Designation: E 1374 – 93 (Reapproved 1998)ϵ1

An American National Standard

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
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Standard Guide for Open Office Acoustics and Applicable ASTM Standards[1]

This standard is issued under the fixed designation E 1374; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

ϵ[1] NOTE—Keywords were added editorially in March 1998.

INTRODUCTION

There are no full height partitions in an open-plan office to block sound transmission between adjacent work stations. Instead, partial height barriers, a sound absorbing ceiling and absorption on vertical surfaces are used to provide sound attenuation between individuals. These, in combination with work station layout and appropriate levels of broad band masking sound are used to obtain acceptable degrees of acoustical privacy.

1. Scope

1.1 This guide discusses the acoustical principles and interactions that affect the acoustical environment and acoustical privacy in the open office. In this context, it describes the application and use of the series of ASTM standards that apply to the open office.

1.2 The values stated in inch-pound units are to be regarded as standard. The SI units in parentheses are provided for information only.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 1041 Guide for Measurement of Masking Sound in Open Offices[2]

E 1110 Classification for Determination of Articulation Class[2]

E 1111 Test Method for Measuring Interzone Attenuation of Ceiling Systems[2]

E 1130 Test Method for Objective Measurement of Speech Privacy in Open Offices Using Articulation Index[2]

E 1179 Specification for Sound Sources Used for Testing Open Office Components and Systems[2]

E 1375 Test Method for Measuring the Interzone Attenuation of Furniture Panels Used as Acoustical Barriers[2]

E 1376 Test Method for Measuring the Interzone Attenuation of Sound Reflected by Wall Finishes and Furniture Panels[2]

E 1414 Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling and Plenum[2]

3. Summary of Guide

3.1 *Acoustical Privacy*—The attenuation of sound between neighboring work stations in an open-plan office is typically much less than that potentially available between closed-plan offices. Nevertheless, a degree of acoustical privacy can be achieved if component selection and interaction are understood. A successful open plan office is the result of careful coordination of the several components, ceiling, wall treatments, furniture and furnishings, heating, ventilating and air-conditioning system, and masking sound system. (See Section 7.)

3.1.1 This guide delineates the role and interaction of the several components and the application of the 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 open offices.

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

4.3 While this guide attempts to clarify the many interacting variables that influence office privacy, 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 open offices, including comparisons of test results carried out according to ASTM standards.

5. General Open Office Acoustical Considerations

5.1 *Introduction—Attenuation with Distance*—In almost any enclosed space, there is some reduction of sound level with

[1] This guide is under the jurisdiction of ASTM Committee E-33 on Environmental Acoustics and is the direct responsibility of Subcommittee E33.02on Open Plan Spaces.

Current edition approved July 15, 1993. Published September 1993. Originally published as E 1374 – 90. Last previous edition E 1374 – 92.

[2] *Annual Book of ASTM Standards*, Vol 04.06.

distance. In many typical spaces, this decrease of sound level with distance is affected by sound reflections from the ceiling, the walls, and floor. In the open plan office the goal is to maximize this loss with distance in order to improve acoustical privacy. This requires a highly absorbent ceiling, some absorption on the floor, and careful treatment of nearby vertical surfaces. The ideal is to approach the conditions of the outdoors, where there are no reflecting surfaces.

5.2 Attaining acoustical privacy between work stations, open or closed plan, is determined by the degree to which the intruding sounds from adjacent work stations exceed the ambient sound levels at the listener's ear.

5.3 The sound pressure levels arriving at the listener's ear from sources in adjacent work stations depend on the following:

5.3.1 The sound source amplitude, directivity, and orientation.

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

5.3.3 The reinforcement of the direct sound due to reflections from office surfaces such as the ceiling, furniture panels, light fixtures, walls, and windows.

5.3.4 The level of ambient sound at the listener's ear. This will often be generated and controlled by a sound masking sound system, but in certain positions and frequency ranges, heating, ventilating, and air conditioning equipment (HVAC) may contribute significantly to the ambient sound level.

5.4 The attributes in 5.3.1 through 5.3.4 apply regardless of the source of the intruding sound. In the open plan, both office equipment and speech are the dominant intruding sources. In many cases, the provision for acceptable speech privacy is the major concern.

5.5 Office layout should be designed to avoid obvious noise intrusion possibilities. 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 between the sound level when a talker faces a listener versus the talker facing away from the listener, of the order of 9 dB.

5.6 *Loud Noises*— Distractions caused by raised voices or loud office equipment usually cannot be controlled by normal open office constructions. It is recommended that some closed plan spaces be provided to contain such loud equipment or enclose noise sensitive spaces such as conference rooms.

5.7 *Problem Noise Sources*—Computers, business machines, copiers, typewriters, and other noise generating devices should be located in isolated (enclosed) rooms or areas to minimize their noise intrusion into the work station. Where this is impractical, care should be exercised in eliminating or minimizing the noise generation aspects. Telephones and "speaker phones" are a frequent problem. The former should be equipped with flashing lights, rather than ringers (audible annunciators). Large typing pools or word processing centers can generate A-weighted sound levels up to 80 dB. These activities should be contained in special work areas affording adequate noise isolation from the surrounding open plan spaces.

5.8 *Undivided Workspaces*—Acoustical comfort may be improved in undivided workspaces such as "bull-pen" offices, drafting rooms, and typing pools by the addition of acoustical absorption to horizontal and vertical surfaces, but no such treatment alone will provide speech privacy.

5.9 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 (see Test Method E 1111), the effect of barriers such as furniture panels (see Test Method E 1375), the effect of flanking or reflections from vertical surfaces (see Test Method E 1376), measurement of masking sound in the open office (see Guide E 1041), and the determination of the articulation class (see Classification E 1110), that is a single number rating of system component performance. Articulation class does not account for the effect of masking sound.

5.10 *Objective Determination of Speech Privacy*—Test Method E 1130 describes a method of objectively measuring the speech privacy in open plan offices. It is based on a determination of the articulation index.

5.10.1 *Articulation Index*—The articulation index (AI) is a computational method for predicting the intelligibility of speech for groups of talkers and listeners. The AI is a weighted fraction representing, for a given speech frequency band and noise condition, the effective proportion of the standard speech signal that is available at the listener's ear for conveying speech intelligibility.

5.10.1.1 The articulation index ranges from 0.00 to 1.00, with 0.00 representing zero intelligibility and 1.00 complete intelligibility.

5.10.1.2 Speech privacy may be described as *confidential* when speech may be detected but not understood.

5.10.1.3 Speech privacy may be described as *normal* or *non-intrusive* when effort is required to understand the intruding speech. Normal speech privacy may also be described as the absence of distraction.

5.10.1.4 Confidential speech privacy occurs at an AI of 0.05 or less. Speech becomes more readily understood with AI values greater than 0.20; at values greater than 0.40 there is essentially no privacy.

NOTE 1—Additional research is needed to verify the relation between the AI and the subjective judgement of *normal* privacy in the open plan. (See the appendix of Test Method E 1130.)

6. Components of the Open Plan Acoustical Environment

6.1 *Ceilings*:

6.1.1 The sound absorbing characteristics required of the ceiling plane for open plan systems are different than those for private offices or conference rooms. In open plan spaces, sound from the source not controlled by part-height space dividers travels toward the ceiling plane, where part can be reflected back into the adjacent work space. To minimize the reflected sound, the ceiling must absorb most of it. In private offices or conference rooms, some lesser absorption or greater reflection may be desirable.

6.1.2 The sound barrier characteristics of the ceiling plane helps provide spatially uniform masking sound from loudspeakers located in the ceiling plenum. If the sound barrier performance is low or variable, it may lead to the perceptions of "hot spots" in the masking sound. Some masking system designs may compensate for these deficiencies or variations.

NOTE 2—There is currently no accepted objective method of specifying single-pass sound barrier performance of ceiling materials.

6.1.3 Lighting fixtures mounted in the ceiling must be chosen with care. Flat, lensed fixtures tend to reflect sound specularly and should be avoided. Parabolic cell fixtures, are preferred because they tend to scatter incident sound. The sound barrier characteristics of the fixtures should also be similar to that of the ceiling, to avoid masking sound "hot spots" underneath them.

6.1.4 Other ceiling elements, such as return air grilles or fixtures, must also be selected with care, to avoid leakage of sound from the masking system or surface reflections of incident sounds.

6.1.5 In closed plan spaces frequently associated with open plan areas, the absorption characteristics of the ceiling are of less importance than its sound barrier characteristics. An accepted method of specifying this performance is by the two-room method, in Test Method E 1414, that evaluates the sound passing through one ceiling into the plenum and then back down through the ceiling into the adjacent space. Where open and closed plan spaces are adjacent, masking sound is frequently useful for providing speech privacy in both spaces. The barrier and absorption characteristics of the ceiling system should be optimized where open and closed spaces will be mixed.

6.1.6 Test Method E 1111 is the preferred method of determining the ceiling absorption characteristics. 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, convenient for ranking the performance of the ceiling, is obtained using Classification E 1110. Specification E 1179 specifies the directional characteristics of loudspeakers used in this and similar tests.

NOTE 3—Articulation class is the preferred measure of the absorption properties necessary for acceptable open plan ceiling performance; sound absorption ratings derived from reverberation room measurements should not be used.

6.2 *Sound Barriers and Vertical Surfaces*:

6.2.1 Sound generated within the work station and potentially intruding into adjacent work spaces is of major concern. This potentially intrusive sound is reduced in the following two ways: (*1*) using barriers that are properly absorptive and appropriately impervious to sound penetration, and (*2*) reducing the tendency of sound to "flank" or diffract around the perimeters of such barriers.

6.2.2 *Sound Reflectors*— All vertical surfaces are possible sound reflectors if not specifically treated. Hard, flat, smooth surfaces represent the worst condition. To reduce or eliminate these reflections, such surfaces should be highly absorptive to sound in the frequency range of concern. A particularly difficult area to treat in this regard is the glass in the typical exterior wall of the office area. Note that materials used to achieve sound absorption usually are not effective sound barriers. The interzone attenuation provided by a vertical surface can be determined in accordance with Test Method E 1376. The single number classification for a vertical surface is the Articulation Class (AC) determined in accordance with Classification E 1110.

6.2.3 *Sound Barriers*— Reduction of sound transmission through barriers separating adjacent work spaces is normally achieved by adding an impermeable septum to the center of the barrier. Care must be exercised in eliminating any possible "through holes" offering unencumbered passageways for sound to "leak" through to adjacent work spaces. The interzone attenuation provided by a barrier can be determined in accordance with Test Method E 1375. The single number classification for barriers is the Articulation Class (AC) determined in accordance with Classification E 1110. Severe conditions, for example, people being located in close proximity to each other or high source levels, need to be assessed for unwanted sound transmission paths ("flanking") or higher barrier performance.

6.2.3.1 *Flanking Transmission*—Flanking can be controlled by proper consideration of the height and length of the barrier, the horizontal distance between adjacent barriers, and the sound absorptive characteristics of the adjacent barriers. The most practical method of reducing flanking is to employ vertical barriers that are as high and as long as possible. This may be in conflict with the desire for "openness" or clear view through the office space. The clearance between the bottom of the barriers and the floor should be minimal, although this path is not as critical as clearance above the barrier.

6.2.3.2 *Barrier Height*— Barrier heights of less than 60 in. (1.5 m) are not effective in performing as acoustical barriers in open plan offices. As a general rule, barrier heights greater than 80 in. (2 m) provide diminishing returns. "Tradeoff" decisions in the determination of the required height against the original motive for considering the aesthetic factors associated with such systems are required.

6.2.3.3 *Electrical Raceways*—Current trends are to include the electrical raceway on the bottom of panels; there is also a shift towards including "wire managment" features at the top and middle of panels. Unless treated to the contrary, such features can diminish both the barrier and absorptive properties of the barrier.

6.2.3.4 *Hang-On Components*—Most contemporary open plan office systems incorporate furniture concepts into the overall system. These components include storage compartments, file bins, work surfaces, tack boards, task and ambient lighting modules, communication and power management items, etc. Most of these items will degrade the absorption properties of the system and may also affect privacy characteristics.

6.3 *Special Considerations*:

6.3.1 Application of absorption to circular columns of less than 1.5 ft (0.5 m) diameter within the work area is seldom necessary; large flat surfaces may require the application of absorption material.

6.3.2 *Windows*—Effective treatment of windows to minimize acoustical reflections conflicts with their normal function as a vision element; acoustically, windows should be eliminated wherever practicable. Locating aisles in the perimeter space is helpful, as is butting the acoustical barrier against the glass, where work stations are placed around the perimeter. Neither sheer curtains nor slatted blinds are acoustically effective. Other possible solutions include tilted or recessed window baffles.

6.4 *Masking Sound*:

6.4.1 Since acoustical privacy is a signal (intruding sound) to noise (prevailing ambient) consideration, precise control of the ambient sound is an essential element for achieving sound privacy in the open plan office. A properly designed, installed, and adjusted electronic sound masking system is the most effective means of controlling the ambient sound.

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

6.4.2.1 A random noise generator stable in sound spectrum and output level.

6.4.2.2 Equalizers for adjusting the masking sound spectrum to the desired contour and to minimize undesirable colorations of the spectrum. (Additional equalizers may be required when paging or background music, or both, is distributed over the masking system, to provide the desired frequency response for these services and to compensate for frequency dependent losses caused by the acoustical ceiling.)

6.4.2.3 The main equalizer should have at least one-third octave resolution. The typical masking sound spectrum slopes downward with increasing frequency at a rate of about 5 dB/octave, with a steeper roll-off above 2 KHz and a low-frequency response determined primarily by the low frequency capabilities of the masking system loudspeakers.

6.4.2.4 When paging or background music, or both, are to be distributed over a masking system, these sources are fed to second inputs of the amplifiers for the areas to receive the services, with a second equalizer to give flat response for them.

6.4.3 Amplifiers to provide the necessary audio power for the contoured masking sound, and, when necessary, for paging announcements or background music, or both.

6.4.4 Loudspeakers, generally located above the suspended acoustical ceiling, arranged to provide the required uniformity of sound distribution throughout the office and other areas. *The selection and placement of the loud speakers is the most critical element in the design of a successful sound masking system.* The frequency range necessary to effectively mask intruding speech is limited to that from approximately 250 to 4 KHz. However, the loudspeakers should be capable of adequate output for at least an octave below this range in order to enhance the natural reproduction of electronically generated sound.

6.4.5 The placement, orientation, spacing, and relative sound levels of masking system loudspeakers should satisfy the objective of uniform masking sound level and spectrum throughout the occupied areas. Factors that influence the loudspeaker layout include the following:

6.4.5.1 Sound transmission characteristics of the entire ceiling, the acoustical ceiling board as well as the other components, particularly the air return openings.

6.4.5.2 The plenum depth, obstructions (ducts, structure, etc.), and sound absorption characteristics within the plenum, for example, concrete frame versus steel with spray-on fireproofing.

6.4.6 It is desirable that other areas frequented by open office occupants have similar masking sound levels, to avoid perception of the open office areas as noisy. Sound masking should be provided in areas such as corridors, lounges, lobbies, etc. Masking is not generally used in "communication" spaces such as conference rooms, board rooms, training rooms, and seminar rooms, where speech communication is vital.

6.4.7 It is important that an electronic masking system be completely "tuned" and appropriate levels set 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 several days. Otherwise, employees may complain that the air conditioning system has been turned up and they are cold or that their work spaces are too noisy.

6.4.8 The uniformity and spectrum of the masking sound can be evaluated using Guide E 1041.

7. Evaluation of Mock-up or Completed Space

7.1 Since the performance of an open office 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 using the techniques in Test Method E 1130.

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