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Standard Test Method for Measurement of Airborne Sound Insulation in Buildings[1]

This standard is issued under the fixed designation E 336; 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.

ϵ^1 NOTE—Equation 3 was editorially revised in August 2003.

INTRODUCTION

This test method is part of a set of standards for evaluating the sound-insulating properties of building elements. It is designed to measure the sound isolation between two rooms or the performance of a partition element installed as an interior part of a building. Others in the set cover the airborne sound transmission loss of an isolated partition element in a controlled laboratory environment (Test Method E 90), 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 E 597), and the measurement of sound transmission through door panels and systems (Test Method E 1408).

1. Scope

1.1 *Measures of Acoustical Insulation*—This test method covers procedures for determining the sound insulation between two rooms in a building. The evaluation may be made including all paths by which sound is transmitted or attention may be focused only on the dividing partition. The word "partition" in this test method includes all types of walls, floors, or any other boundaries separating two spaces. The boundaries may be permanent, operable, or movable.

1.2 *Application to Building Specifications*:

1.2.1 *Sound Transmission Class or Transmission Loss Specifications*—Building specifications may require that partitions have a certain minimum sound transmission class (STC) or transmission losses (TL). When it is required to demonstrate that a specific partition in a finished building complies with such specifications, a test satisfying the requirements of Annex A1 will be required.

1.2.1.1 Measurements may be made in accordance with the main body of this test method and with the requirements in Annex A1 without taking any steps to eliminate flanking transmission along paths other than that through the common partition. Transmission loss values can then be calculated as though the partition in question were the only transmission path. These apparent transmission loss values give a lower limit for the performance of the partition. Clearly when these values exceed the specifications, no further investigation is needed. If the partition is apparently not in compliance, then the procedures described in Annex A2 to reduce flanking transmission should be followed and the partition retested.

1.2.2 *Sound Isolation Specifications*—Where a building code specifies minimum values of noise isolation class (NIC) or normalized noise isolation class (NNIC), then only the procedures in the main body of the test method are necessary. Of the available single number ratings, NNIC relates best to occupant satisfaction in an occupied building.

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

2. Referenced Documents

2.1 *ASTM Standards:*

C 634 Terminology Relating to Environmental Acoustics[2]

E 90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions[2]

E 413 Classification for Rating Sound Insulation[2]

[1] This test method is under the jurisdiction of ASTM Committee E-33 on Environmental Acoustics and is the direct responsibility of Subcommittee E33.03 on Sound Transmission.

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

E 492 Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine[2]

E 597 Practice for Determining a Single-Number Rating of Airborne Sound Isolation for Use in Multiunit Building Specifications[2]

E 966 Guide for Field Measurement of Airborne Sound Insulation of Building Facades and Facade Elements[2]

E 1007 Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures[2]

E 1408 Test Method for Laboratory Measurement of the Sound Transmission Loss of Door Panels and Door Systems[2]

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

2.2 *ANSI Standards:*

S1.4 Specification for Sound Level Meters[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]

S12.31 Precision Methods for the Determination of Sound Power Levels of Broad Band Noise Sources in Reverberation Rooms[3]

2.3 *IEC Standard:*

IEC 804 Specification for Integrating Sound Level Meters[4]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, see Terminology C 634.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *noise reduction, NR*—in sound transmission measurements, in a specified frequency band, the difference between the average sound pressure levels measured in two enclosed spaces or rooms due to one or more sound sources in one of them.

3.2.2 *normalized noise reduction, NNR*—the noise reduction between rooms that would exist if the reverberation time, *T*, in the receiving room were 0.5 s.

NOTE 1—The normalized noise reduction is approximately equal to the noise reduction that would exist between the rooms when ordinarily furnished.

3.2.3 *noise isolation class*, *NIC*—a single-number rating derived from measured values of noise reduction in accordance with Classification E 413.

NOTE 2—NIC provides a measure of the sound isolation between two enclosed spaces that are acoustically connected by one or more paths.

3.2.4 *normalized noise isolation class*, *NNIC*—a single-number rating, similar to noise isolation class, except that it is derived from measured values of normalized noise reduction.

3.2.5 *field transmission loss*, *FTL*—of a partition installed in a building, in a specified frequency band, 10 times the common logarithm of the ratio, of the airborne sound power incident on the partition to the sound power transmitted by the partition and radiated on the other side. The quantity so obtained is expressed in decibels. (See Eq 10.)

3.2.6 *field sound transmission class*, *FSTC*—the sound transmission class of a partition installed in a building derived from values of field transmission loss in accordance with Classification E 413.

3.2.7 *flanking transmission*—sound that travels between a source and a receiving room along paths other than through the partition dividing the two rooms.

4. Summary of Test Method

4.1 The noise reduction between two rooms in a building is obtained by measuring the difference between the average sound pressure levels in each room at specified frequencies in one-third octave bands when one room, the source room, contains a source of noise.

4.2 The rate of decay of sound in the receiving room is measured to enable calculation of room sound absorption or normalization factors.

4.3 The noise reduction may be normalized to a reference reverberation time of 0.5 s (see 3.2.2).

4.4 When room size and absorption requirements are satisfied so sound fields are sufficiently diffuse and when flanking is not significant, the field transmission loss may be calculated and reported (see the conditions in Annex A1 and Annex A2).

5. Significance and Use

5.1 *Measurement of Sound Isolation*—If the purpose of the test is to determine the existing degree of sound isolation between a certain pair of adjacent spaces (rooms), any peculiarities of the environment or of the partition common to the two rooms, including existing flanking transmission paths, must be considered as part of the whole structure to be tested. No preparation of the test specimen is either needed or permitted. Pertinent measures are the noise reduction (NR), noise isolation class (NIC), normalized noise reduction (NNR), and normalized noise isolation class (NNIC) and the procedures in Annex A1 and Annex A2 need not be followed.

5.1.1 The main text of this test method specifies procedures and requirements for measuring the noise reduction between two enclosed spaces or rooms. If these requirements are satisfied, noise reduction measurements can always be made. When all sound paths, including flanking transmission paths, are included in the measurements, noise reduction is a property of the two adjacent spaces, all connecting structures and the separating partition. Under such conditions, the noise reduction or normalized noise reduction provides a measure of the sound isolation between the spaces.

5.2 *Transmission Loss Measurement*—Tests may be made to demonstrate that the sound attenuation of a specific partition in a building complies with a specification. Or, test data, along with other test data on nominally identical test specimens, may be used to typify the field performance of a particular partition type. In such cases, care should be taken to see that all conditions are "typical," that the hazards of measurements are minimized, as specified in 6.2, and that all significant flanking is eliminated. Annex A2 describes procedures for checking that

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

[4] Available from International Electrotechnical Commission (IEC), 3 rue de Varembé, P.O. Box 131, 1211 Geneva 20, Switzerland.

no substantial flanking is present. Pertinent measures are field sound transmission loss (FTL) and field sound transmission class (FSTC).

NOTE 3—It is sometimes possible to use Practice E 597 to determine if the acoustical isolation between two rooms is sufficient to meet building specifications.

5.2.1 The procedures and requirements described in Annex A1 and Annex A2 must be followed when the sound transmission loss properties of a partition are required. The problems of measuring the sound transmission loss properties of a partition in the field are much more difficult than those found in the laboratory or those associated with the field measurement of room-to-room sound isolation. In ordinary buildings, (1) a great variety of room shapes and sizes will be encountered; (2) the amount of energy exchange at the nominal boundaries of the test specimen will vary widely; and (3) there is almost always a problem of flanking transmission. Such variations influence the test results to a degree that is not generally predictable. Therefore, there may be substantial differences between sound transmission losses of similar partitions when measured in the laboratory and when measured in normal buildings, even though efforts are made to minimize leaks and flanking transmission **(1)**.[5] The procedures and requirements described in Annex A1 and Annex A2 are intended to minimize these differences. No effort shall be made to adjust field data to laboratory values under this test method.

5.2.2 It is possible that problems raised by flanking transmission or by an unusual field-test situation will make the measurement of field transmission loss so difficult or meaningless as to be impractical. If this is so, it is preferable to acknowledge the fact instead of attempting to apply an inappropriate measurement procedure.

6. Test Specimens

6.1 The special significance of this field test method is that measurements are made with partitions as found in the field in normally constructed buildings. Nevertheless, some judgment must be used to ensure that the field conditions, as found, are consistent with the purposes of the test.

6.2 *Test Location*—Find or install a test specimen of the desired type in surroundings most suitable for the test. The two spaces separated by the test specimen should be selected on the basis of (1) suitable size and shape, (2) freedom from structural irregularities near the test partition and freedom from offset conditions between the source and receiving room, and (3) (for field transmission loss measurements) freedom from flanking and satisfaction of the other requirements in Annex A1.

6.3 *Size and Mounting*—The minimum recommended lateral dimension and area of a test partition are 2.3 m (7.5 ft) and 5.5 m^2 (60 ft^2) respectively. The size and mounting conditions of the test specimen should be representative of the type of partition under study. Any unusual feature should be avoided unless this peculiarity is characteristic of the structure under investigation. Very small partitions sometimes yield different transmission loss values from similar large ones, and should not be used for test purposes unless the small size is characteristic of the construction being investigated, for example, a door. Any exceptional features shall be made clear in reporting the results.

6.4 Determine the radiating area of the test partition in the receiving room with careful attention to what elements constitute the test specimen. If the test partition presents different areas to the source and receiving rooms, use the area of the part common to both rooms. In this case, however, the test results may deviate considerably from the results for a partition with the same area exposed on both sides.

6.5 *Flanking Transmission*—In almost all installations in the field, sound can arrive in the receiving space by paths other than that directly through the partition nominally under test **(1,2)**. Flanking transmission includes structure-borne sound transmitted to the partition by the other surfaces (side walls, floor, ceiling) of the source room. Whether flanking transmission includes possible leaks around the edge of the partition depends on the type of partition and the purpose of the test. A decision must be made as to whether the leaks around the edge are a part of the partition. Any such decisions must be described in the test report.

6.6 *Drying and Curing Period*—Test specimens that incorporate materials for which there is a curing or drying process (for example, adhesives, plasters, concrete, mortar, and damping compound) shall age for a sufficient interval before testing. Aging periods for certain common materials are recommended in Test Method E 90 and summarized in Table 1 of this test method.

7. Test Signal

7.1 *Signal Spectrum*—The sound signals used for these tests shall be random noise containing an approximately continuous distribution of frequencies over each test band.

7.2 *Bandwidth*—The measurement bandwidth shall be one-third octave. Specifically, the overall frequency response of the electrical system, including the filter or filters in the source and microphone sections, shall for each test band conform to the specifications in ANSI S1.11 for a one-third octave band filter set, Order 3 or higher, Type 1 or better.

7.2.1 Filtering may be done either in the source or the measurement system or partly in both, provided that the required overall characteristic is achieved. Apart from defining

TABLE 1 Recommended Minimum Aging Periods Before Testing

Material	Recommended Minimum Aging Period
Masonry	28 days
Plaster:	
Thicker than 3 mm (⅛ in.)	28 days
Thinner than 3 mm (⅛ in.)	3 days
Wallboard Partitions:	
With water-base laminating adhesives	14 days
With non-water-base laminating adhesives	3 days
With typical joint and finishing compounds	12 h
Other	As appropriate for caulking and adhesive compounds involved

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

the 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 sound power in the test band or bands.

NOTE 4—Paragraphs 7.2 and 7.2.1 are intended to describe the effective results, rather than specific instrumentation. Any system that achieves the specified results is acceptable.

7.3 *Standard Test Frequencies*—The minimum range of measurements shall be a series of contiguous one-third octave bands with mid-band frequencies from 125 to 4000 Hz. It is desirable that the range be extended to include at least the 100 and 5000-Hz bands.

7.4 *Sound Sources*:

7.4.1 The source(s) should radiate sound over a wide angle to avoid a strong direct field component. To satisfy this requirement over the frequency range of the measurements might require the use of loudspeaker systems with separate drivers for the high and low frequencies.

7.4.2 *Location of Sound Sources*—Sound sources should be far enough away from the test partition that the direct field reaching the latter is as small as possible compared to the reverberant field. (For testing walls, sources are usually placed in corners away from the specimen. When the test specimen is a floor the source usually must be placed in the lower room.) Pointing loudspeakers into corners reduces the direct field from the loudspeakers in the source room.

7.5 *Multiple Sound Source Positions*—Measured values of noise reduction especially at low frequencies, may change significantly when loudspeaker position in the source room is changed. Where this occurs, sound transmission loss can 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 noise generators and amplifier channels so the outputs are uncorrelated. Multiple, uncorrelated sound sources also have been found to reduce the spatial variance of sound pressure level in reverberation rooms. If multiple sources are used, they should be well separated in the room.

7.5.1 *Sound Power of Sources*—The sound power of the source(s) must be sufficient to get the signal level in the receiving room far enough above background noise to meet the requirements of 10.5. The power required depends on the source room absorption, the nature of the test specimen, and the background noise in the receiving room.

8. Microphone Requirements

8.1 Microphones are used to measure average sound pressure levels in the rooms and sound decay rates in the receiving room.

8.2 *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.

8.3 *Microphone Calibration*—Calibrate microphone(s) periodically (annually, for example) throughout the test frequency range by a qualified laboratory technique (see ANSI S1.10).

9. Sensitivity Checks

9.1 Carefully check all instruments at the time of the tests. This is particularly important in field measurements where the hazards of transportation increase the likelihood that the equipment will be found out of adjustment at the test site.

9.2 When source room levels and receiving room levels are measured with the same instruments, perform sensitivity checks before beginning the measurements in each room and at intervals during the test, to ensure drift of not more than 0.5 dB.

9.3 When two sets of sound level measuring equipment are used for measurement of sound levels in the source and receiving rooms, check the sensitivity of both sets before field tests are begun and at intervals of not more than 30 min thereafter. Use the same calibration equipment for all calibrations. The microphones should all be of the same make and model.

9.4 Make the sensitivity check of the microphone(s) 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.

9.4.1 A nominal sine wave having less than 10 % distortion and amplitude stability to within 0.2 dB is recommended as a calibration signal.

9.5 The sensitivity check need be made at only one frequency within the range from 200 to 1250 Hz.

9.6 Include the entire measuring setup (including the microphone, all cables, and instruments) in the check for sensitivity. Recheck the entire setup after any changes, adjustments, or substitutions of cables or equipment.

9.7 If equipment is sensitive to line voltage variations, use a line-voltage regulator.

10. Measurement of Average Sound Pressure Levels

10.1 The measurement procedure requires the determination of the average sound pressure levels $\bar{L}_1$ and $\bar{L}_2$ produced in the two rooms by the sound source in the source room. The measurement process must account for variations with microphone position, microphone sensitivity, and possible changes in the spectrum and level of the source, and it must be repeated for each test frequency band. Various spatial sampling arrangements are possible. A single microphone may be moved continuously or placed sequentially at several measurement positions or an array of stationary microphones may be used.

10.2 *Averaging Time*—The average sound pressure level in a given period of time is best obtained using an instrument that provides a direct reading of the required value. Such instruments include integrating sound level meters that meet the requirements of IEC 804 or real-time frequency analysers. Other methods may also be satisfactory.

10.2.1 *Fixed Microphones*—For each sampling position, the averaging time shall be sufficient to yield an accurate estimate of the time-averaged level. 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 center frequency, f, the averaging time, T_a, may be estimated from:

$$T_a = \frac{310}{fe^2} \quad (1)$$

Thus at 125 Hz, the minimum averaging time for confidence limits of $\pm$ 0.5 dB should be 9.9 s. For more information see Ref **(7)**.

10.2.2 *Moving Microphones*—For mechanically or manually swept microphones, integration times should be long enough that repeat measurements are not significantly different. A typical time for a sweep of the room is 60 s.

10.3 *Fixed Microphones*:

10.3.1 *Number of Microphone Positions*—Use at least six microphone positions in each room.

10.3.2 *Microphone Positions*—Locate microphones to sample adequately the sound field in each room with the following restrictions:

10.3.2.1 Except as noted below, the shortest distance from any microphone position to any major extended surface shall be not less than 1 m (3.3 ft) if the requirements for microphone separation (see 10.3.2.4) and number of microphones (see 10.3.1) can be met with this distance. If these requirements cannot be met then the shortest distance from any microphone position to any major extended surface may be reduced but must never be less than 0.5 m (1.6 ft) **(3)**.

10.3.2.2 *Direct Field of Sound Source(s)*—The minimum distance from the source to the nearest measurement point should be such that there is minimal influence on the measurement of the average sound pressure level by the direct sound field. This distance will depend on the absorption of the room and other factors. For practical purposes it is sufficient to ensure that no microphone is within 1.5 m (5 ft) of the source.

10.3.2.3 In the receiving room, position the microphones so that the average sound pressure level is not substantially influenced by the direct field of the partition. Do not place a microphone in the receiving room within 1.0 m (3.3 ft) of the partition.

NOTE 5—In heavily furnished (absorptive) source or receiving rooms, it may not be possible to avoid the effects of the direct field of the source or the partition. In such cases, transmission loss measures would be invalid, but noise reduction measurements may still be reported.

NOTE 6—In certain field situations, the determination of what constitutes the receiving room and its volume may not be obvious. An example is when a living room is connected to a kitchen in the same unit through an opening in a dividing wall that does not extend to the ceiling, and both "rooms" adjoin a party wall under test. Some judgment may be required to define the volume of the "room." It is recommended that sound pressure level measurements be performed in all portions of the room under consideration. The ancillary volume can be disregarded in the calculations if the average sound pressure level is 6 or more decibels below the average level in the principal portion of the source or receiving room.

10.3.2.4 Ensure that fixed microphone positions are separated by at least 1 m (3.3 ft). This separation is deemed sufficient for the purposes of this test method. Do not use microphone arrangements that are obviously symmetrical, such as all in the same vertical or horizontal plane.

NOTE 7—To provide independent samples of the sound field, stationary microphones in an ideal diffuse sound field, should be spaced at least one-half wavelength apart **(3)**.

10.4 *Moving Microphones*—Moving microphones may be used in conjunction with sound level meters or the equivalent that give integrated levels in accordance with IEC 804. This combination has the advantage that it provides average sound pressure levels in the rooms automatically. The same system used to measure the average sound pressure level must be used to measure background noise so that any mechanical or human sounds are present in both cases.

10.4.1 *Mechanically Operated Microphones*—A single microphone continuously moving along a defined traverse such as a circular path may be used instead of stationary microphone positions, provided that the restrictions given in 10.3.2 are met at all points on the path. For the purposes of this test method, it is sufficient if the radius of a circular path is at least 1 m (3.3 ft).

NOTE 8—The number of equivalent fixed microphone positions for a straight line traverse of length L is $2L/\lambda$ and for a circular or closed traverse of length L is $2L/\lambda - 1$ where λ is the wavelength of interest **(4)**.

10.4.2 *Manually Swept Microphones*—The microphone should be held well away from the operator's body (a boom serves to increase the distance). The operator should slowly turn and move the microphone to sample as much of the central volume of the room as possible. The restrictions on microphone proximity to surfaces in 10.3.2 must still be met.

10.5 *Background Noise*—Make measurements of background noise levels routinely in each frequency band to ensure that the observations are not affected by extraneous sound, electrical noise in the receiving system, or electrical cross-talk between source and receiving systems. Make corrections at each measurement position when background level is less than 10 dB below the combined level due to signal and background. If the background level is between 5 and 10 dB below the combined level, the adjusted value of the signal level is calculated as follows:

$$L_s = 10 \log (10^{L_{sb}/10} - 10^{L_b/10}) \quad (2)$$

where:

L_b = background noise level in each band, dB,
L_{sb} = combined level of signal and background, dB, and
L_s = adjusted signal level, dB.

If the signal level cannot be adjusted so that the background level is at least 5 dB below the combined level, then subtract 2 dB from the combined level and use this as the adjusted signal level. In this case, the measurements can be used only to provide an estimate of the lower limit of the noise reduction. Identify such measurements in the test report.

NOTE 9—Since acoustical background noise levels can vary quickly with time, due to transportation, construction, or occupancy noises, it is desirable that the sound source can be operated remotely so that the background noise check is made immediately after each sound level measurement.

10.6 *Determination of Space-Average Levels*—Following the procedures of 10.3.1 and 10.4.1, obtain two sets of average sound pressure levels corresponding to the sampling in the two rooms. For fixed microphones, the space-average level for the room is calculated as follows:

$$\bar{L} = 10 \log_{10}\left[\frac{1}{n}\sum_{i=1}^{n} 10^{L_i/10}\right] \quad (3)$$

where L_i are the set of time-average levels taken at n locations in the room.

NOTE 10—Throughout this test method, log is taken to mean $\log_{10}$, unless otherwise indicated.

11. Determination of Receiving Room Absorption

11.1 Receiving room absorption, A_2, is determined by measuring the rate of decay of sound pressure level in the receiving room in the same one-third octave bandwidths and with the room in the same condition as for the measurement of $<L_1>$ and $<L_2>$. Determine the sound absorption of the receiving room, A_2, as follows.

11.2 Activate sound source(s) in the receiving room for a few seconds, then switch them off and record the curves giving the decay of sound pressure level in the room at each one-third octave band frequency. This may be done using a real-time analyzer or sound level meter with built-in algorithms or interfaced to a computer with appropriate software. With such instrumentation, decay rates or reverberation times can be obtained automatically.

11.2.1 Instrument decay rates in each frequency band should be at least 3 times the room decay rates so measurements of sound decay rates are not biased. The instrument decay rate can be measured by attaching a noise generator directly to the input, switching off the generator, and then measuring the decay.

11.3 *Measurement of Decay Rate from Decay Curves*—First select a point on the decay curve as close as practical to 0.1 s after the sound source has been switched off. Select a second point on the decay curve no more than 25 dB lower in sound pressure level than the first point. The second point must be at least 10 dB above the background noise level. Determine the straight line that best approximates the portion of the decay curve between these two points. The slope of the line, *d*, gives the rate of decay of sound pressure level in decibels per second. Fitting may be done to individual decay curves, or to the average of several.

11.4 *Number of Decay Rate Measurements*—Obtain the mean room decay rate by averaging the rates for at least three decays measured at each of at least three locations 1 m or more apart in the receiving room. For example, the mean decay rate could be obtained by measuring four decays at each of four locations in the receiving room and averaging a total of 16 decays. Microphones placed in room corners may be used. A moving microphone may also be used when measuring the decay rate, in which case spatial averaging will be automatic but an average of several decays is still necessary.

NOTE 11—Sound decay rates vary from one decay to the next because of the random nature of the sound excitation. They also vary with the position of the microphone in the room. Thus an average value should be found.

NOTE 12—Note that because the quantity entering into the transmission loss calculation is only 10 log A_2, highly precise measurements are not essential. Thus a 10 % uncertainty in measuring A_2 results in only a 0.4 dB uncertainty in the calculated transmission loss value.

11.5 A_2 is given by the Sabine equation:

$$A_2 = 0.921 \frac{Vd}{c} \quad (4)$$

where:

A_2 = sound absorption of the room, m^2,
c = speed of sound in air, m/s,
V = volume of room, m^3, and
d = rate of decay of sound pressure level in the room, dB/s.

(Note that $d = 60/T$ where T is reverberation time in seconds.)

When V and c are in cubic feet and feet per second respectively; A_2 is in sabins (square feet).

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

$$c = 20.047 \sqrt{273.15 + t}\ m/s \quad (5)$$

where:

t = receiving room temperature, °C.

12. Calculation

12.1 Calculate the noise reduction, the difference between the space-average sound pressure levels obtained in the source and receiving rooms, using:

$$NR = \bar{L}_1 - \bar{L}_2 \quad (6)$$

where:

$\bar{L}_1$ = average sound pressure level in the source room, dB, and
$\bar{L}_2$ = average sound pressure level in the receiving room, dB.

12.1.1 If required, normalized noise reduction values are calculated as follows:

$$NNR = \bar{L}_1 - \bar{L}_2 + 10 \log (T/0.5) \quad (7)$$

where:

T = reverberation time in the receiving room, s.

(Note that $T = 60/d$ where d is the rate of decay of sound pressure level, dB/s.)

12.1.2 When air temperature is approximately 20°C, room sound absorption is related to the reverberation time as follows:

$$T = 0.161\ V/A_2 \quad (8)$$

where:
A_2 = room absorption, m^2, and
V = room volume, m^3 or

$$T = 0.049\ V/A_2 \tag{9}$$

where:
A_2 = room absorption, sabins, and
V = room volume, ft^3.

12.2 Provided the requirements of Annex A1 have been met, the field sound transmission losses of the partition may be calculated from measurements in the two rooms as follows:

$$FTL = \bar{L}_1 - \bar{L}_2 + 10 \log (S/A_2) \tag{10}$$

where:
S = area of the test partition, m^2(ft^2), and
A_2 = sound absorption in the receiving room, m^2(sabins).

(Note that A_2 is the absorption with the test partition in place; sound transmitted from the receiving room back into the source room through the test partition constitutes part of the sound absorbed from the receiving room.)

12.3 This test method specifies the use of one-third octave bands for measurement and calculation of noise reduction and all derived quantities. It does not allow measurement of octave band noise reductions 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 values are required, they must be calculated using the expression:

$$NR_{oct,fc} = -10 \log \left[\frac{1}{3} \sum_{B = B_c - 1}^{B_c + 1} 10^{-NR_B/10} \right] \tag{11}$$

where f_c is a preferred octave band mid-band frequency as specified in ANSI S1.6. The summation is made over three one-third octave band NR 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 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. (Random noise with this spectrum is known as “Pink noise.”)

13. Report

13.1 Report the following information:

13.1.1 *Statement of Conformance to Standard*—State that the tests were conducted in accordance with this test method. Note any deviations clearly.

13.1.2 *Description of Test Environment*:

13.1.2.1 A general description of the source and receiving spaces and their environs, including furnishings.

13.1.2.2 A sketch showing the layout, dimensions, and volumes of the test rooms.

13.1.2.3 The dimensions of the test partition.

13.1.3 *Description of Test Specimen*:

13.1.3.1 If the information is available and relevant to the purpose of this test method, give a complete description of the test partition, including all of the essential constructional elements, the size, thickness, and an estimate of the average weight per unit area of the specimen.

NOTE 13—If there are no access panels, outlet boxes, etc., that would permit a direct measurement of wall thickness, the specimen thickness can often be deduced by measurement between windows or doorways separated by the test specimen.

13.1.3.2 Any description of the test specimen should as far as practicable be based upon measurement and examination of the specimen itself, rather than upon the building plans or information received from the builder or others.

13.1.3.3 If the construction or installation of the test specimen is, for some reason, such that the results do not represent normal performance of the specimen, state this fact explicitly.

13.2 *Description of Test Procedure*:

13.2.1 The method used to measure room absorption.

13.2.2 The procedures, if used, to evaluate possible flanking transmission.

13.3 *Statement of Test Results*:

13.3.1 State clearly which kind of results are being presented (NR, NNR, or FTL). If flanking transmission has not been evaluated as specified in Annex A2, then field transmission loss values may be referred to as minimum field transmission loss values.

13.3.2 State the mean values of L_1, L_2, A_2 (or RT) for the measurements. As appropriate, state the mean value, rounded to the nearest 1 dB, of NR, NNR, or FTL of the test results at the specified frequencies. This must be done in tabular form and may also be done in graphical form. For measurements made in rooms smaller than the limits given by A1.3.1, mark the values of noise reduction or transmission loss at those frequencies below the limit to show that the measurements are not as reliable.

13.3.3 Where flanking tests have been performed as described in Annex A2, state the measured values of NR or FTL before and after the construction of the supplementary shields.

13.4 *Noise Isolation Class or Normalized Noise Isolation Class (NIC or NNIC)*—Where only sound pressure levels have been measured, state the NIC. Where decay rate measurements have also been made, state the NIC and the NNIC.

13.5 *Field Sound Transmission Class (FSTC)*—For test partitions whose field transmission loss has been measured in one-third octave bands in accordance with this test method including Annex A1 and for which, by applying the methods of Annex A2, either no significant flanking has been found or it has been eliminated, a field sound transmission class (FSTC) may be assigned in accordance with Classification E 413.

13.5.1 Where flanking has not been evaluated but the requirements of Annex A1 have been met, the measured data may be used to calculate transmission loss values that give a lower limit for the sound insulation of the specimen. These data may be used to calculate a value of FSTC that represents the minimum sound insulation the specimen is capable of. This minimum FSTC may be reported but its significance should be clearly stated.

14. Precision and Bias

14.1 *Precision*—The precision of this test method has not been established.

14.2 *Bias*—There is no known bias in this test method.

15. Keywords

15.1 airborne sound transmission loss; flanking transmission; noise isolation class; noise reduction; normalized noise isolation class; sound transmission coefficient; sound transmission loss; transmission loss

ANNEXES

(Mandatory Information)

A1. MEASUREMENT OF FIELD SOUND TRANSMISSION LOSS

A1.1 Field transmission loss is defined in 3.2.5. In the laboratory test procedure (Test Method E 90), transmission loss is determined by mounting the partition between two reverberation rooms, one of which (the source room) contains one or more sound sources. The rooms are arranged so the only significant sound transmission between them is through the test specimen and the sound fields in them are adequately diffuse. Under these conditions, the transmission loss is related, by Eq 10, to the space-time average sound pressure levels in the two rooms, the area of the test partition, and the absorption in the receiving room. When these quantities are measured in appropriate frequency bands, the transmission loss as a function of frequency can be calculated. When this situation is closely approximated in the field, the noise reduction measurements may be used to calculate field transmission loss values also using Eq 10.

A1.2 *Required Conditions*—To make acceptable measurements of sound transmission loss in the field the conditions following must be met.

A1.3 *Room Size:*

A1.3.1 *Minimum Volume*—The volume of each room should be not less than 60 m^3 (2100 ft^3) for measurements down to 100 Hz, 40 m^3 (1400 ft^3) for measurements down to 125 Hz, and 25 m^3 (880 ft^3) for measurements down to 160 Hz. Where these criteria are not satisfied, no attempt should be made to determine field transmission loss, though the noise reduction may always be measured and reported.

NOTE A1.1—The room volume requirement at 125 Hz is obtained by assuming that a minimum of ten room modes will provide a sufficiently good approximation to a diffuse sound field. At other frequencies, the minimum room volume can be calculated by requiring that the same average modal spacing as at 125 Hz is maintained. Thus larger rooms are needed at lower frequencies.

A1.3.2 In situations where either the source room or the receiving room is small compared to the wavelength of sound, the measured noise reduction becomes unduly influenced by the properties of the rooms and no longer characterizes the test specimen. Therefore "incident" or "radiated" sound power and transmission loss cannot be defined in the usual way. This situation will occur in any closed space if the frequency is low enough.

A1.4 *Room Shape*—In addition to the minimum volume requirement in A1.3.1, it is preferable to avoid extreme ratios of room dimensions. Therefore, the room height shall be 2.3 m (7.5 ft) or greater and no lateral receiving room dimension shall be less than 2.75 m (9 ft), the wavelength of the middle frequency of the 125 Hz one-third octave band.

A1.5 *Room Absorption*—At all frequencies, the room absorption, *A*, for each room shall be less than:

$$A = V^{2/3} \tag{A1.1}$$

where *V* is the room volume. If *V* is in cubic metres (cubic feet), then *A* is in square metres (sabins).

NOTE A1.2—The sound absorption in each of the rooms should be low to achieve the best possible simulation of the ideal diffuse field condition, and in order to keep the region dominated by the direct field (in both the source and receiving rooms) as small as possible.

A1.6 *Partition Area*—For transmission loss measurements, the dimensions of the part of the test partition common to both sources and receiving rooms shall be at least 2.3 by 2.4 m (7.5 by 8 ft), unless a door or window is being evaluated.

A1.7 Once the primary measurement of field transmission loss is complete, a supplementary test may be made to demonstrate that no significant flanking transmission is present. Details of suitable tests for flanking transmission are outlined in Annex A2.

A1.8 After evaluating or eliminating flanking transmission, the sound transmission loss of the test partition may then be calculated from measurements in the two rooms in accordance with Eq 11.

A1.9 If flanking transmission is found to be affecting the transmission loss when following the procedures outlined in Annex A2, the calculated FTL values may be referred to as minimum FTL values since they will be at least as great as when no flanking exists.

A2. CHECKS FOR FLANKING TRANSMISSION

A2.1 In measurements where the field transmission loss of the test panel is required, it may be necessary to reduce flanking transmission to a negligible amount so that the measured levels in the receiving room correspond only to that sound which is transmitted through the partition under test. The following test may be performed in accordance with Section 10 and Annex A1 for field transmission loss measurements to demonstrate the absence of significant flanking transmission.

A2.2 *Shielding*—After the initial measurement of apparent transmission loss has been made, cover one side of the test partition with an additional panel designed to reduce transmission through the test specimen by at least 10 dB. A suitable construction consists of a layer of plywood or gypsum board weighing at least 10 kg/m^2 (2 lb/ft^2), free-standing or lightly supported from the test facade and spaced at least 100 mm (4 in.) from it, with soft sound-absorbing material such as glass fiber batts in the space. The blocking panel must be sealed at joints and around the perimeter with tape, gaskets, or caulking compound, so as to form a complete auxiliary wall. It may be convenient to arrange the panels in a splayed, zig-zag configuration so that, when the edges are taped together to form a hinge, the array is free-standing, like a decorative screen.

A2.2.1 Take care that the area shielded comprises all, but not more than, the structural elements making up the specimen under test. For example, in the case of an operable or demountable partition, it is usually understood that the manufacturer has the responsibility of providing an adequate seal to the surrounding structure; this seal, therefore, is part of the specimen under test. In this case, tape the supplementary skin just outside the seal, so that the seal is covered (as part of the specimen) for the second measurement.

A2.2.2 The supplementary skin may be added on either side of the test partition, but if it is applied on the source side, there is no need to remeasure the absorption in the receiving space.

A2.2.3 The apparent TL of this modified partition is then measured and compared with the initial TL measurement. If, in each frequency band, the apparent TL of the modified partition is at least 10 dB higher than the initially measured TL, then the initial measurements may be deemed to represent the true TL of the test specimen. If the difference in apparent TL is less than 5 dB, then there is too much flanking sound transmission to permit a reliable determination of the true TL. If the difference is between 5 and 10 dB, an estimate of the true TL can be made by treating receiving room level measurements with the blocked-off test specimen as background noise, thus:

$$TL_a = -10 \log (10^{-TL_e/10} - 10^{-TL_b/10}) \qquad \text{(A2.1)}$$

where:

TL_b = level with the test specimen blocked off, dB,
TL_e = level with test specimen exposed, dB, and
TL_a = adjusted level due to transmission through the test specimen alone, dB.

A2.3 *Comparison with Laboratory Data*—After the transmission loss calculations have been made, the resulting field data may be compared with laboratory transmission loss data for a similar type of partition. One should not necessarily expect close agreement, but widely divergent trends may indicate the existence of flanking paths, of leaks, or of deviations from the nominal construction of the test specimen.

A2.4 Other procedures may be used to estimate the importance of flanking transmission.

A2.4.1 *Listening Tests*—The simplest procedure is to try to detect obvious leaks where sound is entering the space by way of unintended paths. This can be accomplished by listening at the wall surfaces with either a stethoscope or with a microphone and amplifier driving a pair of ear phones.

A2.4.1.1 A word of caution is in order concerning the investigation of sound fields near interior room surfaces. As the leak test apparatus is moved into a corner, an increase in sound level due to pressure doubling near boundaries and corners is usually heard and measured; this effect should not be mistaken for a sound leak.

A2.5 *Vibration Measurements*—One may also investigate whether the surfaces of the receiving room other than the test partition are vibrating significantly at the test frequencies; an accelerometer may be used to compare the vibration of the test partition with that of the other surfaces. The average vibration level in each band of each of the other room surfaces should be at least 10 dB below that of the test partition.

A2.5.1 The accelerometer should be small and of low mass compared to the surface mass of the room surfaces. Other techniques using advanced instrumentation such as correlation analyzers and sound intensity meters may also be useful but their application is beyond the scope of this test method.

A2.6 Clearly identify in the report all data for which the flanking transmission is observed but cannot be effectively eliminated. It may be stated that the field transmission loss is at least as great as the test data indicate.

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