~~Designation:E90–04~~ Designation: E 90 – 09

Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements[1]

This standard is issued under the fixed designation E 90; 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.

~~This standard has been approved for use by agencies of the Department of Defense.~~

INTRODUCTION

This test method is part of a set for evaluating the sound-insulating properties of building elements. It is designed to measure the transmission of sound through a partition or partition element in a laboratory. Others in the set cover the measurement of sound isolation in buildings (Test Method E 336), the laboratory measurement of impact sound transmission through floors (Test Method E 492), the measurement of impact sound transmission in buildings (Test Method E 1007), the measurement of sound transmission through building facades and facade elements (Guide E 966), the measurement of sound transmission through a common plenum between two rooms (Test Method E 1414), a quick method for the determination of airborne sound isolation in multiunit buildings (Practice ~~E597),~~E 597), and the measurement of sound transmission through door panels and systems (Test Method ~~E1408~~E 1425).

1. Scope

1.1 This test method covers the laboratory measurement of airborne sound transmission loss of building partitions such as walls of all kinds, operable partitions, floor-ceiling assemblies, doors, windows, roofs, panels, and other space-dividing elements.

~~1.2*Laboratory Accreditation*—A procedure for accrediting a laboratory for performing this test method is given in Annex A3.~~

1.2 Laboratories are designed so the test specimen constitutes the primary sound transmission path between the two test rooms and so approximately diffuse sound fields exist in the rooms.

1.3 *Laboratory Accreditation*—The requirements for accrediting a laboratory for performing this test method are given in Annex A4.

1.4 *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:*~~

~~C634Terminology Relating to Environmental Acoustics~~ ASTM Standards:[2]

C 423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method

C 634 Terminology Relating to Building and Environmental Acoustics

E 336 Test Method for Measurement of Airborne Sound ~~Insulation~~ Attenuation between Rooms in Buildings

E 413 Classification for Rating Sound Insulation

E 492 ~~Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Method~~

~~E597Practice for Determining a Single-Number Rating of Airborne Sound Isolation for Use in Multiunit Building Specifications~~

[1] This test method is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.03 on Sound Transmission.

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Current edition approved July 1, 2009. Published August 2009. Originally approved in 1955. Last previous edition approved in 2004 as E 90 – 04.

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

~~For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For~~

[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.

Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine

E 966 Guide for Field Measurements of Airborne Sound Insulation of Building Facades and Facade Elements

E 1007 Test Method for Field Measurement of Tapping Machine Impact Sound Transmission throughThrough Floor-Ceiling Assemblies and Associated Support Structures

E 1111 Test Method for Measuring the Interzone Attenuation of Open Office Components

E 1289 Specification for Reference Specimen for Sound Transmission Loss

E 1332 Classification for Determination of Outdoor-Indoor Transmission Class E1375Test Method for Measuring the Interzone Attenuation of Furniture Panels Used as Acoustical Barriers

E1408Test Method for Laboratory Measurement of the Sound Transmission Loss of Door Panels and Door Systems

E 1414 Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum

E 1425 Practice for Determining the Acoustical Performance of Exterior Windows and Doors

E 2235 Test Method for Determination of Decay Rates for Use in Sound Insulation Test Methods

2.2 *ANSI Standards:*

S1.4Specification for Sound-Level MetersS1.6-1984 (R2006) American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurement[3]

S1.6Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements[3]

S1.10 Pressure Calibration of Laboratory Standard Pressure Microphones[3]

S1.11 Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters[3]

S1.40 Specifications and Verification Procedures for Sound Calibrators[3]

S12.31Precision Methods for the Determination of Sound Power Levels of Broad-Band Noise Sources in Reverberation Rooms[3] S1.43 Specifications for Integrating-Averaging Sound-Level Meters[3]

S12.51 Acoustics—Determination of Sound Power Levels of Noise Sources Using Sound Pressure—Precision Methods for Reverberation Rooms[3]

2.3 *ISO Standards: ISO717 Rating of Sound Insulation for Dwellings*[3]

ISO3741 Acoustics—Determination of Sound Power Level of Noise Sources—Precision Methods for Broad-Band Sources in Reverberation Rooms[3] ISO 717 Rating of Sound Insulation for Dwellings[3]

ISO 3741 Acoustics—Determination of Sound Power Level of Noise Sources—Precision Methods for Reverberation Rooms[3]

2.4 *IEC Standards:*

IEC 60942 Electroacoustics—Sound Calibrators[4]

IEC 61672 Electroacoustics—Sound Level Meters—Part 1: Specifications[4]

3. Terminology

3.1 The following terms used in this test method have specific meanings that are defined in Terminology C 634.

acoustical barrierairborne sound
average sound pressure level
background noise
damp
decay rate
decibel
diffraction
diffuse sound field
direct sound field
flanking transmission
level
octave band
pink noise
receiving room
reverberant sound field
reverberation room sabin

airborne sound
average sound pressure level
background noise
damp
decay rate
decibel
diffraction

sound absorption
sound attenuation
sound energy
sound insulation
sound isolation
sound level
sound power

[3] Available from the American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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

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

[4] Available from International Electrotechnical Commission (IEC), 3 rue de Varembé, Case postale 131, CH-1211, Geneva 20, Switzerland, http://www.iec.ch.

diffuse sound field	sound pressure
direct sound field	sound pressure level
flanking transmission	sound transmission level
level	sound transmission class
octave band	sound transmission coefficient
pink noise	sound transmission loss
receiving room	source room
reverberant sound field	unit

3.1.1 For the purposes of this test method, transmission loss is operationally defined as the difference in decibels between the average sound pressure levels in the reverberant source and receiving rooms, plus ten times the common logarithm of the ratio of the area of the common partition to the sound absorption in the receiving room (see Eq 11). 5).

NOTE 1—Sound transmission coefficient and sound transmission loss are related by either of the two equations:

$$TL = 10 \log(1/\tau) \quad (1)$$

$$TL = 10 \log(1/\tau) \quad (1)$$

(2) $\tau = 10–TL/10$

3.2 *Definitions of Terms Specific to This Standard:*

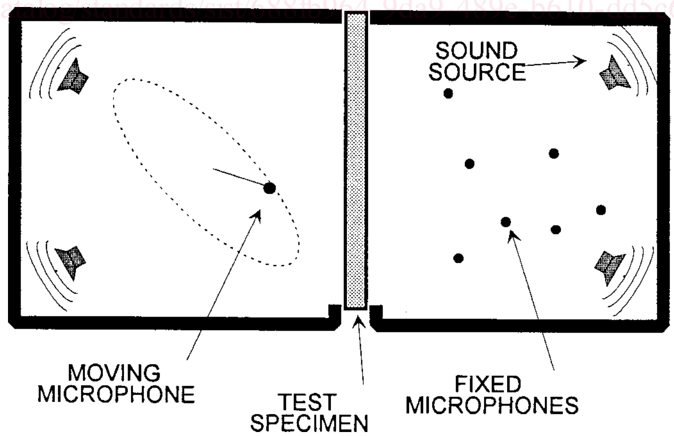
3.2.1 *sound absorption, A, [L^2]*—of a room, in a specified frequency band, the hypothetical area of a totally absorbing surface without diffraction effects which, if it were the only absorbing element in the room, would give the same sound decay rate as the room under consideration. E0090-09_2

4. Summary of Test Method

4.1 Two adjacent reverberation rooms are arranged with an opening between them in which the test partition is installed. Care is taken that the only significant sound transmission path between rooms is by way of the test partition. An approximately diffuse sound field is produced in one room, the source room. Sound incident on the test partition causes it to vibrate and create a sound field in the second room, the receiving room. The space- and time-averaged sound pressure levels in the two rooms are determined (see Fig. 1). determined. In addition, with the test specimen in place, the sound absorption in the receiving room is determined. The sound pressure levels in the two rooms, the sound absorption in the receiving room and the area of the specimen are used to calculate sound transmission loss as shown in Section 1211. Because transmission loss is a function of frequency, measurements are made in a series of frequency bands.

4.2Additional procedures that may be followed when testing doors are given in Test Method E1408

4.2 In theory, it is not important which room is designated as the source and which as the receiving room. In practice, different values of sound transmission loss may be measured when the roles are reversed. To compensate for this, the entire measurement



NON SHOWING CONCEPTUAL ARRANGEMENT OF A WALL SOUND TRANSMISSION LOSS SUITE.—This figure is not meant to be a design guide but is for illustrative purposes only. As an example, the room on the right has fixed microphones to measure average sound pressure level; the room on the left has a continuously moving microphone to measure average sound pressure level. Usually both rooms will have the same microphone system. The sound sources (loudspeakers) in the rooms generate the incident sound fields for the measurement of level differences or of sound decay rates. As shown, either room could serve as source or receiving room.

FIG. 1 Illustration Showing Conceptual Arrangement of a Wall Sound Transmission Loss Suite

may be repeated with the roles reversed; the source room becomes the receiving room and vice versa. The two sets of transmission loss values are then averaged to produce the final result for the laboratory.

4.3 Additional procedures that may be followed when testing doors are given in Test Method E 1425.

5. Significance and Use

5.1 Sound transmission loss as defined in Terminology C 634, refers to the response of specimens exposed to a diffuse incident sound field, and this is the test condition approached by this laboratory test method. The test results are therefore most directly relevant to the performance of similar specimens exposed to similar sound fields. They provide, however, a useful general measure of performance for the variety of sound fields to which a partition or element may typically be exposed.

~~5.2This test method is not intended for field tests. Field tests should be performed according to Test Method E336~~

5.2 In laboratories designed to satisfy the requirements of this test method, the intent is that only significant path for sound transmission between the rooms is through the test specimen. This is not generally the case in buildings where there are often many other paths for sounds—*flanking sound transmission* . Consequently sound ratings obtained using this test method do not relate directly to sound isolation in buildings; they represent an upper limit to what would be measured in a field test.

5.3 This test method is not intended for field tests. Field tests shall be performed according to Test Method E 336.

NOTE 2—The comparable quantity measured using Test Method E 336 is called the apparent sound transmission loss because of the presence of flanking sound transmission.

6. Test Rooms

~~6.1*Room Size and Shape*—To produce an acceptable approximation to the assumed diffuse sound fields, especially in the lowest test frequency band, the sound fields in the rooms must satisfy the requirements in~~

6.1 The test rooms shall be so constructed and arranged that the test specimen constitutes the only important transmission path between them. Laboratories must investigate their flanking limit and prepare a report as described in Annex A5.

6.2 The spatial variations of sound pressure level measured in the each room shall be such that the precision requirements in Annex A2 ~~. They must also satisfy any of the following requirements that are mandatory.~~

~~6.1.1*Minimum Volume*—The volume of the source and receiving rooms must each be 50 m~~ are satisfied at all frequencies.

6.3 *Volume of Rooms*—The minimum volume of each room is 80 m^3 ~~(1765 ft^3) or more.~~

~~6.2.~~.

NOTE 3—See Appendix X1 for recommendations for new construction.

6.4 *Room Absorption*~~—The sound absorption in each of the rooms should be made as low as possible to achieve the best possible simulation of the ideal diffuse field condition and to keep the region dominated by the direct field (of the source or of the test specimen) as small as possible (see 8.5). At each frequency, the sound absorption for each room (as furnished with diffusers) should be no greater than:~~ —The sound absorption in the receiving room should be low to achieve the best possible simulation of the ideal diffuse field condition, and to minimize the region dominated by the direct field of the test specimen. In the frequency range that extends from $f = 2000/V^{1/3}$ to 2000 Hz, the absorption in the receiving room (as furnished with diffusers) should be no greater than:

where:

V = ~~room volume, and~~ the room volume, m^3, and

A = ~~sound absorption of the room.~~

~~When *V* is expressed in cubic metres, *A* is in square metres. When *V* is expressed in cubic feet, *A* is in sabin (square feet). At low frequencies somewhat higher room absorption may be desirable to accommodate other test requirements (for example, ANSI S12.31, ISO 3741). Sound absorption in the room is usually increased at frequencies below *f* = *k*~~ the sound absorption of the room, m^2 ~~/*V*.~~

6.4.1 For frequencies below $f = 2000/V^{1/3}$ ~~(k_2 is an empirical constant equal to 2000 m/s when *V* is in cubic metres, and equal to 6562 ft/s when *V* is in cubic feet). In any case, the sound absorption should be no greater than three times the value given by Eq 3. For frequencies above 2000 Hz, atmospheric absorption may make it impossible to avoid a slightly higher value than that given in Eq 3.~~

~~6.2.1Unless otherwise specified, the average temperatures in each room during all acoustical measurements shall be in the range 22 ± 5°C.~~

~~6.2.2When testing specimens that are windows or window systems, the average temperature of the specimen and in each room during all acoustical measurements shall be in the range 22±2°C~~ , somewhat higher absorption may be desirable to accommodate requirements of other test methods (for example, ISO 3741); in any case, the absorption should be no greater than three times the value given by Eq 3.

~~NOTE2—The sound damping properties of viscoelastic materials used to mount glass often depends on temperature. This requirement minimizes any effects this has on measured sound transmission loss.~~

~~6.2.3During the sound pressure level and sound absorption measurements, variations in temperature and humidity in the receiving room shall not exceed 3°C and 3% relative humidity respectively. Temperature and humidity shall be measured and recorded at the beginning and end of each test to ensure compliance.~~

6.3*Methods to Reduce the Variability of the Sound Fields*—Meeting the requirements of 6.1 and 6.2 can be difficult in the lower test bands where results are likely to depend critically on arbitrary features of the test geometry such as positioning of the sound sources and individual microphones. Spatial variations in sound pressure level and decay rate may be reduced by one or both of the following types of diffusing panels. The recommendations that follow are only included as guidelines. Satisfaction of the requirements of Annex A2 for confidence intervals is the primary criterion, not the size or number of diffusing panels.

6.3.1*Stationary Diffusing Panels*—It is recommended that each test room be fitted with a set of about 3 to 6 diffusing panels, suspended in random orientations throughout the room space. The appropriate number, distribution, and orientation of panels should be determined experimentally by checking to see if spatial variances of sound pressure level or decay rate are reduced. Lateral panel dimensions should be about ½ to 1 wave-length of the sound at the lowest test band, for example, about 1.2 to 2.5 m. The recommended minimum mass per unit area of the panels is 5 kg/m^2 (1 lb/ft^2) for operation down to 100 Hz. (Panels of plywood or particleboard measuring 1.2 ×2.4 m are often used.) To be effective at lower frequencies, the size and mass of diffusing panels should be increased in proportion to the wavelength. It is likely to be impractical to use very large diffusing panels at very low frequencies; they might make the room behave like a number of coupled spaces rather than a single room, and it might be difficult to position microphones.

6.3.2*Rotating or Moving Diffusers*—One or more rotating or moving panels set at oblique angles to the room surfaces may be installed in either or both rooms. The recommendations for weight and size of the panels given in 6.3.1 for fixed diffusing panels apply also to rotating or moving diffusers. The panels should be large enough that during motion they produce a significant variation in the sound field, yet small enough that they do not effectively partition the room at any point in their movement. 4—For frequencies above 2000 Hz, atmospheric absorption may make it impossible to avoid a slightly higher value than that given in Eq 3.

6.5 Unless otherwise specified, the average temperatures in each room during all acoustical measurements shall be in the range 22 ± 5°C and the average relative humidity shall be at least 30 %.

6.5.1 When testing specimens with temperature sensitive materials, such as systems that incorporate laminated glass, the average temperature of the specimen and in each room during all acoustical measurements shall be in the range 22 ± 2°C.

NOTE3—Moving diffusers can generate mechanical noise or wind and wind noise in microphones. This increased background noise may make measurements difficult in some cases.

6.4*Flanking Transmission*—The test rooms shall be constructed and arranged to minimize the possibility of transmission by paths other than that through the test partition. Sound pressure levels produced by such flanking transmission should be at least 10 dB lower than the sound radiated into the receiving room by the test partition. Supporting one or both rooms on vibration isolators (resilient materials or springs) is a common method of reducing flanking transmission. Structural discontinuities are recommended between the source-room and the test specimen and between the receiving room and the test specimen to minimize flanking transmission between them. 5—The sound damping properties of viscoelastic substrates between panels (glass, metal, etc.) and of viscoelastic materials used to mount glass often depend on temperature. This requirement minimizes any effects this has on measured sound transmission loss.

6.6 During the sound pressure level and the corresponding sound absorption measurements, variations in temperature and humidity in the receiving room shall not exceed 3°C and 3 % relative humidity respectively. Temperature and humidity shall be measured and recorded as often as necessary to ensure compliance.

6.6.1 If a relative humidity of at least 30 % can not be maintained in the receiving room, users of the test method shall verify by calculation that changes in the 10 log A_0 term (see 11.1) due to changes in temperature and humidity do not exceed 0.5 dB.

NOTE4—If the specimen is rigidly connected to the source-room structure, there is some risk that, in addition to the incident airborne sound, sound power may enter the specimen at the edges because of vibration of the source-room structure. Similarly, if the specimen is rigidly connected to the receiving room structure, sound power may flow from the specimen to the walls of the receiving room and be radiated from them.

6.4.1The limit on specimen transmission loss measurement due to flanking transmission must be investigated as follows:

6.4.1.1In the test opening, build a partition expected to have high transmission loss.

6.4.1.2Measure the transmission losses following this test method.

6.4.1.3Increase the expected transmission losses by making a substantial improvement to the test partition, for example, by adding a heavy shielding structure in front of the test partition.

6.4.1.4Measure the transmission loss again.

6.4.1.5Repeat steps 6.4.1.3 and 6.4.1.4 until significant additions to the test partition no longer significantly increase the measured transmission loss. The sound transmission loss measured can then be ascribed to flanking paths. The transmission loss values obtained represent the limit that can be measured by the facility. Unless steps are taken to eliminate them, these paths always exist and will reduce the measured transmission loss for partitions whose inherent transmission loss values are within 10 dB of the flanking limit. The sound power transmission along a particular suspected flanking path may be decreased to determine if the measured transmission loss increases. This may be done by temporarily adding shielding structures in front of the surfaces that are suspected of radiating unwanted sound.

6.4.2A potential flanking path is through the perimeter of the partition or the mounting frame **(1)** 6—Procedures for calculating air absorption are described in Test Method C 423. It is therefore important that the partition mounting arrangement used in determining the transmission loss limit be the same as is used for routine testing.

6.4.3An extraneous signal similar in effect to flanking transmission may be produced by electrical "cross-talk" between the electrical system driving the sound source or other devices and the receiving microphone systems. This possibility should be checked, whenever systems are changed, by measuring the residual signals when the loudspeaker is replaced by an equivalent electrical load or by replacing the microphone cartridge with a dummy load.

6.4.4Laboratories must keep records of data collected to establish the flanking limit of their facilities.

6.4.5When the transmission loss measured for a test specimen in a particular frequency band is within 10 dB of the flanking limit established for the laboratory, the transmission loss value must be clearly identified in the test report as being potentially limited by the laboratory. The true value may be higher than that measured.

7. Test Specimens

7.1 *Size and Mounting*—Any test specimen that is to typify a wall or floor shall be large enough to include all the essential constructional elements in their normal size, and in a proportion typical of actual use. The minimum dimension (excluding thickness) shall be 2.4 m, except that specimens of doors, office screens, and other smaller building elements shall be their customary size. Preformed panel structures should include at least two complete modules (panels plus edge mounting elements), although single panels can be tested. In all cases the test specimen shall be installed in a manner similar to actual construction, with a careful simulation of normal constraint and sealing conditions at the perimeter and at joints within the field of the specimen. Detailed reporting and installation procedures for particular types of building separation elements are recommendedgiven in Annex A1.

7.2 *Aging of Specimens*—Test specimens that incorporate materials for which there is a curing process (for example adhesives, plasters, concrete, mortar, damping compound) shall age for a sufficient interval before testing. Manufacturers may supply information about curing times for their products. Aging periods for certain common materials are given in Annex A1.

7.2.1For materials whose aging characteristics are not known, tests shall be repeated over a reasonable time on at least one specimen to determine an appropriate aging period. A suggested procedure is to test at intervals in the series 1, 2, 4, 7, 14, and 28 days from the date of construction, until no significant change is observed between successive tests. The minimum aging period should be the interval beyond which no significant change is observed.

7.2.1.1To decide whether a change is significant, laboratory operators must determine the repeatability of their test procedures. This is done by repeating the complete test procedure several times without disturbing the specimen or other apparatus and with as little time as possible between repeat measurements. From the set of transmission loss measurements, calculate the standard deviation of transmission loss at each frequency. Standard statistical techniques **(2)** may then be used to decide if a test differs significantly from a previous test. In many cases, a visual comparison of two results will be enough to verify that there is no significant difference between two results.

7.3*Testing of Specimens Smaller Than Test Opening* —When the area of the test specimen is smaller than that of the normal test opening, the area of the test opening must be reduced using additional construction. This additional construction, or filler wall, should be designed to transmit as little sound as possible. Nevertheless, a portion of the sound may be transmitted by way of the filler wall (see Fig. 2). Sound transmission through the composite wall can be represented by:

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where:

S_c = area of composite construction ($S_c = S_s + S_f$),
S_s = area of test specimen,
S_f = area of filler element,
τ_c = transmission coefficient of composite construction,
τ_s = transmission coefficient of test specimen, and
τ_f = transmission coefficient of filler element.

NOTE5—The above expressions assume that the two parts of the composite construction react to the sound field independently of each other.

Two general procedures may be used to deal with this situation:

7.3.1*Build and Measure a Complete Filler Wall*—This is the preferred method and is usually most convenient when the specimen area is smaller than the area of the filler wall. Based on experience and knowledge of the test specimen construction, build a filler wall that is expected to transmit a negligible amount of sound relative to that through the specimen. The filler wall should be built with support structures for the test specimen already in place. The opening for the specimen shall be closed and finished with the same construction as the rest of the filler wall, except as noted in 7.3.2.

7.3.1.1Following the procedures in this test method, measure the sound transmission losses for this complete filler wall. The transmission coefficients, τ_f, for the filler wall can be calculated from the corresponding transmission losses using Eq 2.

7.3.1.2Remove the part of the filler wall surfaces covering the opening for the specimen and install the specimen. Make no other significant changes to the filler wall structure.

7.3.1.3Following the procedures in this test method, measure the sound transmission losses for this composite wall. The transmission coefficients, τ_c, can be calculated from the corresponding transmission losses using Eq 2. The area used in calculation is the combined area of the specimen and the filler wall, S_c.

~~7.3.1.4At each test frequency calculate the difference: $10 \log(\tau_c S_c) - 10 \log(\tau_f S_f)$.~~

~~7.3.1.5If the difference is more than 15 dB, calculate τ_s from Eq 5 ignoring the term $\tau_f S_f$.~~

~~7.3.1.6If the difference is between 6 and 15 dB, calculate τ_s using Eq 5. This corrects for transmission through the filler wall. Note in the test report where such corrections have been made.~~

~~7.3.1.7If the difference is less than 6 dB, reliable corrections cannot be made. Calculate τ_s from Eq 5 ignoring the term $\tau_f S_f$. Multiply the value obtained by 0.75 and then use Eq 1 to calculate a lower limit for the transmission loss of the test specimen. (This is equivalent to limiting the difference to 6 dB.) Any values of transmission loss that are limited in this way must be clearly marked as such in the test report.~~

~~7.3.2*Use Additional Structures to Reduce Transmission* —Some test specimens fill a large fraction of the test opening leaving only a small area for a filler wall. In such cases, it is not always convenient to construct and test a complete filler wall and the transmission coefficient of the filler wall is not known. To demonstrate that transmission through the filler wall is negligible, proceed as follows:~~

~~7.3.2.1Measure the sound transmission loss for the composite assembly.~~

~~7.3.2.2Cover each face of the filler wall with sound absorbing material at least 50 mm (2 in.) thick. Cover the sound absorbing material with barrier panels weighing at least 8 kg/m^2 (1.6 lb/ft ^{2}) that are not rigidly attached to the filler wall (see Fig. 2). Normal good practices should be followed for mounting and sealing.~~

~~7.3.2.3Remeasure the sound transmission loss for the composite assembly.~~

~~7.3.2.4If changes are insignificant, it may be assumed that transmission through the filler wall is negligible.~~

~~7.3.3Other combinations of test specimen and filler wall may require other procedures. It is the responsibility of the testing laboratory to show that transmission through filler walls is negligible.~~

~~7.3.4When a small specimen such as a door or window assembly is mounted in a filler wall, the distance from the surface of the filler wall to the specimen surface should be small compared to the lateral dimensions of the specimen.~~

~~7.3.5When a filler wall is used, ensure that sound is not transmitted through the structure where the filler wall and the test specimen join. Such flanking can occur when the filler wall is thicker than the test specimen.~~

~~7.4~~*Office Screens*—The minimum area of an office screen specimen shall be 2.3 m^2~~(25 ft^2).~~ . Testing an office screen according to this test method is only appropriate when the property of interest is sound transmission through the main body of the screen. Screens that incorporate electrical raceways may allow sound to pass through easily in this region. Such parts of an office screen ~~should~~shall be included as part of the specimen. For a complete test of the screen as a barrier, including the effects of diffraction and leakage, Test Method ~~E1375~~E 1111is recommended.

~~7.5~~

7.3 *Operable Door Systems*—Measurements may be in accordance with Test Method ~~E 1408~~E 1425to evaluate door systems in the operable and fully sealed state, and to measure the force required to operate the door.

8. Test Signal Sound Sources

8.1 *Signal Spectrum*—The sound signals used for these tests shall be random noise having a continuous spectrum within each test frequency band.

8.2 *Sound Sources*~~—Sound is usually generated in the rooms using loudspeaker systems although other sources are acceptable if they satisfy the requirements of this test method.~~

~~8.2.1Sources should preferably be omnidirectional at all measurement frequencies to excite the sound field in the room as uniformly as possible. Using separate loudspeakers for high and low frequencies will make the system more omnidirectional. The direct field from the loudspeaker system can be further reduced by aiming the loudspeakers into corners of the room. Laboratory operators may also find that this orientation increases the low frequency sound pressure levels in the room. Another approach to obtaining an omnidirectional speaker system is to use an array of loudspeakers mounted on the faces of a dodecahedron.~~

~~8.2.2*Orientation of Loudspeakers* :~~

—Sound sources shall consist of one or more loudspeakers in an enclosure.

NOTE 7—Sources should preferably be omnidirectional at all measurement frequencies to excite the sound field in the room as uniformly as possible. Using separate loudspeakers for high and low frequencies will make the system more omnidirectional. Aiming the loudspeakers into corners of the room can reduce the direct field from the loudspeaker system. An approximation to an omnidirectional speaker system can be obtained by mounting an array of loudspeakers on the faces of a polyhedron (cube, octahedron, dodecahedron, etc.). Sources in trihedral corners of the room excite room modes more effectively and laboratory operators may find that this orientation increases the low frequency sound pressure levels in the room.

8.3 ~~*Multiple Sound Source Positions*— Measured values of sound transmission loss, especially at low frequencies, may change significantly when a loudspeaker position is changed in the source room. Where this occurs, sound transmission loss should be measured for several loudspeaker positions and the values averaged to provide a less biased result. Sound sources can be used either in sequence or simultaneously. If they are used simultaneously, they must be driven by separate random noise generators and amplifiers. Multiple, uncorrelated sound sources have also been found to reduce the spatial variance of sound pressure level in reverberation rooms.~~

~~8.4*Location of Sound Sources*—Sound source positions shall be selected to minimize spatial fluctuations in the reverberant field in the source room; sources in trihedral corners of the room excite room modes more effectively.~~

~~8.5*Direct Field of Sound Source(s)*— The direct sound field from the source(s) at the test partition, or the nearest microphone~~

shall be at least 10 dB below the sound pressure level of the reverberant field. The distance between the source(s) and the partition or microphones required to achieve this condition will depend on the room properties, the number and orientation of sound sources and frequency. Verify that the distances between a single source and the microphones and test partition satisfy the relationship:

$$r \geq \frac{1}{4}\sqrt{\frac{10A}{\pi}} \tag{6}$$

where:
A = sound absorption in the room, and
r = distance from the source.

When A is in square metres, r is in metres. When A is in sabins (square feet), r is in feet. Multiple Sound Sources—If a laboratory chooses to use multiple sound sources at different locations in the room simultaneously, they shall be driven by separate random noise generators and amplifiers.

NOTE 6—This expression is for a point source and is obtained by determining the point where the sound pressure level of the direct field is 10 dB below the sound pressure level of the reverberant field **(3)**. The expression is thus not strictly accurate for loudspeaker systems especially at high frequencies where the directivity index is greater than unity. Neither is it accurate when multiple sources are used, but, for the purposes of this test method, it is deemed acceptable. 8—Measured values of sound transmission loss, especially at low frequencies, may change significantly when sound source position is changed. Multiple sound sources driven by uncorrelated noise signals have also been found to reduce the spatial variance of sound pressure level in reverberation rooms and thus make it easier to satisfy the requirements of Annex A2.

9. Microphone Instrumentation Requirements

9.1 Microphones and analyzers are used to measure average sound pressure levels in the source and receiving rooms and sound decay rates in the receiving room. Various systems of data collection and processing are possible, ranging from a single microphone moving continuously or placed in sequence at several measurement positions to several microphones making simultaneous measurements (see Fig. 1 for two examples). The measurement process must account for level fluctuations caused by spatial and temporal variations. Microphone sensitivity and moving diffusers must also be accounted for. for two examples). The measurement process must account for spatial and temporal variations of sound pressure level.

9.2 *Microphone Electrical Requirements* — Use microphones that are stable and substantially omnidirectional in the frequency range of measurement. (A 13-mm (0.5-in.) random-incidence condenser microphone is recommended.) Specifically, microphones, amplifiers, and electronic circuitry to process microphone signals must satisfy the requirements of ANSI S1.4 for Type 1 sound level meters, except that A, B, and C weighting networks are not required since one-third octave filters are used. Where multiple microphones are used, they should be of the same model.

9.3 —*Use microphones that are stable and substantially omni-directional in the frequency range of measurement, with a known frequency response for a random incidence sound field. (A 13-mm (0.5-in.) random-incidence condenser microphone is recommended.) Specifically, microphones, amplifiers, and electronic circuitry to process microphone signals must satisfy the requirements of ANSI S1.43 or IEC 61672 for class 1 sound level meters, except that A, B, and C weighting networks are not required since one-third octave filters are used. All microphones used in testing according to this method shall be of the same type.*

9.3 *Calibration* —Calibrate each microphone over the whole range of test frequencies as often as necessary to ensure the required accuracy (see ANSI S1.10). A record shall be kept of the calibration data and the dates of calibration. Calibration checks of the entire measurement system for at least one frequency shall be made at least once during each day of testing.

9.3.1 Make the sensitivity check of the measurement system using an acoustic or electrostatic calibrator that is known to be stable. The sensitivity check will usually consist of impressing a known sound pressure upon the microphone system, keeping account of all variable gain settings in the equipment. This procedure establishes a relationship between electrical output and sound pressure level at the microphone. All subsequent electrical outputs can thus be converted to sound pressure levels at the microphone, taking into account the filter response and any changes of gain in the system.

9.4 *Microphone Positions*—For rooms and test signals that conform to this test method, the sound pressure level will be nearly the same at all positions within a restricted space delineated in 9.4.1-9.4.4. Greater variance in measured data will be found at lower frequencies. Nevertheless, variations in the level of the reverberant sound field are still significant and measurements must be made at several positions in each room to sample adequately the sound field. A moving microphone is one convenient way of doing this. The system adopted for the measurement of average sound pressure levels must produce results that meet the requirements of Annex A2. For all microphone systems, microphones must be located according to the following restrictions:

9.4.1 The shortest distance from any microphone position to any major extended surface shall be greater than 1 m. The same limit applies relative to any fixed diffuser surface (excluding edges) and relative to any possible position of a rotating or moving diffuser.

9.4.2 For this test method, stationary microphone positions shall be at least 1.5 m apart. Rotating microphones shall trace a circle at least 1.2 m in radius. —Calibrate each microphone over the whole range of test frequencies as often as necessary to ensure the required accuracy (see ANSI S1.10). A record shall be kept of the calibration data and the dates of calibration.

9.3.1 Calibration checks of the entire measurement system for at least one frequency shall be made at least once during each day of testing. Make the calibration check of the measurement system using an acoustic calibrator that generates a known sound pressure level at the microphone diaphragm and at a known frequency. The class of Calibrator shall be class 1 per ANSI S1.40 or IEC 60942.

9.4 *Bandwidth*—The overall frequency response of the filters used to analyze the microphone signals shall, for each test band, conform to the specifications in ANSI S1.11 for a one-third octave band filter set, class 1 or better.

9.4.1 If filtering is applied to the source signals to concentrate the available power in one test band or a few bands, the frequency range of the signal shall always be greater than the frequency range of the microphone filter.

9.5 *Standard Test Frequencies*—Measurements shall be made in all one-third-octave bands with mid-band frequencies specified in ANSI S1.11 from 100 to 5000 Hz. For sound transmission loss measurements on building facades, exterior doors or windows, or other building facade elements where the outdoor-indoor transmission class is to be calculated, the minimum frequency range shall be from 80 to 5000 Hz.

NOTE ~~7—If estimates of the confidence interval of average sound pressure level are to be reliable, microphone positions should be sufficiently far apart to provide independent samples of the sound field. For fixed microphones, this requires that they be spaced at least half a wavelength apart (**4**). For a moving microphone see Annex A2.~~

~~9.4.3 In the source room, no microphone shall be so close to any source as to be affected significantly by its direct field (see 8.5~~ 9—It is desirable in any case that the frequency range be extended to include bauds below 125 Hz. Many applications require information on low frequency transmission loss and laboratory operators are encouraged to collect and report information down to at least 50 Hz where feasible. Note that larger room volumes are recommended when measuring at lower frequencies (see X1.2).

~~9.4.4 In the receiving room, microphones shall be more than 1.5 m from the test partition. This is to reduce the influence of the direct field of the specimen.~~

~~9.5 *Number of Stationary Microphone Positions or Size of Microphone Traverse*—Procedures for determining an acceptable number of microphone positions or the size of a microphone traverse are described in detail in~~

10. Measurement of Average Sound Pressure Levels and Room Sound Absorption

10.1 The microphone system used to obtain the average sound pressure level must satisfy the requirements given in Annex A2.

~~10. Frequency Range and Bandwidth for Analysis~~

~~10.1 *Bandwidth*—For each test band, the overall frequency response of the electrical system, including the filter or filters in the source or microphone systems, shall satisfy the specifications given in ANSI Specification S1.11 for a one-third octave band filter set, Order 3 or higher, Type 1.~~

~~10.1.1 Filtering may be done either in the source or measurement system or partly in both, if the required overall characteristic is achieved. Besides defining the one-third-octave bandwidth of test signals, filters in the microphone system reduce extraneous noise lying outside the test bands, including possible distortion in the source system; a filter in the source system serves to concentrate the available power in one test band or a few bands.~~

~~10.2 *Standard Test Frequencies*—Measurements shall be made in all one-third-octave bands with mid-band frequencies specified in ANSI S1.6 from 100 to 5000 Hz. For sound transmission loss measurements on building facades, exterior doors or windows, or other building facade elements where the outdoor-indoor transmission class is to be calculated, the minimum frequency range shall be from 80 to 5000 Hz. It is desirable in any case that the frequency range be extended to include bands below 125 Hz. Many applications require information on low frequency transmission loss and laboratory operators are encouraged to collect and report information down to at least 63 Hz where feasible. Note that larger room volumes are recommended when measuring at lower frequencies (see section X2.4).~~

~~11. Procedure~~

~~11.1 *Measurement of Average Sound Pressure Levels,* $<L_1>$ *and* $<L_2>$—With the sound sources generating the sound field in the source room, and microphone positions in accordance with 9.3.1, measure the space- and time-averaged sound pressure level in the source room, $<L_1>$, and the receiving room, $<L_2>$ using averaging times as follows:~~

~~11.2 *Averaging Time, Stationary Microphones*—For each sampling position, the averaging time shall be sufficient to yield an estimate of the time-averaged level to within ±0.5 dB. This requires longer averaging times at low frequencies than at high. For 95 % confidence limits of $\pm e$ dB in a one-third octave band with mid-band frequency, f, the integration time, T, may be estimated from:~~

$$T = \frac{310}{fe^2} \quad (7)$$

~~Thus at 125 Hz, the minimum averaging time for confidence limits of ± 0.5 dB should be 9.9 s. At 100 Hz, an averaging time of 12.4 s is needed. For more information see Ref (**5**)~~

10.2 *Measurement of Average Sound Pressure Levels,* L_S *and* L_R—With the sound sources generating the sound field in one room, the source room, measure the space- and time-averaged sound pressure level in the source room, L_S, and in the receiving room, L_R .

~~11.2.1 If a moving or rotating diffuser is used, determine the average sound pressure level at each microphone position during~~

an integral number of diffuser cycles. Alternatively, average over a time so long that contributions from fractions of a diffuser cycle are negligible.

11.2.2 *Averaging Time, Moving Microphones*— The averaging time for a moving microphone should be long enough that differences between repeat measurements are negligibly small. A typical averaging time around the traverse is 60 s but operators should determine acceptable times by experiment.

11.2.2.1 Note that if both moving microphones and moving vanes are used, their periods of rotation and displacement and the averaging time should be chosen so each observation adequately samples all the possible combinations of microphone and vane positions.

11.3

10.3 *Background Noise in the Receiving Room and Associated Measurement System* —With the sound sources not operating, measure the background noise levels in the receiving room for each frequency band at the same microphone positions used to measure $<L_2>$. Make these measurements using the same microphone and analyser gain settings as used for measurements of the received level. This accounts properly for residual noise and the dynamic range in instrumentation. At each measurement position corrections must be made unless the background level is more than 10dB below the combination of signal and background. (The signal is the sound pressure level due to the transmission through the test specimen.) If the background level is between 5 an 10 dB below the combined level, correct the signal level. At each measurement position corrections must be made unless the background level is more than 10 dB below the combination of signal and background. (The signal is the sound pressure level due to transmission through the test specimen.) If the background level is between 5 and 10 dB below the combined level, correct the signal level using:

(8) —*With the sound sources not operating, measure the background noise levels in the receiving room for each frequency band at the sa*

$$L_a = 10 \log[10^{L_{sb}/10} - 10^{L_b} \tag{4}$$

(8) —*With the sound sources not operating, measure the background noise levels in the receiving room for each frequency band at the same microphone positio*

$$L_a = 10 \log[10^{L_{sb}/10} - 10^{L_b} \tag{4}$$

/10

L a

where:

L_b = background noise level, dB,
L_{sb} = level of signal and background combined, dB, and
$L_{s}a$ = adjusted signal level, dB.

10.3.1 If the output of the sound sources cannot be increased so the combined level is at least 5 dB above the background level, then subtract 2 dB from the combined level and use this as the corrected signal level. In this case, the measurements can be used only to provide an estimate of the lower limit of the sound transmission loss. Identify such measurements in the test report.

NOTE 8—When the background noise measurements described in 11.3 give values higher than the typical background noise measured in accordance with X1.4.1.9 in the Appendix, it is an indication that the transmission loss measurement are limited by the residual noise and dynamic range of the instrumentation rather than the background noise in the receiving room due to acoustic sources in the test laboratory.

11.3.1If the output of the sound sources cannot be increased so the combined level is at least 5 dB above the background level, then subtract 2 dB from the combined level and use this as the corrected signal level. In this case, the measurements can be used only to provide an estimate of the lower limit of the sound transmission loss. Identify such measurements in the test report.

NOTE 9—Noise measured by the microphone system in the receiving room when the sound sources are not operating may be due to extraneous acoustical sources or to electrical noise in the receiving system, or both.

11.4*Determination of Receiving Room Absorption, A_2*—Measure the mean value of the receiving room absorption at each frequency in accordance with Test Method E2235. level in the room. The determination of A_2 shall be made with the receiving room in the same condition as for the measurement of $< L_1>$ and $<L_2>$ (see 11.1). Specifically, the test specimen shall remain in place so its effective absorption (which includes transmission back to the source room) is included. Sound sources used for measuring A_2 shall be present during the measurement of $< L_2>$, so their absorption is present during both measurements.

11.4.1The speed of sound changes with temperature and it shall be calculated for the conditions existing at the time of test from the equation:

$$c = 20.047 \sqrt{273.15 + t} \text{ m/s} \tag{9}$$

where:

t = receiving room temperature, °C.

11.4.2 *10—Noise measured by the microphone system in the receiving room when the sound sources are not operating may be due to extraneous acoustical sources or to electrical noise in the receiving system, or both.*

10.4 *Determination of Receiving Room Absorption, A_R*—Measure the mean value of the receiving room absorption at each frequency in accordance with Test Method E 2235. The determination of A_R shall be made with the receiving room in the same condition as for the measurement of L_S and L_R. Specifically, the test specimen shall remain in place so its effective absorption