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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 E90; 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 U.S. 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 E336), the laboratory measurement of impact sound transmission through floors (Test Method E492), the measurement of impact sound transmission in buildings (Test Method E1007), the measurement of sound transmission through building facades and facade elements (Guide E966), the measurement of sound transmission through a common plenum between two rooms (Test Method E1414), a quick method for the determination of airborne sound isolation in multiunit buildings (Practice E597), and the measurement of sound transmission through door panels and systems (Test Method E1425).

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 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:*[2]

C423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method
C634 Terminology Relating to Building and Environmental Acoustics
E336 Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings
E413 Classification for Rating Sound Insulation
E492 Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine
E966 Guide for Field Measurements of Airborne Sound Attenuation of Building Facades and Facade Elements
E1007 Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures
E1111 Test Method for Measuring the Interzone Attenuation of Open Office Components
E1289 Specification for Reference Specimen for Sound Transmission Loss
E1332 Classification for Rating Outdoor-Indoor Sound Attenuation

[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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[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.

E1414 Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum
E1425 Practice for Determining the Acoustical Performance of Windows, Doors, Skylight, and Glazed Wall Systems
E2235 Test Method for Determination of Decay Rates for Use in Sound Insulation Test Methods

2.2 *ANSI Standards:*
S1.6-1984 (R2006) American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurement[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]
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:*
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 C634.

acoustical barrier	reverberation room
airborne sound	sound absorption
average sound pressure level	sound attenuation
background noise	sound energy
damp	sound insulation
decay rate	sound isolation
decibel	sound level
diffraction	sound power
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 5).

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

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

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

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

$$\tau = 10^{-TL/10} \quad (2)$$

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. 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 11. Because transmission loss is a function of frequency, measurements are made in a series of frequency bands.

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 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 E1425.

5. Significance and Use

5.1 Sound transmission loss as defined in Terminology C634, 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.

5.2 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 E336.

NOTE 2—The comparable quantity measured using Test Method E336 is called the apparent sound transmission loss because of the presence of flanking sound transmission.

6. Test Rooms

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 are satisfied at all frequencies.

6.3 *Volume of Rooms*—The minimum volume of each room is 80 m^3.

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

6.4 *Room Absorption*—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:

$$A = V^{2/3}/3 \tag{3}$$

where:

V = the room volume, m^3, and
A = the sound absorption of the room, m^2.

6.4.1 For frequencies below $f = 2000/ V^{1/3}$, 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.

NOTE 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.

NOTE 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.

NOTE 6—Procedures for calculating air absorption are described in Test Method C423.

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 given in Annex A1.

7.2 *Office Screens*—The minimum area of an office screen specimen shall be 2.3 m^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 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 E1111 is recommended.

7.3 *Operable Door Systems*—Measurements may be in accordance with Test Method E1425 to 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 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 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 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.

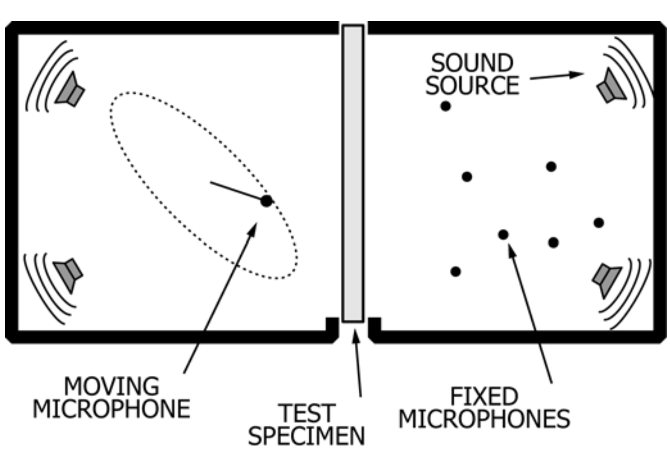
9. Instrumentation Requirements

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 spatial and temporal variations of sound pressure level.

9.2 *Microphone Electrical Requirements*—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.

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.



NOTE 1—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 loudspeakers in the rooms generate the incident sound fields for the measurement of level differences or sound decay rates.

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

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 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).

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.

10.2 *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.

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_R. Make these measurements using the same microphone and analyzer 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 shall 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:

$$L_a = 10\log\left[10^{L_{sb}/10} - 10^{L_b/10}\right] \quad (4)$$

where:

L_b = background noise level, dB,
L_{sb} = level of signal and background combined, dB, and
L_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 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 E2235. 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 (which includes transmission back to the source room) is included. Sound sources used for measuring A_R shall be present during the measurement of L_R, so their absorption is present during both measurements.

10.4.1 *Room Coupling*—Because the two test rooms are coupled by the test specimen, it is possible that the decay rate measurements in the receiving room will be influenced by sound energy transmitted into the source room and then back again during the decay process (**1**).[5] Decay curves may be markedly curved or have two pronounced slopes. To ensure the effect will be small the product τS must be smaller than A_S, the absorption in the source room, or A_R, the absorption in the receiving room, or d_S/d_R, the ratio of decay rates in the two rooms, must be larger than unity. The latter requirement may be met by adding absorption to the source room until no further effect is observed on the measured value of d_R.

NOTE 11—Additional absorption in the source room is required only during measurement of receiving room absorption. It shall not be present during measurement of L_S and L_R.

10.5 For estimates of the direction-averaged transmission loss it is necessary to repeat all measurements with the second room acting as the source. This results in four sets of average sound pressure levels and two sets of room absorptions corresponding to the two directions of sound transmission.

11. Calculation

11.1 For the chosen test directions), calculate the sound transmission loss at each frequency f from:

$$TL(f) = L_S(f) - L_R(f) + 10 \ \log S/A_R(f) \tag{5}$$

where:

$TL(f)$ = transmission loss, dB,
$L_S(f)$ = average sound pressure level in the source room, dB,
$L_R(f)$ = average sound pressure level in the receiving room, dB,
S = area of test specimen that is exposed in the receiving room, m^2, and
$A_R(f)$ = sound absorption of the receiving room with the test specimen in place, m^2 (**1**).

11.2 When measurements are made in both directions, the final value of transmission loss to be reported shall be calculated using:

$$TL(f) = (TL_1(f) + TL_2(f))/2 \tag{6}$$

where $TL_1(f)$ and $TL_2(f)$ correspond to the two directions of measurement.

[5] The boldface numbers in parentheses refer to the list of references at the end of this standard.

11.2.1 If $TL_1(f)$ or $TL_2(f)$ is invalid (for example, because of excessive background noise) then the remaining valid measurement shall be used for $TL(f)$. Identify in the test report transmission loss values that are not averaged as required in 11.2.

11.3 If a laboratory chooses to use only one direction of measurement, then no averaging is required.

11.4 This test method specifies the use of one-third octave bands for measurement and calculation of sound transmission loss. It does not allow measurement of octave band transmission losses because these are very sensitive to the shape of the spectrum in the source room and to the details of the transmission loss characteristics of the test panel. In applications where octave band transmission loss values, TL_{oct}, are required, they shall be calculated using the expression:

$$TL_{oct,f_c} = -10\log\left[\frac{1}{3}\sum_{B=B_c-1}^{B_c+1} 10^{-TL_B/10}\right] \tag{7}$$

where:

f_c = preferred octave band mid-band frequency as specified in ANSI S1.6.

11.4.1 The summation is made over three one-third octave band TL values: one at the frequency f_c with band number B_c and the adjacent one-third octave bands, with band numbers $B_c + 1$ and $B_c - 1$. The octave band transmission loss values calculated from this expression approximate what would be measured if the spectrum in the source room had the same sound pressure level in each one-third octave band.

12. Report

12.1 Include the following information in the test report:

12.1.1 A statement, if true in every respect, that the tests were conducted according to this test method and that detailed test procedures, data for flanking limit tests, repeatability measurements and reference specimen tests are available on request.

12.1.2 A description of the test specimen in accordance with the requirements in Annex A1. The description must be sufficiently detailed to identify the specimen, at least for those elements that may affect its sound transmission loss, unless the test sponsor wishes to withhold information of a proprietary nature. A designation and description furnished by the sponsor of the test may be included in the report provided that they are attributed to the sponsor. If some details of the specimen construction are withheld at the sponsor's request, the report shall state this.

12.1.3 The dates of construction and testing.

12.1.4 If the test specimen is a screen, include a statement, if true, that sound transmission through raceways and other penetrations are included in the evaluation.

12.1.5 State clearly whether the transmission loss values are for a single direction of measurement or are averages of two directions.

12.1.6 A table of sound transmission loss values rounded to the nearest decibel for the frequency bands required in 9.5 and any other bands measured. These data may also be presented as a graph.

12.1.7 Identify data affected by flanking transmission (Annex A5) or background noise.

12.1.8 The temperature and humidity in the rooms during the measurements.

12.1.9 The volumes of the source and receiving rooms.

12.1.10 *Single Number Ratings:*

12.1.10.1 *Sound Transmission Class*—If single number ratings are given, the sound transmission class described in Classification E413 shall be included.

NOTE 12—The weighted airborne sound reduction indexes described in ISO 717 have a similar purpose to STC. These may also be given.

12.1.10.2 *Outdoor-Indoor Transmission Class*—Where the test specimen maybe used as part of a facade of a building, the Outdoor-Indoor transmission class shall be included. This single number rating is intended to rate the effectiveness of building facade elements at reducing transportation noise intrusion. The rating is described in Classification E1332.

13. Precision and Bias

13.1 *Precision*—Measurements at one laboratory show that the repeatability standard deviation for complete rebuilds of wood joist floor ranged from about 1.5 to 3.5 dB in the frequency range 125 to 4 kHz. This repeatability includes normal variations in materials but minimal changes in construction techniques. The repeatability standard deviation for re-installation of a concrete slab was about 4.5 dB at 100 Hz and below, about 3 dB from 125 to 630 Hz, and about 1.5 dB above 630 Hz. Repeatability for this test method depends on the specimen type and not enough data have been collected to allow more specific statements. From round robin testing on copies of the reference specimen described in Specification E1289, it has been determined that the reproducibility standard deviation is 2 dB or less at all frequencies from 125 to 4000 Hz. Further information can be found in reference (**2**).

13.2 *Bias*—There is no bias in this test method since the true value is defined by the test method.

14. Keywords

14.1 airborne sound transmission loss; flanking transmission; sound transmission coefficient; sound transmission loss; transmission loss

ANNEXES

(Mandatory Information)

A1. PREPARATION AND DESCRIPTION OF TEST SPECIMENS

A1.1 *Scope*:

A1.1.1 This annex gives requirements for the preparation, installation and aging of test specimens and the description of the specimen and materials in the test report. The various types of assemblies and materials are categorized and dealt with in separate sections.

A1.1.2 The intent of fully describing the test specimen is that, given only the test report, some other laboratory would be able to construct a specimen that would be practically identical.

NOTE A1.1—The use of sketches and photographs to clarify descriptions of specimens is highly recommended.

A1.2 *Construction*:

A1.2.1 The test specimen may either be built into a suitable frame, which is then inserted in the test opening, or built into the opening itself. Specimens shall be built in accordance with usual construction practice except that extra control procedures may be necessary to ensure maintenance of the specified dimensions. The type of installation and the steps in constructing the specimen (for example, plastering techniques) shall be reported in detail.

A1.2.2 A description of the method of installation of the specimen in the test opening, including the location of framing members relative to the edges, and the treatment of the junction with the test opening shall be given in the test report. The use and type of caulking, gaskets, tape, or other sealant on perimeter or interior joints shall be carefully described.

A1.2.3 The specimen size, including thickness, and the average mass per unit area shall always be reported.

A1.2.4 The curing period, if any, and the condition of the specimen as tested (shrinkage, cracks, etc.) shall be reported.

A1.2.5 *Composite Construction*—If a test specimen includes more than one type of building material, the requirements for each type shall be satisfied. For example, for a concrete block wall or a concrete floor slab to which plaster is applied, the requirements for masonry and plaster must be satisfied.

A1.3 *Aging of Specimens*:

A1.3.1 *Aging*—Unless otherwise noted below, all aging shall be at a room temperature from 18 to 24°C and a relative humidity from 40 to 70 %.

A1.3.2 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. Aging periods for certain common materials are specified in this annex. Manufacturers may supply information about curing times for their products.

A1.3.3 In the case of a specimen incorporating one or more materials whose aging characteristics are not known, repeated tests shall be made to determine when the specimen has stabilized. These repeated tests should be made every few days until for three consecutive tests the change in the one-third octave band sound pressure levels at each test frequency is within the repeatability limits for the laboratory for repeat testing of undisturbed specimens. When only one material with unknown aging characteristics is part of a specimen, the aging period determined in this way may be used in future tests. Test data to support such aging information shall be kept on file in the laboratory.

A1.4 *Concrete and Masonry*:

A1.4.1 *Concrete*—Report the type, thickness, and density of the concrete. In the case of poured reinforced concrete floors, the dimensions and the average weight per square meter of the floor slab shall be reported. If reinforcing rods or wire mesh are used, the dimensions, spacing, gauge and mesh size of these materials shall be reported. In the case of precast or preformed solid concrete slabs or hollow-masonry panel structures, it is recommended that the test specimen include two or more complete slabs or panel units.

A1.4.2 *Concrete or Other Poured Floor Toppings*—Concrete or gypsum concrete is often poured onto a steel pan or a plywood subfloor. For such cases, report the average thickness and the average weight per square meter of the slab. Give all relevant dimensions if the supporting layer is not plane.

A1.4.3 *Masonry*—Report the materials, dimensions, and average weight of an individual masonry unit. Report the thickness of mortar and describe the materials used in its preparation. Determine the mass per unit area of completed concrete or masonry specimens by weighing a representative portion after test or by weighing a small specimen prepared during construction in the same way as the main specimen.

A1.4.4 *Aging*—Unless a shorter aging period has been established by following the procedures of A1.3.3, concrete or masonry specimens shall be allowed to age a minimum of 28 days before testing.

A1.5 *Studs, Joists, Trusses, Wood or Metal Furring and Beam-like Elements*:

A1.5.1 *Wood Studs, Joists, and Furring*—State true as well as nominal dimensions, spacing in test opening, fastening conditions, and mass per unit length.

A1.5.2 *Studs or Furring Formed from Sheet Material*—Report the manufacturer and material. Report the dimensions, including the thickness or gauge, the spacing in test opening, fastening conditions, and mass per unit length.

A1.5.3 *Steel Joists or Wood Trusses*—Report the manufacturer and materials. Report the dimensions, spacing in the test opening, fastening conditions, and mass per unit length.

A1.5.4 *Metal Channels, Furring Strips, Nailing Channels, etc.*—Report the type of material, true dimensions, spacing and orientation with respect to other floor elements, end-fastening conditions, and mass per unit length.

NOTE A1.2—For such elements, sketches or photographs can be most effective.

A1.6 *Sound Absorbing Materials*:

A1.6.1 Report the material, density, thickness, location, and method of installation.

A1.7 *Plaster*:

A1.7.1 *Plaster*—Report the thickness of each layer, the materials used, and the method of application. The actual thickness of plaster layers shall be determined, for example, by inspection of representative sections after test. Report the weight per unit area.

A1.7.2 *Lathing*—Report the dimensions of individual sections and orientation in the test specimen, mass per unit area of wall, number and location of fasteners (see Note A1.2), and treatment of edges of specimen.

A1.7.3 *Aging of Plaster*—Thick coats (greater than ⅛ in.) of gypsum plaster shall age at least 28 days before testing; superficial coats (⅛ in. thick or less) shall age at least 3 days.

NOTE A1.3—Resilient fasteners can be short-circuited by plaster that oozes through the lath. If something is done to prevent this or to break the short-circuits, it should be reported.

A1.8 *Board Materials*:

A1.8.1 Report the number of layers, and for each the material, thickness, dimensions of panels, mass per unit area and end, treatment of joints and edge, and field fastening conditions.

A1.8.2 *Aging of Gypsum Wallboard*—If gypsum wallboard joints and edges are finished with typical joint caulking and finishing compounds, the minimum aging period shall be 12 h.

A1.8.3 *Laminating Adhesives*—Report the type of adhesive, method of application, and thickness.

A1.8.3.1 If laminating adhesives are used, before testing the specimen shall age a minimum of 14 days for water-based adhesives and 3 days for other adhesives.

A1.9 *Subfloor and Other Sheet Materials*:

A1.9.1 *Sheet Materials*—Report the material and orientation in test specimen, the thickness and weight per square meter for each layer, the number of layers, treatment of joints, and the spacing and type of fasteners.

A1.9.2 *Resilient Sheet Underlayments*—Report type of material, thickness, weight per square meter, and method of fastening.

A1.10 *Floor-Surfacing Materials*:

A1.10.1 The installation of floor-surfacing materials shall be in accordance with manufacturer's instruction, especially in regard to cleaning and priming of the subfloor.

A1.10.2 Report the composition of individual floor-surfacing layers and orientation in the test specimen. Report the thickness and weight per square meter of each layer, number of layers, treatment of joints, spacing and type of fasteners.

A1.10.3 *Aging*—It is recommended that flooring materials, including underlayments and adhesives, be stored in an environment similar to that of the upper room of the test suite for at least 72 h before installation, preferably with bundles or cartons broken open. A temperature of 15 to 25°C and a relative humidity of 30 to 60 % are recommended. This procedure is recommended for installation of any flooring material whether by nailing or adhesive techniques. Although most floors are ready for immediate use after being installed if no adhesives are used, if floor surfaces are finished with a quick drying sealer and finishing compounds, the minimum aging period shall be 12 h.

A1.11 *Sealants and Adhesives* :

A1.11.1 Adhesives and materials used to caulk or seal gaps and fissures around the periphery of a specimen shall be listed by brand name and type. Methods of application and approximate dimensions shall be reported.

A1.11.2 *Aging*—If adhesives are used to apply wood block or tile flooring materials to the floor surface, the specimen shall age for a minimum of 24 h. If significant quantities of caulking or adhesive materials are required and no recommended aging period is given, appropriate procedures to determine the necessary aging period shall be used (see A1.3.3).

A1.12 *Fasteners*:

A1.12.1 Where screws, nails, or other fasteners are used, report their type, dimensions, and method of installation. Report also the spacing between fasteners around the periphery and in the field of the specimen.

A1.13 *Other Elements*:

A1.13.1 For all other elements not covered by the above, report as much information as will allow a clear understanding of how the specimen was constructed. Report information such as dimensions, density, spacing between elements and any other significant details.

A1.14 *Demountable Modular Wall Panel Systems*:

A1.14.1 *Materials and Construction*—The testing laboratory shall report as much physical information as can be determined about the materials and method of assembly of all components of the partition including weights and dimensions of the component parts and the average mass per unit area of the completed partition.

A1.14.2 *Installation*—Installation of the test specimen shall be carried out or observed by the testing laboratory and reported in detail.

A1.15 *Operable (Folding or Sliding) Walls*:

A1.15.1 *Materials and Construction*—Report as much physical information as can be determined about the materials and method of assembly of all components of the partition including weights and dimensions of the component parts and the average mass per unit area of the completed partition. If the specimen consists of an assembly of panels, the number and dimensions of panels shall be reported. If the specimen is an accordion-type partition, the number of volutes, their spacing, and width when extended, shall be reported. Header construction and dimensions shall be reported. Weights of header and the hanging portion of the door shall be reported. Latching and sealing devices shall be fully described.

A1.15.2 *Installation*—Installation of the test specimen shall be carried out or observed by the testing laboratory and reported in detail. Clearances at the perimeter between non-deformable portions of door and frame shall be measured and reported. In particular, any features of the installation that require dimensional control closer than 6 mm on the height or width or the test specimen shall be reported.

A1.15.3 *Operation*—The specimen shall not be designated an operable wall unless it opens and closes in a normal manner. It shall be fully opened and closed at least five times after installation is completed and tested without further adjustments.

A1.15.4 The specimen area shall include the header and other framing elements if these constitute a portion of the separating partition in a typical installation.

A1.16 *Doors*—Procedures that may be followed when testing doors are given in Test Method E1425. The specimen shall not be designated a door unless it opens and closes in a normal manner. The report shall state whether it had been operated just prior to test.

A1.17 *Windows*—Window specimens intended to be operable shall open and close in a normal manner. They shall be fully opened and closed at least five times after installation is completed and tested without further adjustments. The report shall state whether the window is operable or fixed and whether it had been operated just prior to test.

A2. QUALIFICATION OF ROOM SOUND FIELDS AND MICROPHONE SYSTEMS USED FOR SAMPLING

A2.1 *Scope*:

A2.1.1 This annex prescribes procedures for establishing a standard measurement protocol for obtaining the average sound pressure levels in a reverberation room with confidence intervals small enough for the purposes of this test method.

A2.1.2 One principle underlying this test method is that the reverberant sound fields in the rooms show only small variations with position in the room. In practice, variations in the level of the reverberant sound field are still significant, especially in the lower frequency bands, and measurements of sound pressure level and sound decay rate must be made at several positions in each room to sample adequately the sound field.

A2.1.3 Two methods are commonly used for sampling sound fields in reverberation rooms: stationary microphones or moving microphones (usually mounted on a rotating boom). This annex deals with both types.

A2.2 *Microphone Positions*—For all microphone systems, microphones must be located according to the following restrictions:

A2.2.1 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.

A2.2.2 Stationary microphone positions shall be at least 1.5 m apart.

NOTE A2.1—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 (**3**). For a moving microphone see Annex A2.

A2.2.3 In the source room, microphones shall be more than 2 m from any source.

A2.2.4 In the receiving room, microphones shall be more than 1.5 m from the test partition. No two microphone positions shall have the same height above the floor of the room. Heights shall be varied so as to sample as much of the room volume as possible

A2.3 *Averaging Time, Stationary Microphones*—For each microphone position, the averaging time shall be sufficient to yield an estimate of the time-averaged level to within ±0.5 dB at each frequency. 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, is given by:

$$T = \frac{310}{fe^2} \quad \text{(A2.1)}$$

Thus at 125 Hz, the minimum averaging time for confidence limits of ±0.5 dB is 9.9 s. At 100 Hz, a minimum averaging time of 12.4 s is required. For more information, see Ref (**4**).

A2.3.1 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.

A2.3.2 The plane of a moving microphone shall not be parallel to any room surface. The plane shall be tilted so as to sample as much of the room volume as possible.

A2.4 *Averaging Time, Moving Microphones*—Using a moving microphone means that the time-and space-averaged sound pressure level is obtained automatically from the analyzer. The averaging time for a moving microphone shall be long enough that differences between repeat measurements are negligibly small. A typical averaging time around the traverse is 60 s but operators shall determine acceptable times by experiment.

A2.5 *Measurement Procedures and Calculations*:

A2.5.1 The confidence interval of a sound transmission loss determination is derived from the confidence intervals for the individual acoustical quantities in Eq 5, namely, L_S, L_R, and A_R. (The uncertainty of the measurement of area S is taken to be zero.) The following paragraphs describe the steps to be taken to collect the data and calculate the confidence intervals for the measurement.

A2.5.2 Install a specimen with a sound transmission class rating in the 25–50 range. Sound levels in the receiving room shall be at least 10 dB above background noise in the room at all frequencies. A suitable specimen is described in Specification E1289.

A2.5.3 In each room select at least six positions that satisfy the requirements in A2.2. Observing the procedural requirements in the main body of the test method, make the following measurements, for all required frequencies, preferably using a reference transmission loss specimen:

A2.5.4 At each position in the source room, measure the average sound pressure levels using a stationary microphone.

A2.5.5 At each position in the receiving room, measure the average sound pressure levels due to transmission through the specimen and average decay rates in the room using a stationary microphone.

A2.5.6 For each frequency band calculate the space-averaged level for each room using:

$$\bar{L} = 10\log\left[\frac{1}{n}\sum_{i=1}^{n} 10^{L_i/10}\right] \quad \text{(A2.2)}$$

where:

L_i = the time-averaged level taken at location i, and
n = the number of microphone positions.

NOTE A2.2—The convention used in this test method is that if X is the symbol for a physical quantity, log X denotes the common logarithm of the numerical value of the quantity.

A2.5.7 Calculate the standard deviation for sound pressure level and sound absorption in each room from the expression:

$$s(f) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left[X_i(f) - \overline{X(f)}\right]^2} \quad \text{(A2.3)}$$

TABLE A2.1 Factors for 95 % Confidence Limits for Averages

Number of Measurements, *n*	Factor *a* for Confidence Limits,[A] *X* ± *as*
4	1.591
5	1.241
6	1.050
7	0.925
8	0.836
9	0.769
10	0.715
11	0.672
12	0.635

[A] Limits that may be expected to include the "true" average, *X*, 95 times in 100 in a series of problems, each involving a single sample of observations.

where:

$s(f)$ = the standard deviation at frequency f,
$X_i(f)$ = an individual determination of sound pressure level, and
$\overline{X(f)}$ = the arithmetic mean of the set of sound pressure levels.

A2.5.8 If testing of specimens will be conducted in both directions, change the direction of measurement by interchanging the roles of the source and receiving rooms and repeat the procedures in A2.5.4 to A2.5.7.

A2.5.9 Calculate the 95 % confidence interval for the individual quantities from:

$$\Delta X = as \tag{A2.4}$$

where the factor a, which depends on the number of measurements, is given in Table A2.1 and ΔX and s represent the confidence interval and standard deviation of L_S, L_R, and A_R as appropriate.

A2.5.10 Calculate the confidence interval for transmission loss for the direction(s) of measurement from:

$$(\Delta TL)^2 = (\Delta L_S)^2 + (\Delta L_R)^2 + 18.9(\Delta A_R/A_R)^2 \tag{A2.5}$$

If the absorption of the receiving room has been calculated from the average decay rate d, $18.86(\Delta d/d)^2$ may be substituted for the last term of Eq A2.3.

A2.5.11 Calculate the confidence interval for a complete measurement from:

$$\Delta TL_t = \sqrt{(\Delta TL_1)^2 + (\Delta TL_2)^2} \tag{A2.6}$$

A2.6 *Required Confidence Interval for Transmission Loss Measurements*:

A2.6.1 For any pair of rooms and microphone system, the 95 % confidence interval, ΔTL_t, for transmission loss must be no greater than the values given in the following table:

One-third Octave Band Mid-Frequency, Hz	Confidence Interval, ΔTL
80	6
100	4
125, 160	3
200, 250	2
315 to 4000	1

NOTE A2.3—Confidence intervals that can be attained above and below these frequencies will depend strongly on the test suite characteristics.

A2.6.2 If the confidence intervals calculated do not meet the criteria in A2.6, then the measurements must be repeated with a larger number of microphone positions until the criteria are met.

A2.6.3 If the requirements of A2.2 do not allow enough measurement positions to be used in the room and thus reduce the confidence interval, then the rooms do not qualify for measurements according to this standard. Changes to loudspeaker or diffuser arrangements may make the sound fields more uniform.

A2.6.4 If the confidence intervals calculated meet the criteria in A2.6, then the rooms qualify for measurements according to this test method with the set of microphone positions used.

A2.7 *Selection of a Microphone System for Routine Testing*:

A2.7.1 *Fixed Microphone Positions*—From the array of microphone positions used to determine the confidence limits above, select a subset of locations that yield the same average result, within experimental error, and still meet the confidence requirements of A2.6. The minimum number of fixed microphone positions to be used for the measurement of sound pressure level in each room shall be four.

A2.7.2 *Moving Microphones*—Using the standard deviations calculated for the sound pressure levels in the source and receiving rooms, find the hypothetical minimum number of fixed microphone positions necessary in each room for an acceptable confidence interval in the lowest frequency band. (This requires repeating the calculations for the transmission loss confidence interval using the values of standard deviation found for the large array of microphones and trying different values of n and a from Table A2.1 until the confidence limits are satisfied.) If n_{min} is the minimum number of microphones required in the room and λ is the wavelength of sound at the lowest frequency of interest, then the minimum size of traverse for each room is calculated from:

Rotating Microphones:

$$r_{min} = \frac{n_{min}\lambda}{4\pi} \tag{A2.7}$$

where:

r_{min} = minimum radius of the circular path traversed by the microphone.

Linear Traverses:

$$L_{min} = (n_{min} - 1)\lambda/2 \tag{A2.8}$$

where:

L_{min} = minimum length of straight line traverse.

The minimum radius of the circular path for a rotating microphone shall be 1.2 m.

A2.7.3 The confidence intervals found by these procedures must be re-measured at least annually or whenever significant changes are made to room geometry, loudspeakers, or diffusers. The data from which the estimates of confidence intervals were made must be kept on record.

A2.7.4 Calculations of confidence intervals do not have to be made for each test, although laboratories can do so if they wish.

NOTE A2.4—Meeting the requirements of this annex 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 through the use of diffusing panels (see Appendix X1).

A2.8 *Repeatability Tests*:

A2.8.1 The laboratory must determine the repeatability limits for their test procedures as follows:

A2.8.1.1 Using any specimen, conduct at least six complete sets of measurements according to this test method without disturbing the specimen or the room.

A2.8.1.2 At each frequency, calculated the standard deviation of the transmission loss values, s_r using Eq A2.1.

A2.8.1.3 At each frequency, calculate 2.8 s_r. This is the 95 % confidence limit for such repeat tests.

NOTE A2.5—This confidence limit does not relate to the values that would be obtained if the specimen were dismantled and a nominally identical specimen were constructed and tested.

A2.8.2 These repeatability tests need only be re-done when significant changes are made to the measurement procedures.

A3. PROCEDURES FOR DEALING WITH SPECIMENS SMALLER THAN THE TEST OPENING

A3.1 *Scope*:

A3.1.1 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. A3.1). Sound transmission through the composite wall can be represented by:

$$\tau_c S_c = \tau_s S_s + \tau_f S_f \quad \text{(A3.1)}$$

or

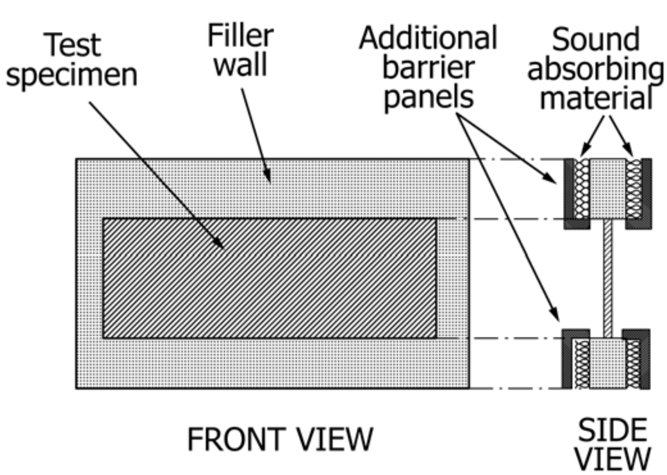
$$\tau_s = (\tau_c S_c - \tau_f S_f)/S_s \quad \text{(A3.2)}$$

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.

NOTE A3.1—The above expressions assume that the two parts of the composite construction react to the sound field independently of each other.

A3.1.2 Two general procedures may be used to deal with this situation:



NOTE 1—This figure is not meant to be a design guide but is for illustrative purposes only. The side view shows the application of additional panels as discussed in A3.3.

FIG. A3.1 Illustration Showing Filler Wall and Test Specimen that is Smaller Than the Test Opening

A3.2 *Build and Measure a Complete Filler Wall*:

A3.2.1 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.

A3.2.2 Following 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.

A3.2.3 Remove 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.

A3.2.4 Following 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.

A3.2.5 At each test frequency calculate the difference: $10 \log(\tau_c S_c) - 10 \log(\tau_f S_f)$.

A3.2.6 If the difference is more than 15 dB, calculate τ_s from Eq A3.2 ignoring the term $\tau_f S_f$.

A3.2.7 If the difference is between 6 and 15 dB, calculate τ_s using Eq A3.2. This corrects for transmission through the filler wall. Note in the test report where such corrections have been made.

A3.2.8 If the difference is less than 6 dB, reliable corrections cannot be made. Calculate τ_s from Eq A3.2 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.

A3.3 *Use Additional Structures to Reduce Transmission*:

A3.3.1 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:

A3.3.2 Measure the sound transmission loss for the composite assembly.

A3.3.3 Cover each face of the filler wall with sound absorbing material at least 50 mm thick. Cover the sound absorbing material with barrier panels weighing at least 8 kg/m^2 that are not rigidly attached to the filler wall (see Fig. A3.1). Normal good practices shall be followed for mounting and sealing.

A3.3.4 Measure the sound transmission loss for the composite assembly.

A3.3.5 If changes are insignificant, it may be assumed that transmission through the filler wall is negligible.

A3.3.6 Other 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.

A3.3.7 When 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.

A3.3.8 When 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.

A4. LABORATORY ACCREDITATION

A4.1 *Scope*:

A4.1.1 This annex describes the information that must be supplied by a laboratory to an accrediting authority and the procedures required to demonstrate compliance with all the provisions of this standard method of test.

A4.1.2 Accrediting authorities are obviously free to add to the set of requirements here. This set comprises a minimum requirement in the opinion of ASTM committee E33.

A4.1.3 The information required from the laboratory needs to be interpreted by a knowledgeable accreditor. It is the responsibility of the accrediting agency to employ such individuals.

A4.2 *Referenced Documents*:

A4.2.1 *ASTM Standards:*[2] C634 Terminology Relating to Environmental Acoustics

E1289 Specification for Reference Specimen for Sound Transmission Loss

ASTM STP 15D Manual for the Presentation of Data and Control Chart Analysis

A4.3 *Laboratory Information* :

A4.3.1 The laboratory shall provide drawings showing the test facilities in plan and elevation. All room linear dimensions and volumes shall be given on these drawings.

A4.3.2 The laboratory shall provide drawings showing the dimensions of the test specimen opening, the method for supporting specimens and how the opening connects to the rest of the test rooms.

A4.3.3 The laboratory shall provide the dimensions and total area (one-side) of any diffusing panels in the rooms.

A4.3.4 The laboratory shall provide a description of any other procedures used to reduce spatial variations in the rooms.

A4.3.5 The laboratory shall provide a description of the system used to ensure that the temperature and relative humidity in the rooms are maintained within the specified limits.

A4.3.6 The laboratory shall provide a copy of the report of measurements made following Annex A2 to qualify the receiving room.

A4.3.7 The laboratory shall provide a copy of the report of measurements made to determine the flanking limit for the facility (Annex A5).

A4.4 *Measurement and Calculation Procedures*:

A4.4.1 The laboratory must describe the means of generating the sound signals used.

A4.4.2 The laboratory shall provide the number of loudspeakers, their type and disposition in the rooms.

A4.4.3 The laboratory must describe the type of analyzer used to measure the sound pressure levels in the room. (Provide copies of the parts of the operator's manual that describe the filter response and the specifications.) Provide a description of any procedures followed to verify that the analyzer meets the specifications of the manufacturer and of this test method. Provide the date of the last calibration or check of the instrument.

A4.4.4 The laboratory shall provide the type of microphone(s) used in the receiving room.

A4.4.5 The laboratory must describe the procedure for determining the average sound pressure level in the receiving room: averaging time, the number of microphone positions and their locations or type of moving microphone (Provide radius of a circular path or length of a linear traverse.)

A4.4.6 The laboratory must describe the procedure for determining the sound absorption in the receiving room.

A4.4.7 The laboratory must provide a detailed description of how the calculations required by the test method are carried out. If a customized program makes calculations during routine testing, evidence must be presented that the calculations are correct. This evidence might, for example, be a spreadsheet making the same calculations and giving the same answers as the customized software.

NOTE A4.1—To facilitate checking of calculations, it is useful to have custom software save all measured data and calculated values to files.

A4.5 *Test Specimens*:

A4.5.1 The laboratory must provide descriptions of procedures for aging test specimens.

A4.5.2 The laboratory must provide descriptions of procedures for installing the types of specimens typically tested in the laboratory: for example, joist floors, concrete slabs etc.

A4.6 *Test Procedures*:

A4.6.1 The laboratory must provide a copy of the work instructions followed by the technician running the test.

A4.6.2 *Quality Control*—The laboratory must describe the responsibilities of those members of the staff involved in the measurement and approval steps of routine testing.

A4.6.3 *Test Reports*—The accreditor will select several past tests run by the laboratory and ask to see the records of all physical measurements made on the test specimen and the materials comprising it, and the final test reports for these tests.

A4.6.4 *Repeatability*—To decide when changes in transmission loss values are significant, laboratories must measure their repeatability standard deviation as follows.

A4.6.4.1 With any specimen in place, measure the transmission losses at least six times without disturbing the specimen in any way.

A4.6.5 The laboratory must provide a copy of the data obtained during repeatability testing (A2.8).

A4.7 *Reference Specimen*:

A4.7.1 To be accredited, laboratories must obtain and test routinely a copy of the reference specimen described in Specification E1289. Additional reference specimens may also be useful.

A4.7.2 Significant departures from the mean values given in Specification E1289 should be investigated thoroughly. After necessary physical adjustments to the rooms and changes in test procedures, laboratories should be able to demonstrate that their results for the reference specimen are not significantly different from those reported in Specification E1289. Arithmetic corrections to measured data to obtain closer agreement with the data in Specification E1289 must not be made.

A4.7.3 The reference test specimen should be tested at least annually. It must be removed and reinstalled between tests. It must have been installed and tested within the 12 months prior to any test using this test method.

A4.7.4 When a new reference specimen is introduced in a laboratory, a set of test records for that specimen needs to be established quickly for use by accreditors as well as the laboratory staff. Initially, the reference specimen shall be tested at intervals of about 6 months or less until 5 sets of data have been obtained. Thereafter, annual testing will suffice. Laboratories are always free to check reference specimens more frequently.

A4.7.5 Data resulting from repeated tests made on the reference specimen shall be analyzed by the control chart method described in Part 3 of ASTM STP 15D (**5**). The analysis shall be according to the subsection entitled "Control—No Standard Given".

A4.7.6 All records of the tests and the statistical analysis of the results for the reference test specimen shall be made available to the accrediting authority.

A5. INVESTIGATION OF LABORATORY FLANKING LIMITS

A5.1 The test rooms should be constructed and arranged to minimize the possibility of transmission by paths other than that through the test partition. If the specimen is rigidly connected to the source-room structure, in addition to the incident airborne sound, sound power can 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 can flow from the specimen to the walls of the receiving room and be radiated from them. 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.

A5.2 The limit on specimen transmission loss measurement due to flanking transmission must be investigated as follows:

A5.3 In the test opening, build a partition expected to have high transmission loss.

A5.4 Measure the transmission losses following this test method.

A5.5 Increase 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.

A5.6 Measure the transmission loss again.

A5.7 Repeat steps A5.5 and A5.6 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.

A5.7.1 The sound power transmission along a particular suspected flanking path may be decreased by temporarily adding shielding structures in front of the surfaces that are suspected of radiating unwanted sound. If the measured transmission loss increases, permanent changes to the facility might be considered worthwhile.

A5.8 A potential flanking path is through the perimeter of the partition or the mounting frame (**6**). 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.

A5.9 An 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 can be checked 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.

A5.10 Laboratories must prepare a report showing the data collected to establish the flanking limit of their facilities.

A5.11 When 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.

APPENDIX

(Nonmandatory Information)

X1. RECOMMENDATIONS FOR NEW CONSTRUCTIONS

X1.1 The following paragraphs are intended as guidance for those designing new facilities to satisfy the requirements of this test method.

X1.2 For meaningful measurements at low frequencies, large room volumes are considered necessary to ensure acceptably uniform sound fields. For example, for measurements down to 125 Hz, a minimum room volume of 80 m^3 is recommended. For measurements down to 100 Hz, a minimum room volume of 125 m^3 is recommended. For measurements down to 80 Hz, a minimum room volume of 180 m^3 is recommended. For new construction, room volumes of at least 200 m^3 are recommended to allow more reliable measurements at low frequencies.

NOTE X1.1—The minimum preferred room volume of 80 m^3 at 125 Hz is derived by assuming that a minimum of approximately 18 modes in the 125 Hz one-third octave band will ensure a satisfactorily diffuse sound field in the room. The recommendations for 80 and 100 Hz are obtained by assuming that the same mean modal separation required for measurements at 125 Hz will be adequate for measurements at these lower frequencies.

X1.3 It is recommended that the volumes of the source and receiving rooms differ by at least 10 %.

X1.4 *Room Shapes*—It is recommended that no two dimensions of the pair of rooms be the same or in the ratio of small whole numbers. The ratio of largest to smallest dimension of either room should be less than two. The intent of this recommendation is to avoid having resonances at the same frequency in each room in the low frequency bands.

X1.4.1 Theoretical studies of rectangular rooms (**7, 8, 9**) suggest that the proportions 1:1.26:1.59 provide a good distribution of modes in the lowest bands. Minor deviations in construction, or the presence of sound diffusing devices, will alter the actual distribution.

X1.5 For new test suites, test specimens should preferably form a whole room surface (wall or floor (**10**)). Alternatively, the depth from the principal surface of each room to the specimen surface should be small compared to the lateral dimensions of the specimen, about 0.5 m or less.

X1.6 *Diffusing Panels*—Even in receiving rooms meeting the above recommendations, measurements in the lower test bands are likely to show large spatial variations. Using a diffusing panel system that incorporates stationary or moving diffusing panels, or both can minimize variations in measured sound pressure levels. Panels meeting the following requirements have been found effective in reverberation rooms.

X1.6.1 *Stationary Diffusing Panels*—It is recommended that rooms 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 wavelength 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 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.

X1.6.2 *Rotating or Moving Diffusers*—One or more rotating or moving panels set at oblique angles to the room surfaces may be installed in a room. The recommendations for weight and size of the panels given in X1.6 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.

NOTE X1.2—Moving diffusers can generate mechanical noise or wind and wind noise in microphones. This increased background noise may make measurements difficult in some cases.

X1.6.3 The recommended total single-sided area of fixed plus moving panels should be greater than 10 to 15 % of the total surface of the room.

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