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.

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Standard Test Method for Objective Measurement of Speech Privacy in Open Plan Spaces Using Articulation Index[1]

This standard is issued under the fixed designation E1130; 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.

INTRODUCTION

This is one of a series of test methods for assessing speech privacy in buildings. This specific standard is designed to assess the speech privacy between locations in open plan spaces, where occupants are separated only by partial-height partitions and furnishings. Another test method deals with assessing speech privacy for closed rooms. A related test method deals with the laboratory measurement of interzone attenuation for open plan components intended to provide speech privacy, such as partial height space dividers, ceiling systems and wall finishes.

1. Scope

1.1 This test method describes a means of objectively assessing speech privacy between locations in open plan spaces. This test method relies upon acoustical measurements, published information on speech levels, and standard methods for assessing speech communication. This test method does not measure the performance of individual open plan components which affect speech privacy; but rather, it assesses the privacy which results from a particular configuration of components (**1, 2**).[2]

1.2 This test method is intended to be a field test for the assessment of speech privacy in actual open plan spaces. However, this test method could be used in mock-up spaces and in environments arranged to simulate an open plan space.

1.3 This test method is suitable for use in many open plan spaces including traditional open offices, focus areas, and collaboration spaces. In addition to office buildings, these types of spaces will also be found in healthcare buildings, institutional spaces, schools, etc. It is not directly applicable for measuring the speech privacy between open plan and enclosed spaces or between fully enclosed spaces.

1.4 This test method relies upon the Articulation Index, which objectively predicts the intelligibility of speech. While both the Articulation Index and this test method can be expected to reliably predict speech privacy, neither predicts the specific effective speech privacy afforded to particular individual occupants.

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

1.6 *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.*

1.7 *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:*[3]

C634 Terminology Relating to Building and Environmental Acoustics

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

2.2 *ANSI Standards:*[4]

ANSI/ASA S1.4-2014/PART 1/IEC 61672:1-2013 Specification for Sound Level Meters

[1] This test method is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.02 on Speech Privacy.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this test method.

[3] 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.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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ANSI/ASA S1.6-1984 (R2011) Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements

ANSI/ASA S1.11-2014/Part 1/IEC 61260:1-2014 Specification for Octave-Band, and Fractional-Octave-Band Analog and Digital Filters

3. Terminology

3.1 *Definitions:*

3.1.1 The acoustical terminology used in this test method is consistent with Terminology C634. Of special importance are the terms *average sound pressure level* and *arithmetic mean sound pressure level*, both of which are defined in Terminology C634, and *source point* which is defined in Specification E1179.

4. Summary of Test Method

4.1 Select two locations in an open plan environment, between which the speech privacy is to be assessed. Designate one location as the *talker* or *source* location and the other as the *listener* or *measurement* location. These locations should typify the usual positions of occupants within the open plan space.

4.2 All masking sound systems and HVAC systems shall be operating in their usual manner.

4.3 At the listener location, measure both the ambient sound pressure levels in each one-third octave-band from 200 to 5000 Hz and the A-weighted ambient sound level.

4.4 Locate a qualified sound source (per Specification E1179) at the talker location and orient it toward the listener location. Drive the source with pink (or white) noise at a level sufficient to increase the one-third octave-band sound pressure levels at the measurement location by at least 10 dB above the ambient over the entire frequency range of interest. The sound pressure levels produced by the sound source at a 1.0 m (3.3 ft) reference position in an anechoic space or free field for a known electrical input will have been previously established (**3**).

4.5 Measure the sound pressure levels in one-third octave bands at the listener location with the source operated according to 4.4.

4.6 Calculate the level reduction in each one-third octave band, that is, the difference in sound pressure levels produced by the sound source at the 1.0 m (3.3 ft) reference position per 4.4 and that measured at the listener location per 4.5.

4.7 Select the appropriate reference speech spectra to be used for the calculation of the predicted received speech level. The *'normal'* voice spectrum of male speech peaks from Table 1 (see also (**4**) and (**5**)) must be used in all cases; however, the *'casual'* voice spectrum may also be used in cases for focused areas where behavioral and technical measures have been taken to limit voice levels, and similarly the *'raised'* voice spectrum may also be used in cases for collaboration areas where group discussions may occur.

4.8 Calculate the one-third octave-band sound pressure levels for the predicted received speech spectrum at the listener location. This is carried out by subtracting the measured level reductions given in 4.6 from the chosen reference speech spectrum from Table 1.

TABLE 1 Speech Peaks for Males[A,B]

One-Third Octave-Band Center Frequency, Hz	One-Third Octave-Band Sound Pressure Levels of Speech Peaks for *Casual* Voice Effort (dB re: 20 µPa)	One-Third Octave-Band Sound Pressure Levels of Speech Peaks for *Normal* Voice Effort (dB re: 20 µPa)	One-Third Octave-Band Sound Pressure Levels of Speech Peaks for *Raised* Voice Effort (dB re: 20 µPa)
200	58	60	63
250	58	64	68
315	56	63	67
400	59	65	70
500	60	66	72
630	57	64	70
800	50	58	66
1000	49	57	65
1250	51	59	66
1600	51	56	63
2000	47	52	59
2500	45	53	59
3150	45	53	58
4000	47	50	56
5000	46	46	52

[A] Speech peaks calculated from rms values given in (**4**) by adding 12 dB, in accordance with (**5**).

[B] The A-weighted sound level and linear sound pressure level of the casual voice effort given in Table 1 are 63 and 67 respectively, for the *normal* voice effort these are 69 and 73, respectively, and for the *raised* voice effort are 76 and 78, respectively.

4.9 Calculate the signal-to-noise ratio in each one-third octave band by subtracting the measured ambient sound pressure levels in 4.3 from the calculated speech levels at the listener location given in 4.8.

4.10 Calculate the Articulation Index in accordance with Section 11 using the one-third octave-band signal-to-noise ratios.

4.11 Report the Articulation Index to two decimal places as the measure of speech privacy. Additionally, the speech privacy index PI may also be reported.

5. Significance and Use

5.1 The speech privacy between locations in an open plan space is determined by the degree to which intruding speech sounds exceed the ambient sound pressure levels at the listener's ear; a classic signal-to-noise ratio situation.

5.2 The sound pressure levels at the listener's ear from intruding speech depend upon:

5.2.1 The individual vocal effort and orientation of the talker,

5.2.2 The attenuation of speech signals due to distance or intervening barriers, and

5.2.3 The reinforcement of speech signals due to reflections from surfaces such as the ceiling, furniture panels, light fixtures, walls, or windows.

5.3 The ambient sound levels within a space often must be increased in order to mask intruding speech using an electronic sound masking system. However, in certain locations and in specific frequency ranges, the building mechanical, electrical

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and plumbing (MEP) equipment, and the heating, ventilating, or air conditioning equipment (HVAC) may increase ambient sound levels or add tonal noise components that may require mitigation before tuning the masking sound.

5.4 The primary purpose of this test method is to assess the speech privacy for an average speech spectrum using the standard Articulation Index method. This requires measurement of the relevant acoustical characteristics discussed in 5.2 and 5.3 for a pair of locations and calculation of the Articulation Index using an average speech spectrum. The average speech spectrum is for male talkers speaking with *normal* voice effort. In specific cases such as designated quiet work zones for 'focused work' where administrative measures have been taken to reduce speech levels, a *'casual'* voice spectrum should be used to calculate speech privacy, whereas in designated group work zones for 'collaborative work' where lively discussion is expected, a *'raised'* voice spectrum should be used to calculate speech privacy.

5.5 The Articulation Index ranges from a low value of 0.00, where speech is generally perceived to be unintelligible, to a high value of 1.00, where all individual spoken words can be understood. Caution should be exercised in interpreting the numerical AI results of this test method since the percentage of single words, phrases, and sentences understood will be different for the same AI value **(5)**.

5.6 This test method can be used to:

5.6.1 Compare the relative speech privacy afforded between different locations within open plan spaces.

5.6.2 Evaluate how changes in open plan components (barriers, furniture, ceilings, masking sound, or wall panels) affect speech privacy.

5.6.3 Assess speech privacy objectively for correlation with subjective responses.

5.7 This test method could be one element of a performance or acceptance test procedure. However, many additional items would need to be specified to allow the use of this test method for performance testing of an open plan environment, such as, the number of locations to be tested and method of selecting those locations, and the method of assessing the results. Specifying a numerical criterion in terms of the Articulation Index is also necessary for acceptance testing; however, the selection of such a criterion and permissible deviations should be undertaken with care in view of the present state-of-the-art as discussed in 5.5.

6. Test Space

6.1 The test space shall be an actual or a mock-up open plan environment.

6.2 The ceiling of the test space shall be complete, including ceiling board, light fixtures, and air diffusers.

6.3 The floor covering and wall finishes shall be completely installed prior to testing.

6.4 All furnishings shall be in place.

6.5 Any masking sound system shall be set as intended for use in the occupied space.

NOTE 1—If the masking system is adjusted to produce higher sound pressure levels, greater speech privacy is obtained; however, the upper limit of acceptability is generally determined by the subjective comfort of the occupant rather than by speech privacy achieved. In traditional open plan office spaces, the A-weighted sound level of the background masking sound is commonly set between 45 and 48 dB. Levels at or above 50 dB should be avoided as these will tend to be annoying in-of-themselves.

6.6 The open plan space should be unoccupied during the tests.

NOTE 2—If the purpose of testing is to evaluate the change in speech privacy which results from component changes (for example, installing wall finishes or adjusting the masking system) the different conditions for each test result shall be carefully documented.

7. Apparatus

7.1 The minimum instrumentation required for this test method is as follows:

7.1.1 *Microphone and Amplifier,* that meet or exceed the requirements of ANSI S1.4 for Class 1 sound level meters.

7.1.2 *One-Third Octave-Band Filter Set,* meeting the requirements of ANSI S1.11 for class 1 or better. The nominal center frequencies of the filters shall include all the preferred one-third octave bands from 200 to 5000 Hz conforming to ANSI S1.6. This range may be extended.

7.1.3 *Sound Level Meter,* or other device from which the sound pressure level can be read.

7.1.4 *Calibrated Sound Source,* of known sensitivity and directivity, completely described in Specification E1179 and calibrated in accordance with the Annex of this test method.

7.2 *On-Site Data Acquisition Instruments,* that may consist of a microphone with calibrator, a precision sound level meter capable of measuring average sound pressure level, a one-third octave-band analyzer, and a strip chart recorder (optional). Test data may be read on-site or recorded for later analysis. Recording instruments may consist of a microphone with calibrator, precision sound level meter (optional), and an instrument quality recorder. Laboratory data reduction instruments may consist of a recorder, a one-third octave-band analyzer and a computer.

7.3 The background noise of measuring instruments in each one-third octave band must be at least 10 dB below the measured sound pressure levels.

8. Test Signal

8.1 The test signal shall be contiguous, one-third octave bands of pink or white noise, from 200 to 5000 Hz, and this range may be extended.

9. Speech Spectra

9.1 The *normal* voice effort spectrum **(2)** of speech peaks given in Table 1 shall be used for the calculations. Additionally, other spectra may be used such as the *casual* or *raised* voice spectrum of speech peaks in Table 1.

10. Procedure

10.1 *Measurement Location:*

10.1.1 Select a listener (measurement) location at the typical ear-height of a seated or standing listener, that is, the

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microphone shall be located 1.2 m (4 ft) above the floor (seated) or 1.67 m (5 ft 6 in.) above the floor (standing).

10.1.2 The measurement location should be at least 1 m (3.3 ft) from any vertical surfaces such as walls, columns, desks, or furniture. In the event that this cannot be met, the selected location shall be at an occupant's usual position.

10.2 *Ambient Measurements:*

10.2.1 With the test signal off, the average sound pressure level shall be measured according to either 10.2.1.1 or 10.2.1.2.

10.2.1.1 *Fixed Microphone Method*—In each one-third octave band over a time period of at least 4 s at four positions at 90° intervals around a circle of 0.3-m (1-ft) radius centered on the listener (measurement) location. The arithmetic mean sound pressure level shall be calculated for each band from the four measured values. The A-weighted sound level shall also be measured and calculated in this manner. All data shall be obtained with the microphone diaphragm parallel to the floor and facing upwards.

10.2.1.2 *Scanning Microphone Method*—In each one-third octave band over an integration time period of at least 10 s sweep the microphone around a circle of approximately 0.3 m (1 ft) radius centered on the listener (measurement) location starting at the designated height per 10.1.1 less 0.15 m (6 in.) while spiraling upwards by 0.3 m, and complete at least 2 integer revolutions. The A-weighted sound level shall also be measured in this manner.

10.2.2 Verify that the measured ambient sound pressure levels exceed the background noise of the instruments by at least 10 dB in each band. If not, the data shall not be used.

10.3 *Source Location and Orientation:*

10.3.1 The sound source shall be placed at the talker location and the source point shall be located 1.2 m (4 ft) or 1.67 m (5ft 6 in.) above the floor, to represent a seated or standing talker, respectively.

10.3.2 The loudspeaker axis should be oriented so that its projection in the horizontal plane is along a straight line from the talker to the listener location.

10.3.3 In the vertical plane, the loudspeaker axis should be oriented to be 25° above horizontal for a source height of 1.2 m (4 ft) or oriented to be horizontal (parallel to the floor) for a source height of 1.67 m (5 ft 6 in.).

10.4 *Level Reduction Measurements:*

10.4.1 Turn the test signal on and measure (and adjust if necessary) the electrical signal voltage to be the same as used for the measurement of the reference levels per 4.4 (see Annex A1).

10.4.2 Repeat the measurements described in 10.2.1 with the test signal on.

10.4.3 Verify that the measured sound pressure levels exceed the *ambient* values measured in 10.2 by at least 10 dB in each band. If not, the data shall not be used.

10.4.4 Calculate the level reduction due to the office configuration in each one-third octave band, by subtracting the values measured at the measurement location from the source reference levels (see Annex A1).

11. Calculation

11.1 Select a sound pressure level spectrum of speech peaks from Table 1. One set of calculations shall use the normal voice spectrum from Table 1, as required by 9.1.

11.2 Calculate the sound pressure levels of peak speech signals in each one-third octave band at the listener location by subtracting the level reductions from the spectrum selected in 11.1.

11.3 Calculate the signal-to-noise ratio in each one-third octave band: the amount by which the peak speech levels calculated in 11.2 exceed the ambient values measured in 10.2. Whenever the signal-to-noise ratio is zero or less, use a value of zero; whenever the signal-to-noise ratio is 30 dB or more, use a value of 30.

11.4 Calculate the Articulation Index by multiplying the band weighting factors from Table 2 by the signal-to-noise ratios and summing as follows:

$$AI = \sum_{i=1}^{15} W_i \cdot R_i \quad (1)$$

where:

AI = Articulation Index,
W_i = weighting factor (from Table 2) for band i, and
R_i = signal-to-noise ratio for band I.

NOTE 3—Fig. 1 presents a data sheet that may be helpful in performing these calculations.

12. Report

12.1 Report the following information:

12.1.1 Statement, if true in every respect, that tests were conducted in accordance with the provisions outlined in this test method. Any options or exceptions to this test method shall be noted.

12.1.2 Description of the test space including the ceiling material, the type of ceiling suspension system, light fixtures, ceiling height, the partial height space dividers, and the floor covering. Optionally, descriptions may be useful for ceiling diffusers, construction details above and below the ceiling, the plenum depth, wall finishes, and interior furnishings.

TABLE 2 Articulation Index Weighting Factors for Preferred One-Third Octave Bands

One-Third Octave-Band Center Frequency, Hz	Weighting Factor
200	0.0004
250	0.0010
315	0.0010
400	0.0014
500	0.0014
630	0.0020
800	0.0020
1000	0.0024
1250	0.0030
1600	0.0037
2000	0.0038
2500	0.0034
3150	0.0034
4000	0.0024
5000	0.0020

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