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Standard Guide for Office Acoustics and Applicable ASTM Standards[1]

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ε[1] NOTE—Title editorially corrected in February 2018.

INTRODUCTION

Office environments include open and closed spaces with varying acoustical performance requirements depending on space function and occupant needs. Sound control tools and methods are identified which combine to provide appropriate amounts of speech privacy, freedom from distraction and acoustic comfort whether in focus, private, collaborative or other office areas.

1. Scope

1.1 This guide discusses the principles and interactions that affect the acoustical performance of open and closed offices. It describes the application and use of the relevant series of ASTM standards.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method

E90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements

E336 Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings

E795 Practices for Mounting Test Specimens During Sound Absorption Tests

E1007 Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures

E1110 Classification for Determination of Articulation Class

E1111 Test Method for Measuring the Interzone Attenuation of Open Office Components

E1130 Test Method for Objective Measurement of Speech Privacy in Open Plan Spaces Using Articulation Index

E1179 Specification for Sound Sources Used for Testing Open Office Components and Systems

E1414 Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum

E1573 Test Method for Measurement and Reporting of Masking Sound Levels Using A-Weighted and One-Third-Octave-Band Sound Pressure Levels

E2638 Test Method for Objective Measurement of the Speech Privacy Provided by a Closed Room

E2964 Test Method for Measurement of the Normalized Insertion Loss of Doors

3. Summary of Guide

3.1 *Acoustical Performance*—Acoustics in open and closed office spaces must be considered during the design stage in order to provide occupants with an appropriate degree of speech intelligibility and speech privacy while minimizing noise distraction as appropriate for the space usage. Speech privacy and distraction are controlled by the ratio of intruding voice level to background sound. In the open plan, a degree of speech privacy, noise control and comfort can be achieved if

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

component selection and interaction are understood. A successful open plan office is the result of careful coordination of many components, including those which influence the transmission of sound, such as the ceiling, furniture and furnishings, flooring, wall treatments and lighting; the heating, ventilating and air-conditioning system which limits maximum background noise levels and the sound masking system which controls minimum background sound levels. (See Section 6.) In closed plan offices, many of the same considerations are taken into account with the important addition of partition construction methods.

3.2 This guide delineates the role and interaction of these components and the application of relevant ASTM Standards.

4. Significance and Use

4.1 This guide is intended for the use of architects, engineers, office managers, and others interested in designing, specifying, or operating office environments.

4.2 It is not intended to be applied to other environments, for example, open plan schools.

4.3 While this guide attempts to clarify the many interacting variables that influence acoustical performance, it is not intended to supplant the experience and judgment of experts in the field of acoustics. Competent technical advice should be sought for success in the design of offices, including comparisons of test results carried out according to ASTM standards.

5. General Office Acoustical Considerations

5.1 *Signal to Noise Ratio*—Noise intrusion and the level of acoustical privacy between work spaces, in either open or closed plan, is determined by the degree to which the sounds from a nearby work space exceed the background sound levels. It is essential that both the spread of sound from voices and other sources and the background sound are carefully controlled. The following attributes apply regardless of the source of the intruding sound.

5.1.1 The sound source amplitude, directivity, and orientation.

5.1.2 The total attenuation of the sound due to a combination of distance and shielding by intervening barriers and attenuation due to sound absorptive surfaces.

5.1.2.1 *Absorption*—In the open plan office, the goal is to maximize attenuation with distance in order to improve sound isolation. This may require a highly absorptive ceiling, some absorption on the floor, and careful treatment of some vertical surfaces. Where the highest level of sound attenuation is required, the ideal is to approach the conditions of the outdoors, where there are no reflecting surfaces. In both open and closed spaces, absorption reduces sound reflection and reverberation which contributes to acoustic comfort.

5.1.2.2 *Sound Barriers*—Sounds passing through, over or around a physical barrier will be reduced in level. Barriers, such as walls, windows, doors and workstation partitions are an essential part of both open and closed plan acoustical design. The acoustical performance of each will depend on their design and construction.

5.1.3 The strengthened spread of sound due to reflections from office surfaces such as the ceiling, furniture panels, light fixtures, walls, and windows.

5.1.4 The level and spectrum of background sound at the listener's ear generated by sources other than speech. To ensure predictable levels of speech privacy where insufficient levels of continuous minimum background sound exist, electronic sound masking systems offer the best means of raising the ambient sound level in a tunable (optimized) manner.

5.2 *Density*—Occupant density affects both the number and proximity of people in a given space. Higher density results in both greater noise and distraction from increased quantity of conversation and activity.

5.3 *Layout*—The open office layout must consider needs for isolation and concentration or collaboration and ease of communication between workstations as appropriate. Where the need for concentration is of higher importance, the layout can be designed to assist in minimizing noise intrusion. For example, individual work stations should be positioned relative to columns, walls, and each other to avoid uninterrupted sound paths between contiguous work stations. Occupant orientation is also important, because there is a significant difference in the sound level when a talker faces a listener versus the talker facing away from the listener, of the order of 9 dBA. In a closed plan space, door openings on either side of a corridor should be staggered.

5.4 *Undivided Workspaces*—Collaborative open office design has all but eliminated vertical barriers in order to foster communication and interaction between coworkers. For job functions requiring freedom from distraction in the open plan, it may be achieved with the inclusion of appropriate sound barriers. In open spaces with workstation partitions below seated head height, acoustical performance may be improved by the addition of acoustical absorption and sound masking, but an expectation of speech privacy or significant noise isolation is unrealistic in this circumstance.

5.5 *Intrusive Noises*—Distraction caused by raised voices or noisy equipment may not be sufficiently controlled by open office constructions. Spaces requiring increased speech privacy and noise isolation such as conference rooms should be designed using appropriately higher sound isolation criteria. Noise generating devices and occupant functions should be located in isolated enclosed rooms or areas to minimize noise intrusion into other work spaces. For example, speaker phones and call centers can generate high sound levels. These should be contained in special work areas affording adequate noise isolation from the surrounding spaces. Care should be exercised in eliminating or minimizing the noise generation aspects. Open office etiquette guidelines should be established and enforced.

5.6 *Component Testing*—ASTM test methods exist for testing components and systems for open plan offices. These include measuring the attenuation between work stations by the ceiling path, the effect of barriers such as furniture panels, the effect of flanking or reflections from vertical surfaces (see Test Method E1111), measurement of masking sound in the open office (see Test Method E1573), and the determination of the articulation class (see Classification E1110) that is a single number rating of system component performance. Articulation class does not account for the effect of masking sound.

5.7 *Objective Measurement of Speech Privacy*—Test Method E1130 describes a method of objectively measuring the speech privacy in open plan offices, using the articulation index (AI). Test Method E2638 describes a method of objectively measuring the speech privacy in enclosed rooms, using the speech privacy class (SPC). AI and SPC results are applicable only between the two measurement positions and cannot be used to generalize over wide areas as there are many factors which will affect the speech privacy levels from one location to the next.

6. Components of Open Office and Closed Office Acoustical Environment

6.1 *Ceiling Systems, Open Plenum Systems, and Integrated Devices:*

6.1.1 *General Goals*—Acoustical ceiling finishes for open-plan and closed offices should be selected to achieve the chosen office acoustics design requirements, including maximum limits for reverberation times. Ceiling finish material options can include suspended acoustic tile ceiling systems, baffles, banners, and clouds. Acoustical ceiling finishes for open-plan offices are additionally chosen to reduce noise levels generated by activities, and to improve speech privacy between work stations by reducing direct and reflected sound propagation. Goals for designs of ceiling finishes in closed offices, meeting rooms, training rooms, and conference rooms include the optimizing of speech intelligibility within the space. Further goals of the design of a continuous suspended ceiling system can be to attenuate sound emitted from plenum-installed ducts and mechanical components, and to attenuate airborne and impact sound generated on the building floor above.

6.1.2 *Sound Absorption Rating*—The sound absorption ratings of acoustical ceiling finishes are measured in a laboratory using Test Method C423, which determines a single number rating, the sound absorption average (SAA). Test Method E795 describes how these various materials are to be mounted during the absorption testing. For ceiling panels used in open office areas, the preferred laboratory absorption test method is Test Method E1111. It is a component test and is restricted to measurement with a fixed-height space divider, fixed sound source height, and microphone positions. A single number rating, articulation class, is obtained using Classification E1110. Specification E1179 defines the directional characteristics of loudspeakers used in this and similar tests.

6.1.3 *Sound Isolation Rating*—The airborne sound attenuation between closed offices is an important office design factor. Optimal sound isolation is achieved when demising partitions are designed to extend to the deck above. Closed offices are sometimes designed with partitions that extend only to the installed suspended acoustic tile ceiling system, which provides a common ceiling plenum over the rooms. The sound attenuation between rooms with a ceiling system over a demising partition and a common plenum can be measured in a laboratory using Test Method E1414, which determines a single-number rating, the ceiling attenuation class.

6.1.4 *Lighting*—Light fixtures must be chosen with care. Flat lensed fixtures reflect sound and therefore should be minimized and (if used) not located directly above dividers in open office areas. Suspended light fixtures are an ideal choice, as they allow for a higher percentage of acoustic material to be used in the ceiling, do not degrade the ceiling sound attenuation and provide the opportunity to use open plenum systems such as baffles and clouds.

6.1.5 *Air Distribution System*—When a contiguous plenum exists above a ceiling system, it is often used as a return air plenum. The return air grilles in the ceiling can create significant flanking sound paths that can allow sound transmission between rooms through the ceiling and plenum. Air return baffles (or "boots") can help to maintain the acoustical integrity of the ceiling system.

6.1.6 *Isolation Strategy*—When rooms are enclosed, in part to provide speech privacy, care must be taken to consider the isolation strategy in terms of wall assemblies, plenum barriers, ceiling systems, the prevention of noise flanking paths and the control of the minimum continuous background sound level using sound masking.

6.2 *Sound Barriers:*

6.2.1 Sound generated within an open or closed work space that is transmitted into adjacent work spaces can cause distractions and reduce speech privacy. Barriers can be used to attenuate sound transmission between open-plan offices and between open and closed offices. The selection and layout of the open-plan barriers should consider the barrier sound transmission loss properties, the sound absorption characteristics, and the height and width of the barrier. These factors affect the degree of sound transmission between spaces both through the barrier and by paths around the edges of the barrier resulting from sound diffraction and surrounding surface sound reflections. The design of closed office partitions should consider the sound transmission loss properties, as well as means to minimize flanking sound paths through and around the installed partitions.

6.2.2 *Open-Plan Office Barriers:*

6.2.2.1 The primary sound transmission path between workstations in open-plan offices is reflection off finished ceiling components and diffraction over the tops of barriers. The barrier should minimize effects of sound diffraction with proper selection of height and proper construction that minimizes sound transmission directly through the barrier. Barriers ideally should extend to the floor, otherwise, any opening between the bottom of the barriers and the floor that can create a flanking sound path should be minimized.

6.2.2.2 *Barrier Height*—Barrier heights of less than 48 in. (1.2 m) do not sufficiently interrupt the common path from a talker's mouth to a listener's ear and as result do not effectively attenuate sound transmission between workstations in open-plan offices. The degree of sound attenuation between workstations improves as the barrier height increases to 60 in. (1.5 m). The acoustic value of taller barriers is diminished in offices where the sound absorption rating of the installed finish ceiling system is not sufficiently high, except where the exposed barrier surfaces have appropriately high sound absorption ratings. The selection of open-plan barrier type, height, and layout can depend on the owner's goals for communication between workers and desires for office appearance and openness in contrast to achieving optimum sound isolation.

6.2.2.3 *Barrier Construction*—Open-plan barriers should be selected having appropriately high sound transmission loss ratings and appropriate sound absorption ratings on one or both sides. Barriers can be selected having solid septums to increase the sound transmission loss rating, as needed. The sound isolation of barriers is normally higher for types having fewer panel sections rather than a modular component design that can result in flanking sound paths at every joint.

6.2.2.4 *Attenuation Testing*—The interzone attenuation provided by a barrier can be determined in accordance with Test Method E1111. The single number classification for barriers is the articulation class (AC) determined in accordance with Classification E1110.

6.2.3 *Closed Office Partitions:*

6.2.3.1 *Sound Attenuation*—Closed office partitions, doors, and windows should be selected that achieve the desired office sound isolation goal between offices. The components should be selected based on ratings of sound transmission class (STC) obtained from acoustical modeling or obtained from measurements performed in accordance with Test Method E90. Measured doors must be evaluated in an operable condition that includes any applied jamb and door bottom seals as will be used in the field. To achieve higher degrees of sound attenuation, doors without perimeter seals that will allow significant sound leakage should be avoided. The apparent sound attenuation of the partition in the field that includes the effects of flanking sound transmission paths are assessed in terms of ASTC in accordance with Test Method E336. The sound isolation between rooms can alternately be assessed in terms of NIC, in accordance with Test Method E336 as a means to evaluate the sound attenuation between rooms with the effects of room finishes. The insertion loss of installed doors can be evaluated with test method Test Method E2964 to obtain the single number rating door transmission class (DTC). The speech privacy class (SPC) provided by a closed room is evaluated using Test Method E2638.

6.2.3.2 *Flanking Transmission*—The sound attenuation between pairs of rooms can be reduced due to extraneous airborne and structure-borne sound transmission paths, which are referred to as flanking sound paths. Examples of airborne flanking sound paths in partitions include gaps along the edges of the partition and electrical penetrations in the face of the partition. Examples of airborne flanking paths through a ceiling system and ceiling plenum can include the opening above a partition that does not extend to deck above an acoustical ceiling, open return grilles, connecting ducts, and light fixtures. Options to mitigate airborne flanking paths in partitions can include using acoustical sealants and solid panels to fill gaps and penetrations. Options to mitigate flanking paths in ceiling systems can include extending demising partitions to the deck, installing plenum header barriers, improving the barrier properties of the ceiling system, and using ventilation crosstalk silencers. Office doors can allow significant flanking sound transmission between spaces. Even if there are no doors directly between adjacent spaces, corridor doors without gaskets and door sweeps can allow flanking sound transmission through connecting corridors. Structure-borne sound transmission can occur through adjacent partitions, ceilings, and floors that are continuous from one space to another past a demising partition. Options to mitigate structural paths can include providing structural breaks and isolated assemblies.

NOTE 1—Apparent Sound Transmission Class (ASTC) values are often less than published lab tested (STC) results due to the factors above.

6.3 *Vertical Absorptive and Reflective Surfaces:*

6.3.1 Both closed office partitions, and open plan office barriers with hard surfaces can reflect sound and increase sound propagation sound between offices. In either the open or closed office environment such reflections can occur in corridor areas where sound going out of an office opening can reflect from a surface and through an opening into another office. In open offices, reflections from a surface in front of a talker can increase the strength of sound in the direction behind the talker. Also, sound coming into a workspace can be amplified by reflections from hard surfaces.

6.3.2 Acoustical finishes on such surfaces can reduce the degree of reflected and thus propagated sound. This sound-absorptive surface finish may be a material added to the basic structure, or in the case of open plan office barriers, it is often built into the structure. Note that materials used to achieve sound absorption usually are not effective sound barriers. Thus, such absorptive materials alone cannot be used as an open plan office barrier.

6.3.3 The interzone attenuation provided by an absorptive finish on such vertical surfaces can be determined in accordance with Test Method E1111. The single number classification for an absorptive vertical surface is the articulation class (AC) determined in accordance with Classification E1110.

6.4 *Flooring:*

6.4.1 *Sound Absorption*—Floor carpet can provide a modest amount of sound absorption in the range of speech frequencies. Floor carpet can also reduce footfall noise, chair scraping noise, and other impact noise within the space.

6.4.2 *Noise transmission to lower floors*—To help control noise intrusions from footfalls, the performance of the floor-ceiling assembly referred to as the impact insulation class can be evaluated using Test Method E1007.

6.5 *Masking Sound:*

6.5.1 Control of the ambient sound is an essential element for achieving speech privacy as well as contributing to acoustic comfort in any open and closed office setting. Utilizing a mixture of sound frequencies, electronic sound masking systems accomplish this by controlling the minimum continuous sound level necessary to reduce the intelligibility of received speech and to reduce annoyance from intruding sounds.

6.5.2 An electronic masking system consists of the following major components:

6.5.2.1 Random masking sound generators stable in sound spectrum and output level.

6.5.2.2 Amplifiers to provide the necessary audio power for the masking sound.

6.5.2.3 Equalizers and volume controls for adjusting the masking sound to the specified levels to account for localized architectural conditions.

6.5.2.4 Loudspeakers, generally suspended above the ceiling, with the placement, orientation, spacing, and relative sound levels satisfying the objective of uniform masking sound level and spectrum throughout the occupied areas.

6.5.3 Most sound masking spectra incorporate one-third octave band frequencies ranging from 100 to 5000 Hz. Acousticians may specify frequencies outside of this range to mask sounds other than speech. The level of speech privacy achieved can be measured using Test Method E1130 for open space and Test Method E2638 for enclosed rooms.

6.5.4 Sound levels and spectra should be designed to be uniform throughout occupied areas. Masking zones should be designed so that levels are adjusted to suit the sound control needs of the occupants whilst accounting for local architectural conditions. This includes communication spaces such as private offices and conference rooms where a minimum "noise-floor" should be maintained for overall spectral uniformity, acoustic comfort and speech privacy without impacting the ability to communicate effectively within these spaces.

6.5.5 It is important that an electronic masking system be properly "tuned" before the spaces are occupied. Where occupied buildings are retrofitted with a masking system, the system should include a method of raising the level over a period of at least several days in order to acclimate the occupants to the masking sound.

6.5.6 Guidelines for the measurement of the masking sound, used to determine if it has met specified performance criteria are defined in Test Method E1573.

7. Evaluation of Mock-up or Completed Space

7.1 Since the acoustical performance of an office space is dependent on the interaction of several components, it is important that the influence of the various elements and components be investigated early in the planning phase. A mock-up of several typical office modules can be evaluated for speech privacy levels using the techniques in Test Method E1130 and Test Method E2638.

7.2 If convenient, a field evaluation can be made at or near job completion, to determine if program or specification requirements have been met.

8. Keywords

8.1 acoustics; open office; open-plan