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Acoustics — Acoustic quality of open office spaces

Acoustique — Qualité acoustique des espaces de bureaux ouverts

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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.

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 1, *Noise*.

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 offices are increasingly common. They can cause apprehension from users due to noise and the difficulty of performing two theoretically contradictory activities in terms of acoustics: oral communication and focused individual work. In this type of space, disturbance caused by speech can result in tension between people who want to concentrate and people who are required to talk to perform their activity.

This document is concerned with the acoustics of open-plan spaces and, more specifically, cognitive effects of noise, i.e. acoustic comfort and noise disturbance linked to the obligations of the activity.

It is intended for stakeholders working in the planning, design, construction or layout of open-plan offices. Its aim is to help them provide users with a good level of acoustic comfort. It is meant as a basis for discussion and dialogue between the stakeholders involved in creating office spaces. In particular, it is intended for project owners to fine-tune the drafting of the acoustic specifications and help project management companies decide upon their objectives and the resources linked to the architecture and layout of open-plan offices.

The aim of this document is to offer principles, descriptors and measurement methods to characterise acoustics, which are easy to use and correspond to the perception of the acoustical environment by the occupants of the spaces.

Studies[3] to[5] have shown that noises that are uncontrollable, intelligible and with no link to the activity of an individual are the most disturbing and shall be minimised. They most often come from adjacent workstations, recreational areas, shared areas or neighbouring offices. For this reason, this document is focused on containing speech propagation.

The approach chosen for open-plan spaces is to limit disturbance between adjacent workstations but also to optimize comfort for short-distance conversations. The underlying idea is that a high level of intelligibility in the area of communication (near to the workstation) results in less disturbance at more distant workstations. This document addresses the issues of noise comfort, in particular via the concepts of "discretion" and "distraction reduction".

This document provides an opportunity to reflect further, by including an analysis of activities that involve more or less collaboration on the one hand, and by addressing everything that constitutes an open-plan space on the other, in particular in terms of surface treatments and additional office layout such as furniture, acoustic screens or low dividers, etc.

This document establishes a link between acoustic quality and the acoustic performance to be achieved in an open office. The used principles and descriptors apply to usual situations in terms of acoustic disturbance, privacy and discretion. They also include the working practices inherent to these spaces and the expectations of the organisations that use them regarding productivity and the well-being of employees.

This document reflects the technological and economic context of constructing office in relation to both operations in unfurnished offices and resulting layout practices. In addition, this document reflects the expectations of the end users, based on the experience from the members of the commission and publications available at the date the text was drafted.

Acoustics — Acoustic quality of open office spaces

1 Scope

This document provides technical guidance to achieve acoustic quality of open office spaces to support dialogue and formal commitment between the various stakeholders involved in the planning, design, construction or layout of open-plan workspaces: end customers, project owners, prescribers, consultants, etc.

It is applicable to all open-plan offices in which the following activities are performed:

— Space type 1: activity not known yet – vacant floor plate;

— Space type 2: activity mainly focusing on outside of the room communication (by telephone/ audio/video);

— Space type 3: activity mainly based on collaboration between people at the nearest workstations;

— Space type 4: activity based on a small amount of collaborative work;

— Space type 5: activity that can involve receiving public;

— Space type 6: combining activities within the same space.

More specifically, this document applies to refitting projects of existing business sites (renovation and/ or change or add activities) and layout projects for new spaces and spaces delivered unfurnished.

It covers both the activities and the operations of the following stakeholders:

— end customers: diagnosis, survey, expression of needs in keeping with their knowledge in the area of acoustics;

— project owners: drafting contract specifications;

— project management companies (architects, acousticians, ergonomists, economists and consulting engineers): indicating the performance of acoustic solutions and the layout principles used to achieve the result expressed in the specifications;

— building traders: reaching a clear and verifiable target with respect to the choices of materials and implementation;

— Building developer: promoting indoor environmental quality, including acoustic comfort, in estate operations in order to use it as a competitive element;

— specialists in occupational health, safety and quality;

— expert assessments and consultancy.

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 354, *Acoustics — Measurement of sound absorption in a reverberation room*

ISO 11654, *Acoustics — Sound absorbers for use in buildings — Rating of sound absorption*

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 http://www.electropedia.org/

3.1 General terms

3.1.1
target value
value set as an indication in order to evaluate a situation and act upon it

Note 1 to entry: Compliance with a target value is not a requirement of this document.

3.1.2
required value
value set as an objective

Note 1 to entry: Compliance with required values is a requirement of this document.

3.2 Terms related to the workspace layout

3.2.1
office
space where professional or administrative duties are performed

3.2.2
open-plan space
open-plan office
open space
shared space
workspace designed to accommodate multiple persons working without full separation between workstations

Note 1 to entry: The activities performed in an open-plan space can be discriminated: telephone, administrative work, etc.

3.2.3
workstation
position occupied to perform a task

3.2.4
workspace
open-plan space (3.2.2), in which the workstations required to perform the activity are distributed

3.2.5
open-plan space area
total floor area, in square metres, of the open plan office

EXAMPLE Areas, floorplates.

3.2.6
occupancy ratio
number of workstations occupied at a given time, divided by the total number of workstations

3.2.7
divider and screen
vertical partition, which partially divides the space and crosses the virtual line joining a noise source (e.g. someone speaking) and a reception point

Note 1 to entry: It can be composed of several assembled items. In particular, it is used to:

— reduce sound propagation between workstations;

— provide extra absorption;

— delimit a route for movement between a set of workstations;

— delimit acoustically an area for informal, short discussions in an open-plan space;

— confine a source of occasional noise, such as a photocopier, fax machine, water fountain, etc.

3.2.8
screen fixed to the worktop
low divider
vertical item held by the worktop, used to delimit the workstation visually, reduce noise between workstations and provide acoustic absorption close to users

Note 1 to entry: This screen can be installed in front or to the side of the user.

3.2.9
activity
physical actions and interactions that people undertake in the workplace environment

EXAMPLE Individual work, collaboration, communication, recreation and restoration.

3.3 Terms related to acoustics

3.3.1
intelligibility
percentage of speech understood

3.3.2
noise disturbance
physiological (sensory) and psychological (perceptual and cognitive) process incurred by intrusively unwanted sound, which tends to create a situation of unease or discomfort by disturbing the concentration of an individual

Note 1 to entry: Among others, it depends on physical factors such as noise level, frequency and repeatability of the acoustic phenomena, to which the individual is subjected. Different sources cause different disturbances. It is noted that other non-acoustic factors can affect noise disturbance. Generally, individual's sensitivity to noise disturbance is not the same.

3.3.3
discretion
situation obtained when an effort is required to understand the content of a conversation emitted from a neighbouring workstation

Note 1 to entry: Under these conditions, conversation is not a cause of distraction. A high level of discretion reflects low intelligibility and rapid decrease in the energy coming from the source workstation.

3.3.4
Lombard effect
phenomenon of a person unconsciously altering his/her way of speaking (adaptation of fundamental frequency, sound level and articulation) to make up for the presence of surrounding noise and to be better understood by his/her conversation partners

3.3.5
social and welfare spaces
spaces designed specifically for social interaction

Note 1 to entry: These type of spaces may not be compatible with operation of open plan offices, if the spaces are physically connected, used simultaneously and without regard to normal working operations.

Note 2 to entry: Game areas utilising table tennis, table football or with gym equipment can be very disruptive to office working and need to be carefully managed and/or physically separated.

3.3.6
signal-to-noise ratio
arithmetical difference between the effective signal level and the disturbing noise level

Note 1 to entry: The signal-to-noise ratio is given in dB.

3.4 Acoustic descriptors and related terms

3.4.1
workstation noise level
$L_{\mathrm{Aeq},T}$
LAeq is the A-weighted, equivalent continuous sound level in decibels measured over a stated period of time T:

$$L_{\mathrm{Aeq},T} = 10\lg\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2}\left(\frac{p_{\mathrm{A}}^2(t)}{p_0^2}\right)\mathrm{d}t\right]\ \mathrm{dB}$$

where

T is a time interval starting at t_1 and ending at t_2 (s);

p_0 is the reference acoustic pressure value ($p_0 = 2 \times 10^{-5}$ Pa);

$p_{\mathrm{A}}(t)$ is the instantaneous A-weighted sound pressure at the workstation (Pa).

Note 1 to entry: The noise level at the workstation is measured with normal activity in the room (with office equipment operating and a human presence).

Note 2 to entry: The measurement is performed as described in Annex E.

3.4.2
spatial decay rate of speech
$D_{2,\mathrm{S}}$
rate of spatial decay of A-weighted sound pressure level of speech per distance doubling

Note 1 to entry: Spatial decay rate of speech is expressed in decibels (dB).

Note 2 to entry: S refers to "speech".

[SOURCE: ISO 3382-3:2012, modified — Original Note deleted, new Notes to entry 1 and 2 were added.

3.4.3
reverberation time
T_{r}
time, in seconds, required for the existing noise level inside a room to decrease by 60 dB, when the noise source is instantly interrupted

Note 1 to entry: Reverberation time is determined by octave bands for frequencies from 125 Hz to 4000 Hz and is defined in ISO 3382-2:2008.

Note 2 to entry: In this document, Engineering level accuracy should be used for the measurement of reverberation time according to ISO 3382-2.

Note 3 to entry: Microphone positions should be between 2 m and 8 m from the sound source, while still respecting the minimum distance described in ISO 3382-2.

3.4.4
in situ acoustic attenuation of speech
$D_{A,S}$
difference, in decibels, between an A-weighted speech source spectrum at 1 m from an omni-directional source in the free field and the A-weighted sound pressure level at a reception point

Note 1 to entry: Calculation method is detailed in Annex A.

Note 2 to entry: S refers to "speech".

3.4.5
A-weighted sound pressure level of speech at a distance of 4 m
$L_{p,A,S,4\ m}$
nominal A-weighted sound pressure level of normal speech at a distance of 4 m from the sound source

Note 1 to entry: The measurement position does not need to be located at this distance from the sound source. $L_{p,A,S,4\ m}$ is obtained using a linear regression line from the spatial sound distribution of the A-weighted sound pressure level (SPL) of speech.

Note 2 to entry: S refers to "speech".

[SOURCE: ISO 3382-3:2012, modified — Note to entry 2 was added.]

3.4.6
A/S_{Floor}
equivalent absorption area divided by the floor surface area

3.4.7
weighted standardized level difference
$D_{nT,w}$
single indicator constituted by the value at 500 Hz, expressed in decibels, of a reference curve, applied to standardized level difference, D_{nT}

Note 1 to entry: The reference curve is as defined in ISO 717-1.

Note 2 to entry: The standardized level difference, D_{nT}, is defined by ISO 16283-1 as the difference between the sound pressure levels created by a source in one of the rooms affected by the reverberation time T in the receiving room applied to a reference reverberation time T_0.

3.4.8
insulation from internal airborne noise
$D_{nT,A}$
sum of the *weighted standardized level difference* (3.4.7) and matching factor C

Note 1 to entry: The matching factor C is defined in ISO 717-1.

3.4.9
normalized flanking level difference
$D_{n,f}$
difference in the space and time averaged sound pressure level produced in two rooms by one or more sound sources in one of them, when the transmission only occurs through a specified flanking path and the result is normalized to an equivalent sound absorption area in the receiving room according to:

$$D_{n,f} = L_1 - L_2 - 10\lg\frac{A}{A_0}$$

where

L_1 is the average sound pressure level in the source room, in dB;

L_2 is the average sound pressure level in the receiving room, in dB;

A is the equivalent sound absorption area in the receiving room, in m^2;

A_0 is the reference equivalent sound absorption area, in m^2; $A_0 = 10\ m^2$.

Note 1 to entry: This quantity is expressed in decibels.

Note 2 to entry: For clarity, the term $D_{n,f}$ is used when only one flanking path determines the sound transmission (such as with suspended ceilings) and the term $D_{n,f,ij}$ is used when only one specified transmission path *ij* out of several paths is considered (such as with structure-borne sound transmission on junctions of three or four connected elements).

[SOURCE: ISO 10848-2:2017, 3.1]

3.4.10
maximum sound level
L_{max}
Maximum A weighted sound level, during a measurement period or a noise event.

4 General approach

4.1 Introduction to the general approach

An open-plan space is often promoted as a flexible space, a space for communication (visual and oral) and activity associated with a job, and for discussion, where information flows freely. However, not all the speech generated in an open-plan office is always helpful to the work of persons in every area of this space. As such, open-plan office acoustics involves combined management of co-occupancy, communication and concentration options required for performing individual activities. To find an optimum solution in an open-plan space and fully understand the complexity of its acoustics, employee activity, interactions and relative distances between workstations, work teams and departments should be taken into account for a given open-plan space. Site environment and the technical and architectural constraints should also be considered.

4.2 Methodology

This document aims to guide the design, building and layout of open-plan workspaces. It makes no recommendation on adopting or modifying the individual or social behaviour of people at work. However, it takes them into account as determining elements of the acoustic environment.

This document defines six types of open-plan space covering all existing activities and to which the reader shall refer for subsequently applying the related acoustic criteria. For each type of activity, this document sets target values and required values (see 3.1.1 and 3.1.2.).

To comply with this document, all the required acoustic criteria defined shall be met for each activity. In the case of combining multiple activities, it is intended to respect set up values defined for each activity when defined. The chosen criteria are simple and verifiable, so they can be included and used in a contractual framework by all parties responsible for an open-plan space building or renovation process.

This document cannot anticipate individual perception, which is also linked to working conditions and the way rooms are used. The document therefore offers a comprehensive approach to assisting management of the acoustic component in open-plan projects.

It includes the following tools that shall be implemented:

— calculation method on D_n: specified in Annex A

— a flow chart summarising the whole approach: specified in Annex B, in B.1 (renovation) and B.2 (new building),

— an aid to analysing layouts: Workspace layout and room acoustics, specified in 6.1, 6.2 and 6.3,

— an aid to identifying existing acoustic treatments and priorities: specified in 6.4.

Additional recommendations and information:

— a charter on collective use of open-plan spaces: etiquette, see Annex C,

— a model survey of the acoustics of open-plan offices for users: see Annex D,

— minimum optional requirements for measuring $L_{\mathrm{Aeq},T}$ during the activity: see Annex E,

— sound masking systems: see Annex F,

— acoustic indicators and values when the activity is not known yet: see Annex G.

The following tools can be used to support every steps of a project as defined in Annex B.

5 Typology, acoustic challenges and requirements

5.1 General

Open-plan spaces shall be adapted to support the activities undertaken therein. The noise environment (number of noise sources, noise source level, etc.) can be very different depending on the type of activities.

The acoustic challenges specific to these spaces call upon closely linked notions of intelligibility and discretion: the same words can convey a helpful message for one employee and be a source of disturbance for another. A compromise between intelligibility for communication helpful to an activity and discretion shall therefore be sought in order to reduce disturbance at more distant workstations.

This document defines below six types of open-plan space, which cover all existing activities and to which the reader shall refer for subsequent application of the related acoustic criteria.

Open plan offices are not suitable for activities, which require confidential communication.

5.2 Space type 1: activity not known yet – vacant floor plate

5.2.1 Description

In this particular situation, the activity is not yet precisely defined. This is the case when property developers or a landholding trust are building office spaces. Yet, some attention needs to be brought to some basic acoustic criteria so that the offices are acoustically acceptable.

5.2.2 Noise environment characterising this type of space

Any future fit-out is reliant on the basic provision of the base build. The base build therefore requires adequate flexibility to accommodate a diverse range of tenancy and fit-out requirements. The less flexible the base build provision, the less attractive it is to property agents who market it, and tenants who may want to fit out the space.

5.2.3 Acoustic challenges

A blank office space is developed to be later partitioned and furnished depending on the end user. Thereby, the main acoustic challenge is to create adequate condition for a later office planning corresponding to desired objectives. Assuming that external noise intrusion and building services