, which affect the reported single-number values, shall be located at workstations along the measurement path at the position of a sitting occupant's head, which is 1,20 m above the floor. Standing occupant is not considered in this document. The distance of the microphone positions shall be at least 1,00 m from the nearest wall of the room. Discrepancy from this requirement shall be mentioned in the report. Chairs are moved away from the workstations of the measurement path during the measurements. The first measurement position shall be located at the workstation nearest to the OSS.

It is possible that the measurements need to be conducted in an unfurnished open-plan office, where the workstations and other furniture are absent, but the room surfaces and building services are otherwise finished. This is necessary when the acoustic target values concern the unfurnished open-plan office. In such a case, the number of measurement paths per acoustic zone shall be the same as above. The measurement positions shall be chosen using expected workstation distances. The measurement positions could be located, e.g., at distances 2,5 m, 5,0 m, 7,5 m, 10,0 m, 12,5 m, and 15,0 m from the OSS. It should be noted that the room acoustic performance of an unfurnished open-plan office is usually worse than the performance of the furnished open-plan office.

In furnished flexible work areas without pre-defined workstations, the measurement positions shall be chosen using expected workstation distances.

4.2.4 Measured quantities

At every measurement position, four measurements or determinations are made:

— distance to the OSS disregarding the obstacles, r;

— unweighted equivalent SPL of wide-band noise produced by the OSS, $L_{p,oss}$;

— unweighted equivalent SPL of background noise, $L_{p,B}$;

— STI;

The distance means the horizontal distance from the middle point of the OSS to the middle point of the microphone. The accuracy of distance measurement shall be less than 0,10 m. Distances should be based on physical measurements on site. If the distance cannot be measured due to, e.g., obstacles on measurement path, and the distance must be based on layout drawings, the accuracy of these drawings (open-plan office dimensions, furniture positions) shall be confirmed by physical measurements on site.

$L_{p,oss}$ and $L_{p,B}$ shall be measured in octave bands from 125 Hz to 8 000 Hz. The integration time of equivalent SPL measurements shall be at least 15 s.

5 Determination of single-number values

5.1 Spectrum of normal speech

The sound power level (SWL) of normal effort speech is used to determine the reported single-number values. The values represent normal effort unisex speech (average of female and male speech). The octave band SPL at a distance of 1,0 m from the middle point of the OSS in the free field, $L_{p,S,1m,ff}$, is presented in Table 1. The SWL of normal effort speech is related to the SPL of speech at the distance of 1,0 m in free field by $L_{W,S} = L_{p,S,1m,ff} + 11$ dB. Since the OSS is used in all measurements, the SPL at the distance of 1,0 m from the OSS represent the average sound radiation in all directions from the OSS.

5.2 Spatial decay rate of speech

5.2.1 Conventional method

The conventional method is based on the measurements of SPL produced by the calibrated OSS (abbreviated by "oss" in related subindices). The SWL of the OSS producing wide-band noise, $L_{W,oss}$, shall be sufficiently high in each octave band so that the SPL exceeds the background noise level at least by 6 dB at the most distant measurement position. $L_{W,oss}$ needs to be usually greater than $L_{W,S}$ of Table 1 to fulfil this requirement. The spectrum shape of $L_{W,oss}$ needs not to follow the shape of $L_{W,S}$ in Table 1.

$L_{W,oss}$ is determined beforehand using a measurement standard having at least engineering grade accuracy. An overview of appropriate methods is given in ISO 3740[8]. The determination shall be made using the specified SWL which is planned to be applied in the open-plan office. The calibrated value of $L_{W,oss}$ is associated with specific settings of all apparatus related to the OSS.

Table 1 — Unweighted SPL of directional and omnidirectional speech at 1,0 m distance from the sound source in free field and the corresponding SWL of speech

(A-weighting is needed in Formula (5))

Band No.	**Frequency**	**SPL of speech directional**	**SPL of speech omnidirectional**	**SWL of speech**	**A-weighting**
i	f Hz	$L_{p,S,1m,ff,d}$ dB re 20 µPa	$L_{p,S,1m,ff}$ dB re 20 µPa	$L_{W,S}$ dB re 1 pW	A dB
1	125	51,2	49,9	60,9	-16,1
2	250	57,2	54,3	65,3	-8,6
3	500	59,8	58,0	69,0	-3,2
4	1 000	53,5	52,0	63,0	0,0
5	2 000	48,8	44,8	55,8	1,2
6	4 000	43,8	38,8	49,8	1,0
7	8 000	38,6	33,5	44,5	-1,1
	A-weighted	59,5	57,4	68,4	

NOTE The SPL of directional speech within 250 Hz to 8 000 Hz is based on ANSI S3.5[9]. The value at 125 Hz has been chosen to be 6 dB smaller than the value at 250 Hz. The SPL of omnidirectional speech is derived in Reference [10] assuming the directivity pattern of speech reported in Reference [11]. Both directional and omnidirectional sources produce the same SWL.

The SPL at a distance of 1,0 m from the middle point of the OSS in free field, $L_{p,oss,1m,ff}$, is calculated according to Formula (1):

$$L_{p,oss,1\,m,ff,i} = L_{W,oss,i} + 10 \cdot \log_{10}\left(\frac{1}{4\pi \times 1{,}0^2}\right) \text{dB} \approx L_{W,oss,i} - 11 \text{ dB} \quad (1)$$

where

$L_{W,oss,i}$ is the calibrated SWL of the OSS in octave bands;

i denotes the octave band.

In an open-plan office, the calibrated OSS is placed in a selected source position and the SPL produced by the calibrated OSS, $L_{p,oss,n,i}$, is determined in the N measurement positions located on the measurement path. The attenuation $D_{n,i}$ [dB] of wide-band noise at the considered measurement position n at distance r_n is determined by Formula (2):

$$D_{n,i} = L_{p,oss,1\,m,ff,i} - L_{p,oss,n,i} \quad (2)$$

where

$L_{p,oss,1m,ff,i}$ is the background-noise corrected SPL of the OSS at 1,0 m distance in free field according to Formula (1), dB;

$L_{p,oss,n,i}$ is the measured SPL produced by the OSS at position n;

Background noise corrected SPL of the OSS is determined according to Formula (3):

$$L_{\text{p,oss}} = 10 \cdot \log_{10}\left(10^{L_{\text{p,tot}}/10} - 10^{L_{\text{p,B}}/10}\right) \text{ dB} \tag{3}$$

where

$L_{\text{p'oss}}$ is the background noise corrected SPL of OSS, dB;

$L_{\text{p,B}}$ is the SPL of background noise (OSS is off), dB;

$L_{\text{p,tot}}$ is the measured SPL which is a superposition of background noise and wide-band noise produced by the OSS, dB.

If $L_{\text{p,tot}} - L_{\text{p,B}} < 6$ dB, the SWL of the OSS shall be increased, the sound power calibration of the OSS shall be repeated using a louder level, and the measurements in the open-plan office shall be repeated.

The $D_{n,i}$ values are valid for any other SWL of the OSS. Because speech is the most prevalent type of sound in occupied open-plan offices, it is justified that the attenuation values $D_{n,i}$ are applied to the SWL of speech. The SPL of normal effort speech, $L_{\text{p,S},n,i}$, in measurement position n is calculated by Formula (4):

$$L_{\text{p,S},n,i} = L_{\text{p,S,1m,ff},i} - D_{n,i} \tag{4}$$

where $L_{\text{p,S,1m,ff},i}$ is the SPL of normal speech (S) in a free field at 1 m distance from the OSS, see Table 1.

The determination of the SPL of speech at a single measurement position n is demonstrated in Figure 2. The overall A-weighted SPL of speech in position n, $L_{\text{p,A,S},n}$ [dB], is determined by Formula (5):

$$L_{\text{p,A,S},n} = 10 \cdot \log_{10}\left(\sum_{i=1}^{7} 10^{\frac{L_{\text{p,S},n,i}+A_i}{10}}\right) \text{dB} \tag{5}$$

where A_i is the A-weighting of octave band i shown in Table 1.

The value of $D_{2,\text{S}}$ [dB] is determined from the measurement results of $L_{\text{p,A,S}}$ obtained at distances within 2 m to 16 m from the OSS. A logarithmic distance axis and linear regression shall be used in graphic presentations. If the last measurement position is close to a reflecting wall, the SPL and STI values may be elevated. If the level is higher than in the second last position, the last measurement position can be ignored. The value of $D_{2,\text{S}}$ is determined using the least squares method as given in Formula (6):

$$D_{2,\text{S}} = -\log_{10}(2) \cdot \left(\frac{N \cdot \sum_{n=1}^{N}\left[L_{\text{p,A,S},n} \cdot \log_{10}\left(\frac{r_n}{r_0}\right)\right] - \left[\sum_{n=1}^{N} L_{\text{p,A,S},n}\right] \cdot \left[\sum_{n=1}^{N} \log_{10}\left(\frac{r_n}{r_0}\right)\right]}{N \cdot \sum_{n=1}^{N}\left[\log_{10}\left(\frac{r_n}{r_0}\right)\right]^2 - \left[\sum_{n=1}^{N} \log_{10}\left(\frac{r_n}{r_0}\right)\right]^2} \right) \text{dB} \tag{6}$$

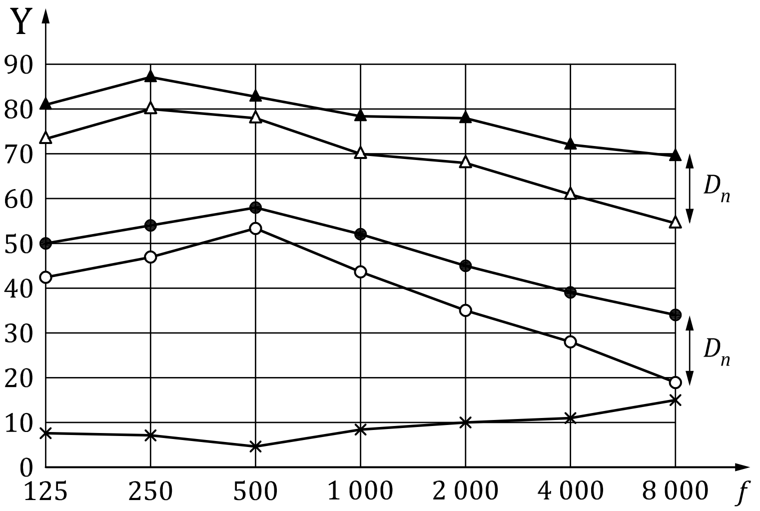
where

N is the total number of measurement positions within distance range 2 m to 16 m;

r_n is the distance from the middle point of OSS to the measurement position n, [m];

r_0 is a constant reference distance, r_0=1,0 m.

The determination of $D_{2,\text{S}}$ is presented graphically in Figure 3 a).



Key

f	centre frequency of octave band, dB
Y	SPL or D_n, dB
—▲—	$L_{p,oss,1m,ff}$
—△—	$L_{p,oss,n}$
—●—	$L_{p,S,1m,ff}$
—○—	$L_{p,S,n}$
—×—	attenuation at measurement position n

Figure 2 — Determination of the SPL of speech in measurement position *n*
(the attenuation D_n between —▲— and —△— is the same as between —●— and —○—)

5.2.2 Impulse response method

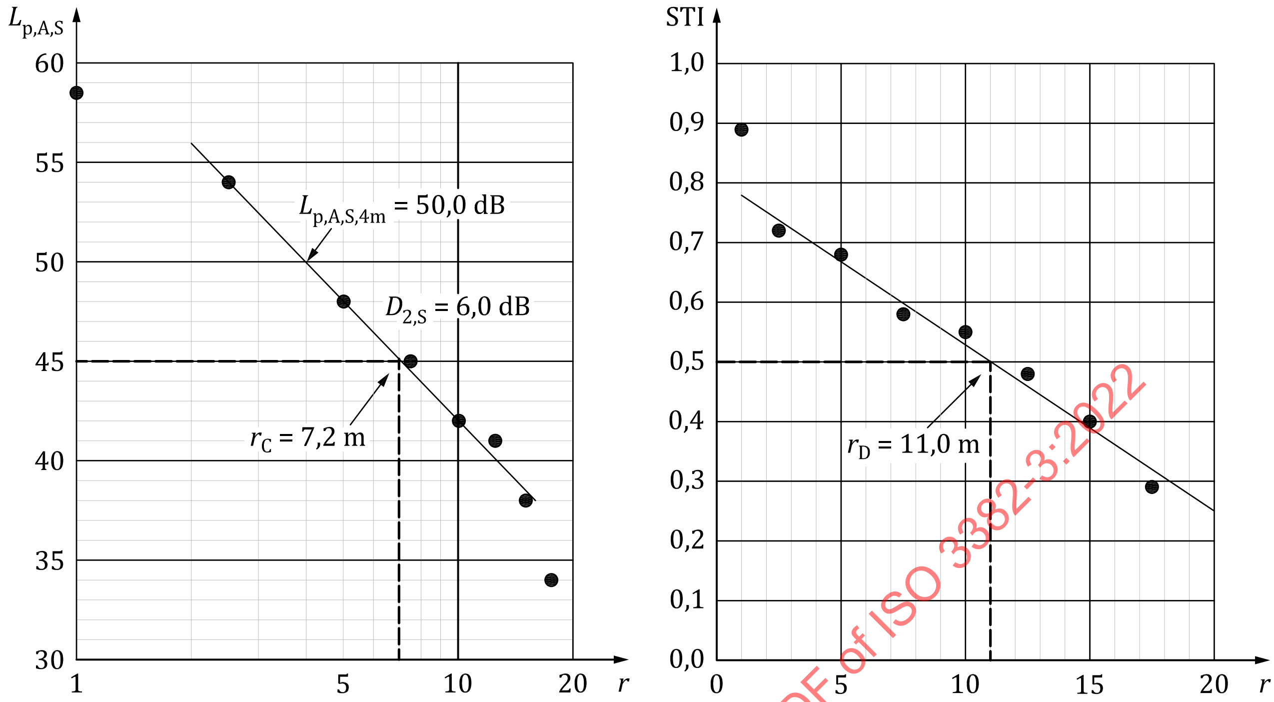
Impulse response method (see Annex B) can be applied instead of the conventional method. The measurement apparatus shall still meet the requirements specified in 4.1.

5.3 Speech level at 4 m distance

$L_{p,A,S,4m}$ is determined using a linear regression line from the spatial decay of the A-weighted SPL of speech based on measurement positions within 2 m to 16 m from the middle point of the OSS (see Figure 3 a). The value is determined according to Formula (7)

$$L_{p,A,S,4m} = \frac{1}{N} \cdot \sum_{n=1}^{N} L_{p,A,S,n} + D_{2,S} \cdot \frac{1}{N} \sum_{n=1}^{N} \log_2 \left(\frac{r_n}{4} \right) \tag{7}$$

NOTE None of the measurement positions needs to locate precisely at 4 m distance from the OSS.



a) Determination of $D_{2,S}$, $L_{p,A,S,4m}$, and r_C. Linear fitting includes the positions within 2 m to 16 m from the OSS

b) Determination of r_D. Linear fitting includes all positions located beyond 1 m from the OSS

Key

$L_{p,A,S}$ overall A-weighted SPL of speech, dB

r distance to the OSS, m

$D_{2,S}$ spatial decay rate of speech, dB

$L_{p,A,S,4m}$ A-weighted SPL of speech at 4,0 m, dB

r_C comfort distance, m

STI speech transmission index

r_D distraction distance, m

Figure 3 — Values from spatial decay curves (measured values are shown by circles)

5.4 Background noise level

The background noise level is measured at each measurement position in octave bands from 125 to 8 000 Hz. The average SPL of background noise at the measurement positions of the path is determined in octave bands. The average SPL is used in the determination of STI. The average A-weighted SPL of background noise at the measurement positions, $L_{p,A,B}$, and the related standard deviation are reported.

5.5 Speech transmission index

The STI shall be determined according to IEC 60268-16 for each measurement position. The OSS shall be used to produce the test sound. The indirect method shall be used where the modulation transfer functions between source and receiver are measured. The octave band weighting factors α (STI weighting factor) and β (redundancy factor) for male gender shall be used. The reason of using male gender is that SPL for 125 Hz octave band is not available for female voice but both genders can be present in offices.

The STI values shall be adjusted for the influence of the background noise level in each position. The background noise level averaged over every measurement position of the measurement path shall be used instead of position-dependent background noise levels. Spatial variation of background noise level along the measurement path can increase direction-dependent differences of r_D and this situation is avoided by taking the average over the measurement positions.

STIPA (speech transmission index for public address systems) shall not be used to replace STI measurements.

5.6 Comfort distance and distraction distance

This document defines two single-number quantities which both have a unit of meter: comfort distance and distraction distance.

Comfort distance describes the effect of spatial attenuation in the office without paying attention to speech privacy, background noise level, or sound masking. Comfort distance, r_C [m], is determined using Formula (8)[12]:

$$r_C = 2^{\left(L_{p,A,S,4m} - 45 + 2 \cdot D_{2,S}\right)/D_{2,S}} \quad (8)$$

If $L_{p,A,S}$ is below 45 dB at the first measurement position (the nearest workstation to the OSS), r_C is determined by extrapolation and it shall be stated to be smaller than the distance from the OSS to the first measurement position. This situation is possible in an open-plan office having very high ceiling, large sound absorption, and high screens between workstations. If $L_{p,A,S}$ is above 45 dB even in the remotest measurement position, r_C is determined by extrapolation and it shall be stated to be larger than the distance from the OSS to the remotest measurement position. This situation is possible in a very reverberant open-plan office.

Distraction distance, r_D [m], is a predictor of the objective speech privacy of the open-plan office. It considers both spatial attenuation and background noise level. The justification of r_D is explained in Annex A. Distraction distance is determined by plotting the STI as a function of the linear distance to the OSS as shown in Figure 3b. All measurement positions are used for the regression line except the reference position at 1,0 m distance. According to Reference [12], r_D is usually shorter than 16 m and it can be determined using interpolation.

If STI < 0,50 at the first measurement position (the nearest workstation to the OSS), r_D is stated to be smaller than the distance from the OSS to the nearest measurement position. If STI > 0,50 even in the remotest measurement position, r_D is reported to be larger than the distance from the OSS to the remotest measurement position. In both cases, the exact value of r_D shall be determined using extrapolation.

5.7 Typical single-number values

Examples of typical single-number values are shown in Annex C.

6 Precision

Precision of the single-number values is described in Annex D.

7 Test report

The test report shall include the following information:

a) A statement that the measurements were made in conformity with this document, i.e. ISO 3382-3:2022;

b) Address of the building and the location of the open-plan office in the building;

c) A sketch of the plan and furniture layout, with an indication of the acoustic zones, and their horizontal and vertical dimensions;

d) A description of the furniture which affect the propagation of sound, such as screen heights and storage unit height. If the screens are fixed to the table, the screen height during the measurement shall be reported. If the workstations and other furniture are absent, it shall be stated;

e) Condition of the open-plan office during the measurement (number of persons present, operation of HVAC systems, operation, and setting of sound masking system, background noise conditions);

f) Description of floor, wall, and ceiling finishes regarding their coarse sound absorption properties;

g) A detailed description of the sound signals, signal generator, OSS with directivity characteristics, microphones, analyzers, recorders, and the calibrator;

h) Positions of the OSS and microphones on the plan, including screens and storage units between the OSS and the microphone;

i) A statement that the height of both microphone and middle point of the OSS was 1,2 m;

j) Measured single-number values of Table 2 for each acoustic zone (named by A, B, C, etc.) rounded to one decimal;

k) Spatial distribution curves as shown in Figure 3, based on the values of $L_{p,A,S}$, $L_{p,A,B}$, and STI for each measurement position;

l) Measurement date and names of the measuring organization and measurement staff;

m) Precision expressed using either the data of Annex D or another estimation if it is publicly available.

Table 2 — Single-number values to be reported for each acoustic zone of an open-plan office

Single-number quantity	Zone A
Distraction distance, r_D, in m	
Spatial decay rate of A-weighted SPL of speech, $D_{2,S}$, in dB	
A-weighted SPL of speech at 4,0 metres, $L_{p,A,S,4m}$, in dB	
Comfort distance, r_C, in m	
Average and standard deviation of A-weighted SPL of background noise over the measurement positions within the acoustic zone, $L_{p,A,B}$, in dB	
NOTE Within each acoustic zone, the reported value is the mean of the values of all paths measured within that acoustic zone. If the acoustic zone contains only one measurement path, the reported value is the mean of the two values obtained from the opposite directions along the same measurement path.	

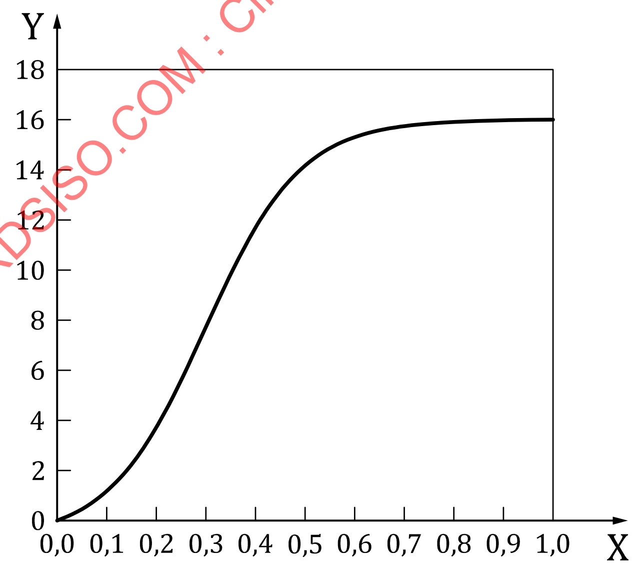
Annex A
(informative)

Psychological reasoning of distraction distance

Noise in an open-plan office consists of, e.g., speech and laughter, phone ringing tones, footsteps, ventilation noise, external noise, appliance noises, and cleaning noises. According to field studies, speech is the most annoying and the loudest sound source. Although open-plan offices are primarily designed for interactive work, they are often applied for any kinds of work types. If the work requires concentration and cognitive resources instead of communication or routine work, surrounding irrelevant but intelligible speech can be distracting and may deteriorate work performance. In addition, confidential conversations can be impossible to carry out in open-plan offices. In such situations, low speech intelligibility, i.e., high speech privacy, between workstations is desirable.

The effect of irrelevant speech on cognitive performance has been studied in numerous psychological laboratory experiments[2][3]. Perfectly intelligible speech (STI > 0,50) significantly reduces the performance of cognitively demanding tasks compared to a situation when speech is absent (STI = 0.00). Cognitively demanding tasks include, e.g., verbal, or mathematical tasks requiring the use of working memory.

The room acoustic quality (affected by factors listed in Introduction) and the distance between the speaker and the listener cause the STI to vary a lot within the same open-plan office[5][6][7]. Reference [2] presented a model, which suggested that there is an association between the reduction of cognitive performance and STI. Later review of experimental data[3] supported the model of Reference [2] and presented strong scientific evidence that performance in short-term memory tasks is strongly dependent on STI (Figure A.1). It shows that the adverse effects of irrelevant speech on performance begin to vanish rapidly when the STI falls below 0,50. Therefore, the distraction distance r_D has been defined to be the distance from the speaker where STI falls below 0,50.



Key

X speech transmission index, STI

Y reduction of cognitive performance in percentage

Figure A.1 — Effect of STI of irrelevant speech on cognitive performance[3]

Annex B
(informative)

Alternative methods for determining the spatial decay rate

ISO 3382-1 allows alternative methods to measure impulse response (IR) of a room according to ISO 18233[13]. For example, sine sweep, or maximum length sequence (MLS) may be used as excitation signal to determine the IR. These methods typically require a computer that produces the excitation signal and records the measurement signal from the microphone. With sine sweep excitation, the IR is obtained from the measured response to the excitation by deconvolution. An exponential sine sweep, where the frequency increases exponentially with time, is used since it corresponds to pink noise in the traditional method. The sweep frequency shall range from 80 Hz to 12 500 Hz to include the full octave bands 125 Hz to 8 000 Hz. ISO 3382-1 determines a room acoustic quantity sound strength, G, as given in Formula (B.1):

$$G_{r,i} = 10 \cdot \log_{10} \left[\frac{\int_0^\infty p_{r,i}^2(t)\,\mathrm{d}t}{\int_0^\infty p_{10,i}^2(t)\,\mathrm{d}t} \right] \mathrm{dB} = L_{\mathrm{pE},r,i} - L_{\mathrm{pE,10ff},i} \tag{B.1}$$

where

i	is the index of the octave band;
t	is the time, in s;
$p_{r,i}(t)$	is the instantaneous sound pressure of the IR at the distance r in the open-plan office, in Pa;
$p_{10}(t)$	is the instantaneous sound pressure of the IR at the distance of 10 m in a free field, in Pa.

Sound pressure exposure level (SPEL) at a distance r, $L_{\mathrm{pE},r}$, depends on the IR measured in the open-plan office at the distance r [m] according to Formula (B.2):

$$L_{\mathrm{pE},r,i} = 10\log_{10}\left[\frac{1}{T_0}\int_0^\infty \frac{p_{r,i}^2(t)\,\mathrm{d}t}{p_0^2}\right] \mathrm{dB} \tag{B.2}$$

where p_0 = 20 µPa, and T_0 = 1 s. Correspondingly, SPEL at 10 m distance, $L_{\mathrm{pE,10m},ff}$, depends on the IR measured at 10 m distance in free field as given in Formula (B.3):

$$L_{\mathrm{pE,10}m,\mathrm{ff},i} = 10\log_{10}\left[\frac{1}{T_0}\int_0^\infty \frac{p_{10m,\mathrm{ff},i}^2(t)\,\mathrm{d}t}{p_0^2}\right] \mathrm{dB} \tag{B.3}$$

The moment t = 0 corresponds to the time when the direct sound arrives and moment t=∞ corresponds to a time that is greater than or equal to the point where the SPL has decreased by 30 dB.

Calibration means that the value of $L_{\mathrm{pE,10m}}$ is determined for the whole measurement system including their settings. That is, the calibration concerns not only the OSS, which is the case with the conventional method, but the whole measurement chain, which consists of OSS, amplifier with specific volume settings, microphone, microphone amplifier, microphone input sensitivity, sound card settings, and input and output settings of the measurement software. ISO 3382-1 presents two alternative environments for the calibration of the sound source: anechoic room (free field) or reverberation room (diffuse field).

The calibration in the reverberation room is presented in the following. When the devices and their settings have been chosen, $L_{\mathrm{pE},r}$ is measured in the reverberation room in at least six measurement

