Designation: E336 – 16a

Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings[1]

This standard is issued under the fixed designation E336; 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 of standards for evaluating the sound-insulating properties of building elements. It is designed to measure the sound isolation between two rooms or to estimate lower limits for sound transmission through 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 E90), 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/E1414M), and measurement of the normalized insertion loss of doors (Test Method E2964).

1. Scope

1.1 The sound isolation between two spaces in a building is influenced most strongly by a combination of the direct transmission through the nominally separating building element (as normally measured in a laboratory) and any transmission along a number of indirect paths, usually referred to as flanking paths. Fig. 1 illustrates the direct paths and some possible structural flanking paths. Additional non-structural flanking paths may include transmission through common air ducts between rooms, or doors to the corridor from adjacent rooms. Sound isolation is also influenced by the size of the separating partition between spaces and absorption in the receiving space, and in the case of small spaces by modal behavior of the space and close proximity to surfaces.

1.2 The main part of this test method defines procedures and metrics to assess the sound isolation between two rooms or portions thereof in a building separated by a common partition or the apparent sound insulation of the separating partition, including both direct and flanking transmission paths in all cases. Appropriate measures and their single number ratings are the noise reduction (NR) and noise isolation class (NIC) which indicate the isolation with the receiving room furnished as it is during the test, the normalized noise reduction (NNR) and normalized noise isolation class (NNIC) which indicate the expected isolation when the receiving room is a normally furnished living or office space that is at least 25 m^3 (especially useful when the test must be done with the receiving room unfurnished), and the apparent transmission loss (ATL) and apparent sound transmission class (ASTC) which indicate the apparent sound insulating properties of a separating partition. The measurement of ATL is limited to spaces of at least 25 m^3 where modal effects create fewer problems. With the exception of the ATL and ASTC under specified conditions, these procedures in the main part of the test method are only applicable when both room volumes are less than 150 m^3.

NOTE 1—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.

1.3 The NR and NIC between two locations may always be measured and reported though conditions present will influence how measurements are made. Restrictions such as minimum room volume or dimensions or maximum room absorption are imposed for all other measures and ratings in this standard. Thus, conditions may exist that will not allow NNR (NNIC), ATL (ASTC) or FTL (FSTC) to be reported. Where a partition between rooms is composed of parts that are constructed differently, or contains an element such as a door, it is not possible to measure the ATL and ASTC of the individual elements or portions of the partition. To evaluate the field

[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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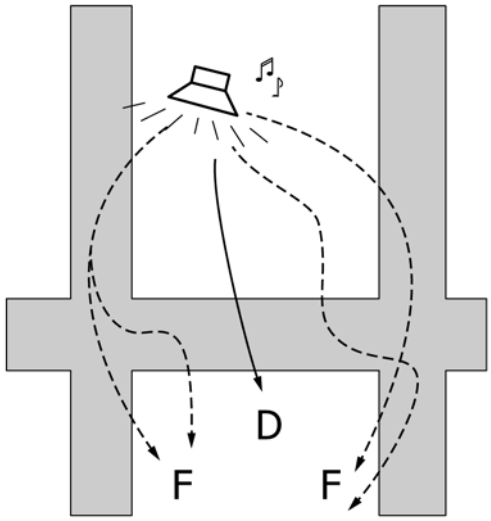


FIG. 1 Direct (D) and Some Indirect or Flanking Paths (F and Dotted) in a Building

performance of a door less than 6 m^2 in area, use Test Method E2964. The various metrics are inherently different quantities, so that NIC cannot be used instead of NNIC or ASTC when specifications are written in terms of one of those metrics that cannot be reported with the conditions present.

1.4 Annex A1 provides methods to assess the sound transmission through a partition or partition element with the influence of flanking transmission reduced. These methods may be used when it must be demonstrated that a partition has achieved a specified minimum sound attenuation. The results are the field transmission loss (FTL) and field sound transmission class (FSTC).

1.5 Annex A2 provides methods to measure the sound isolation between portions of two rooms in a building separated by a common partition including both direct and flanking paths when at least one of the rooms has a volume of 150 m^3 or more. The results are the noise reduction (NR) and noise isolation class (NIC).

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 The text of this test method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.8 *This standard may involve hazardous materials, operations, and equipment. 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]

C634 Terminology Relating to Building and Environmental Acoustics

E90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements

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

E1414/E1414M Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum

E2235 Test Method for Determination of Decay Rates for Use in Sound Insulation Test Methods

E2964 Test Method for Measurement of the Normalized Insertion Loss of Doors

2.2 *ANSI Standards:*[3]

S1.10 Pressure Calibration of Laboratory Standard Pressure Microphones

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

[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.

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

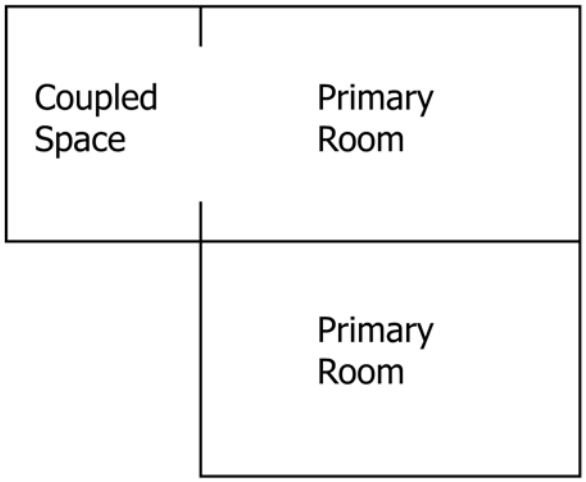


FIG. 2 Coupled Spaces Adjacent to a Primary Space

S1.40 Specification and Verification Procedures for Sound Calibrators
S1.43 Specifications for Integrating-Averaging Sound Level Meters
2.3 *IEC Standard:*[4]
IEC 60942 Electroacoustics–Sound Calibrators
IEC 61672 Electroacoustics–Sound Level Meters
2.4 *ISO Standard:*[5]
ISO 16283-1:2014 Acoustics -- Field measurement of sound insulation in buildings and of building elements -- Part 1: Airborne sound insulation

3. Terminology

3.1 The following terms used in this test method have specific meanings that are defined in Terminology C634:

3.1.1 airborne sound; background noise; decay rate; decibel; diffuse sound field; field sound transmission class, FSTC; field transmission loss, FTL; flanking transmission; pink noise; receiving room; self-noise; sound absorption; sound attenuation; sound insulation; sound isolation; sound pressure level; sound transmission loss, TL; source room

NOTE 2—The unqualified term *average sound pressure level* in this document means that sound pressure levels were averaged over the measurement region for specified periods of time.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent transmission loss, ATL (dB), n—of a partition installed in a building, in a specified frequency band* is operationally defined as:

$$ATL = \bar{L}_1 - \bar{L}_2 + 10\log\left(\frac{S}{A_2}\right) \quad (1)$$

where:

S = the area of the partition common to both source and receiving rooms, m^2

A_2 = the sound absorption in the receiving room, m^2

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

$\bar{L}_2$ = the receiving room average sound pressure level resulting from the combined effect of direct and flanking transmission, dB.

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

3.2.1.2 *Discussion*—This definition attributes all the power transmitted into the receiving room, by direct and flanking paths, to the area of the partition common to both rooms. If flanking transmission is significant, the ATL will be less than the TL for the partition. Apparent transmission loss (ATL) is equivalent in meaning to apparent sound reduction index (ASRI) used by ISO 16283-1:2014.

3.2.2 *apparent sound transmission class, ASTC, n*—a single number rating obtained by applying the classification procedure of Classification E413 to apparent transmission loss data.

3.2.3 *coupled space, n*—a secondary space that is adjacent to and partially open to the primary space on the same side of the separating partition and which meets spatial and sound level distribution requirements sufficient to allow the secondary space to be included as part of the measurement space with the primary space.

3.2.3.1 *Discussion*—Fig. 2 and Fig. 3 illustrate conditions that may be coupled spaces.

3.2.3.2 *Discussion*—To qualify as a coupled space in this standard the space must meet requirements specified in 9.4.1.

3.2.4 *direct transmission, n*—sound that travels between a source and a receiving room only through the common (separating) building element.

3.2.5 *noise reduction, NR, (dB), n—in a specified frequency band*, the difference between the sound pressure levels at two well-defined locations.

3.2.6 *noise isolation class, NIC, n*—a single-number rating calculated in accordance with Classification E413 using measured values of noise reduction.

3.2.7 *normalized noise reduction, NNR, (dB), n—between two rooms of less than 150*[3] *where the receiving room is at least*

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

[5] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

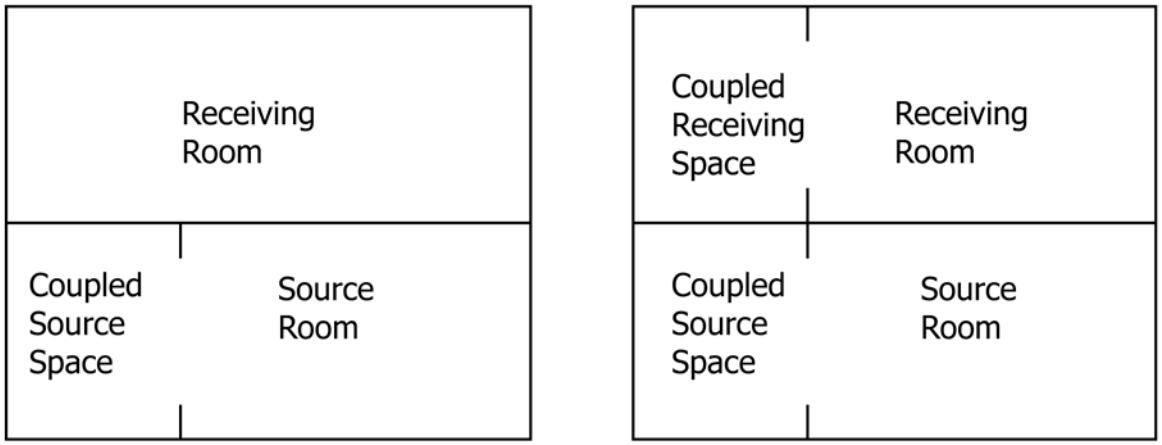


FIG. 3 Receiving Spaces Adjacent to a Coupled Source Space

25 m³, in a specified frequency band, the value that the noise reduction, NR, in a given field test would have if the reverberation time in the receiving room were 0.5 s. NNR is calculated as follows:

$$NNR = NR + 10\log\left(\frac{T}{0.5}\right) \quad (2)$$

where:

NR = noise reduction, dB, and
T = reverberation time in receiving room, s.

3.2.7.1 *Discussion*—The normalized noise reduction is intended to approximate the noise reduction that would exist in an ordinarily furnished receiving room.

3.2.8 *normalized noise isolation class, NNIC (dB), n*—a single-number rating for noise isolation between two rooms both less than 150 cubic meters calculated in accordance with Classification E413 using measured values of normalized noise reduction. (See *normalized noise reduction*.)

4. Summary of Test Method

4.1 The source and receiving rooms are selected, the measurement spaces and volumes in each room are defined and the metrics to be measured are identified based on information given in Section 5 within the restrictions given in 11.3 and Annex A2.

4.2 The number and location of sound sources are chosen, sound is produced in the source room and sound pressure levels are sampled spatially in the measurement spaces in both the source and receiving rooms.

4.3 Sound decay rates are measured as necessary depending on the result to be reported.

4.4 If a value for noise reduction is to be measured between rooms immediately adjacent to a common partition where either is 150 m^3 in volume or greater, the requirements and procedures of Annex A2 must be satisfied.

4.5 If values of NNR are to be reported, the requirements of 9.3 must be satisfied. If values of ATL are to be reported, the requirements of 9.4.1 must be satisfied and if ATL is to be reported for a partition between spaces where either is 150 cubic meters in volume or greater, the requirement of 9.4.1.2 must be satisfied.

4.6 If a value for the field transmission loss (FTL) is to be measured, the requirements and procedures of Annex A1 must be satisfied.

4.7 Results and single number ratings are calculated and reported.

5. Significance and Use

5.1 The main part of this standard uses procedures originally developed for laboratory measurements of the transmission loss of partitions. These procedures assume that the rooms in which the measurements are made have a sound field that reasonably approximates a diffuse field. Sound pressure levels in such rooms are reasonably uniform throughout the room and average levels vary inversely with the logarithm of the room sound absorption. Not all rooms will satisfy these conditions. Practical experience and controlled studies (**1**)[6] have shown that the test method is applicable to smaller spaces normally used for work or living, such as rooms in multi-family dwellings, hotel guest rooms, meeting rooms, and offices with volumes less than 150 cubic meters. The measures appropriate for such spaces are NR, NNR, and ATL. The corresponding single number ratings are NIC, NNIC and ASTC. The ATL and ASTC may be measured between larger spaces that meet a limitation on absorption in the spaces to provide uniform sound distribution.

5.2 Annex A2 was developed for use in spaces that are very large (volume of 150 m^3 or greater). Sound pressure levels during testing can vary markedly across large rooms so that the degree of isolation can vary strongly with distance from the common (separating) partition. This procedure evaluates the isolation observed near the partition. The appropriate measure is NR, and the appropriate single number rating is NIC.

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

5.3 It is sometimes necessary to demonstrate that the sound insulation of a partition meets or exceeds a specific criterion. Annex A1 provides additional requirements, and describes how shielding procedures can be used to reduce flanking transmission in stages to show that a partition has achieved a minimum value of the FTL or minimum value of the FSTC which may meet or exceed the criterion. If it is demonstrated that no significant flanking exists through shielding of all potential flanking paths, then, and only then, FTL and FSTC may be reported without qualification.

NOTE 3—Measuring the sound transmission loss properties of a partition itself to demonstrate that it meets or exceeds a specific criterion is very difficult in the field due to the presence of flanking (**2, 3**). Room volume and absorption requirements must also be met.

5.4 Several metrics are available for specific uses. Some evaluate the overall sound isolation between spaces including the effect of absorption in the receiving space and some evaluate the performance or apparent performance of the partition being evaluated. The results obtained are applicable only to the specific location tested.

5.4.1 *Noise Reduction (NR) and Noise Isolation Class (NIC)*—Describe the sound isolation found between the two spaces under consideration. Noise reduction data are based on the space- and time averaged sound pressure levels meeting the requirements of 11.3 or A2.3 as required depending on the sound absorption, volume, and shape requirements of 9.2. Noise reduction values are influenced by the absorption in the receiving space as well as the apparent performance of the partition. The noise reduction values in unfurnished spaces will usually be less than in furnished spaces, and noise reduction values between the spaces may differ depending on the test direction used and the sound absorption in the spaces. However, these effects are lessened when the method of Annex A2 is used.

5.4.2 *Normalized Noise Reduction (NNR) and Normalized Noise Isolation Class (NNIC)*—Describe the sound isolation between two residential or office spaces meeting the requirements of 9.3.1 adjusted to standardized room conditions typical of such spaces when normally furnished.

5.4.3 *Apparent Transmission Loss (ATL) and Apparent Sound Transmission Class (ASTC)*—Describe the apparent sound insulation of a partition separating two spaces. All sound transmission, including any flanking transmission, is ascribed to the partition. The actual transmission loss of the partition will usually be higher than the apparent transmission loss. These results are in theory the same in each direction but may differ with direction in practice.

5.4.4 *Field Transmission Loss (FTL) and Field Sound Transmission Class (FSTC)*—These results should theoretically approach the actual sound insulation of a partition or partition element as would be measured in a laboratory, but in practice they often do not. These values may be reported only if the stringent requirements of Annex A1 to reduce flanking transmission are met. Since all flanking is removed to obtain these metrics, they do not reflect the sound attenuation experienced by the occupants when flanking transmission is significant. These results are in theory the same in each direction but may differ with direction in practice.

NOTE 4—Since the metric ASTC includes the effect of direct and flanking transmission, the ASTC will be less than or equal to the FSTC. The difference depends on the magnitude of the flanking transmission. Thus, the ASTC can be used to demonstrate that a partition at least meets an FSTC requirement and may exceed it. If ASTC is measured under conditions that do not satisfy the more stringent requirements in Annex A1, this may introduce other variations.

6. Test Equipment

6.1 *Sound Sources and Signals*—Sound sources shall be loudspeaker systems driven by power amplifiers. The input signal to the amplifiers shall be random noise containing an approximately continuous distribution of frequencies over each test band. White or pink electronic noise sources satisfy this condition.

NOTE 5—Ideally, loudspeaker systems should be omnidirectional. In practice, using multiple driver elements to cover different frequency ranges and placing and aiming sources into trihedral corners of the room will normally be adequate.

6.1.1 The sound power of the source(s) must be sufficient to raise the signal level in the receiving room far enough above background noise to meet the requirements of 11.8.

6.2 *Measuring Equipment*—Microphones, amplifiers, and electronic circuitry to process microphone signals and perform measurements shall satisfy the requirements of ANSI S1.43 or IEC 61672 for Type 1 integrating-averaging sound level meters, except that B and C weighting networks are not required.

6.2.1 Measurement quality microphones 13 mm or smaller in diameter and that are close to omnidirectional below 5000 Hz shall be used.

NOTE 6—If measurements are to be made above 5000 Hz, a diffuse-field (random-incidence) microphone or corrector is preferred.

6.2.1.1 If multiple microphones are used, they shall all be of the same make and model.

6.3 *Bandwidth and Filtering*—The measurement system filters or each test band, shall meet or exceed the specifications of ANSI S1.11 for one-third-octave band filter set, class 1 or better.

6.3.1 The minimum range of measurements shall be a series of contiguous one-third-octave bands with mid-band frequencies from 125 to 4000 Hz.

NOTE 7—It is desirable that the frequency range be extended to include at least the 100 and 5000-Hz bands.

6.4 *Calibrators*—The field calibrator used for sensitivity checks shall be an acoustic or electroacoustic calibrator meeting class 1 requirements of ANSI S1.40 or IEC 60942.

7. Calibration and Sensitivity Checks

7.1 A thorough calibration of acoustical instrumentation by a calibration laboratory at regular intervals is necessary to help assure that the equipment is operating within instrument standards and manufacturer's specifications. The appropriate calibration interval depends on several factors including the complexity of the instrument, frequency of use, frequency of field use and transportation, manufacturer recommendations, and history of reliability or problems as observed in prior calibrations.

NOTE 8—ANSI S1.10 provides more information on calibration.

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

7.3 Perform sensitivity checks of the entire measuring setup (including the microphone, all cables, and instruments) with the same calibration equipment before and after the measurements. If the calibration values differ by more than 0.5 dB, the results are invalid and measurements shall be repeated.

8. Test Site Conditions

8.1 No building elements that separate and define the source and receiving rooms shall be modified by any temporary means to improve performance except when attempting to measure the field transmission loss in accordance with Annex A1. Any permanent modifications made after the beginning of testing shall be reported.

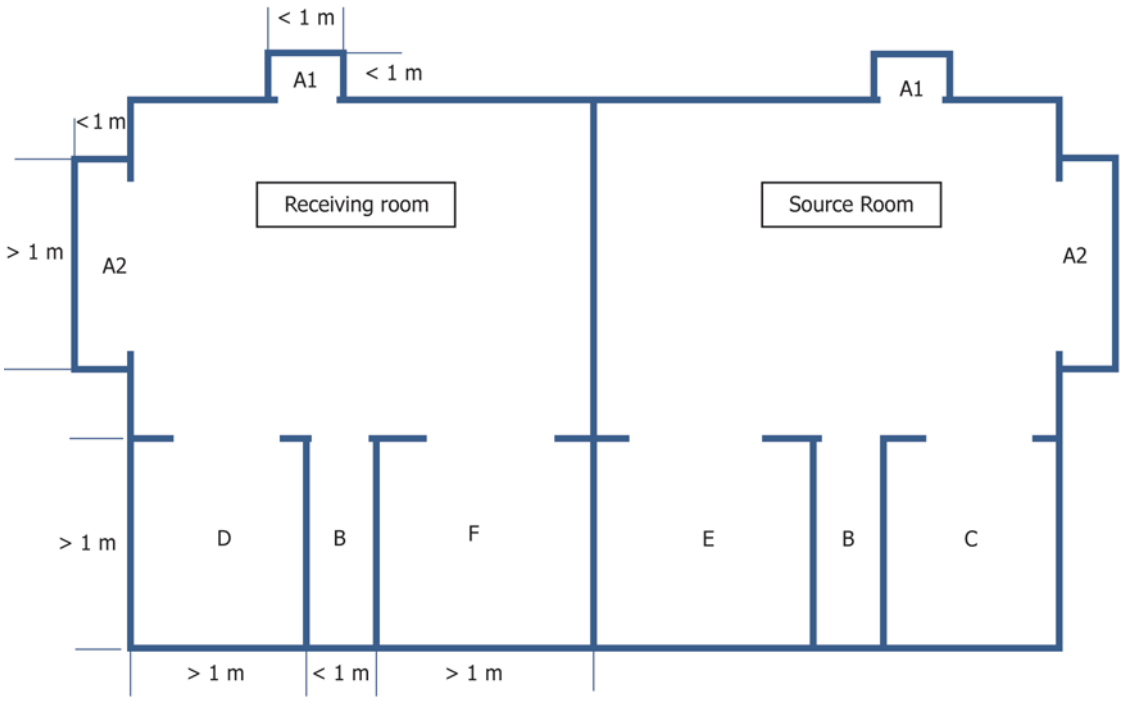
8.2 Flanking transmission in the structure will be present. No efforts to suppress such structural flanking transmission shall be made.

8.3 Major flanking due to doors or other openings into common areas adjacent to the source and receiving rooms may exist. Efforts to suppress such major flanking may be made only if the intent of the test is to evaluate the partition between rooms and structural flanking without the effects of such major flanking. Such efforts must be reported.

8.4 Coupled spaces may exist as part of a basic design where there are adjacent spaces that are partially divided but not separated by doors, or may be created by fully opening doors between adjacent spaces. Multiple coupled spaces may exist adjacent to a given primary space as shown in Fig. 4. Any coupled space included in measurements must be verified. For a space to be considered a coupled space for purposes of this standard, the following conditions must be met:

8.4.1 The opening between the primary and secondary spaces must be at least 33% of the total area of the partition separating the primary and secondary spaces.

8.4.2 Unless one or more of the dimensions of a secondary space is less than 1 m (such as spaces A1, A2, and B in Fig. 4), it must be demonstrated by measurement with the sound source operating that the difference between the space-averaged A-weighted overall sound level in the primary and secondary spaces (such as D and F in Fig. 4) is not more than 6 dB.



A. Always include spaces such as A1 and A2 in volume unless closed off
B. Never include in volume and measurements
C. Do not include in volume and measurements unless needed to meet minimum volume
D. If conditions 8.4.1 and 8.4.2 are met, include in volume and measurements unless closed off
E. Closed off or ensure condition 9.4.10 is met
F. If E is not closed off, include in measurement and volume. If E is closed off, include F in volume and measurements if conditions 8.4.1 and 8.4.2 unless F is closed off also.

FIG. 4 Examples of Potential Coupled Spaces

8.4.3 If either dimension of the secondary space in the plane of the opening between spaces is less than 1 m (such as space B in Fig. 4), the dimension perpendicular to that plane shall not be more than 1 m.

NOTE 9—A bay window, niche, or open shallow closet-like space of less than one meter depth (such as A1 and A2 in Fig. 4) are examples of spaces that could be coupled and considered part of the overall volume without measurements within them but with measurements approaching them.

NOTE 10—A corridor less than 1 m wide and extending away from the primary space for more than 1 m (such as space B in Fig. 4) would not be considered coupled and its volume would not be included as it would be impossible to measure within it.

8.5 *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 (unless the intent is to evaluate a partition that is not fully cured). Aging periods for common materials are recommended in Test Method E90 and summarized in Table 1 of this test method. If materials have not aged as shown in Table 1, testing shall be repeated after an appropriate period until no significant change is observed in results

9. Source and Receiving Space Requirements

9.1 The areas to be used for measurements and restrictions on the size and absorption present in spaces depend on the type of measurement being made. These matters are addressed in this section specifically for each type of measurement.

9.2 There are limited restrictions on the measurements of NR though the procedures differ depending on circumstances. The spaces must be large enough to meet at least the most relaxed requirements of Section 11.

9.2.1 When measurements are being made to determine sound isolation between a particular pair of rooms, the choice of source and receiving room may be specified by the party requesting the test. When this is not specified and the rooms are significantly different in size and furnishings, if NR is to be measured in just one direction, it shall be measured in the direction expected to produce the lowest numerical result.

NOTE 11—Since NR and NIC are not normalized to the sound absorption in the receiving room, it is possible that there will be a significant difference in NR and NIC values measured when the source and receiving rooms are interchanged. This is especially true when the rooms are of substantially different size and degree of sound absorption (which is often determined by the type and amount of furnishings).

TABLE 1 Recommended Minimum Aging Periods Before Testing

Material	Recommended Minimum Aging Period
Masonry	28 days
Plaster:	
Thicker than 3 mm	28 days
Thinner than 3 mm	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

9.2.2 If the volume of the source room (including coupled spaces, if any) and the volume of the receiving room (including coupled spaces, if any) are each less than 150 m^3, the procedures of Section 11 shall be used. While NR is most commonly measured between two fully enclosed spaces, it is possible to define limited areas within such spaces such as a living area or dining area or kitchen area of a larger space and measure just within those areas. When doing so, the specific areas included in the measurements must be clearly identified on a drawing in the report.

9.2.3 If the volume of the source room (including coupled spaces, if any) or the volume of the receiving room (including coupled spaces, if any) are either 150 m^3 or more, the procedures of Annex A2 shall be used. In this case the space may not be divided into smaller functional spaces such as a living or dining area for measurement using the procedures of Section 11.

9.2.4 When the receiving space for an NR measurement is a corridor, the measurement space in the corridor shall be defined as follows and as illustrated in Fig. 5:

9.2.4.1 When the corridor is perpendicular to the separating partition, take measurements in the region 1 to 2 m from the separating partition.

9.2.4.2 When the corridor is parallel to the separating partition, take measurements in the region between the ends of the separating partition.

9.3 *Normalized Noise Reduction*—NNR can only be measured between spaces which meet further restrictions.

9.3.1 NNR may be measured between two spaces meeting the following conditions:

9.3.1.1 The volumes of the spaces on each side of the partition must each be less than 150 m^3.

9.3.1.2 The volume of the receiving room (including coupled spaces, if any) must be at least 25 m^3 and the smallest dimension of the receiving space must be at least 2.3 m. This requirement also applies to functional areas such as living, dining, or kitchen area for which NNR is to be measured.

NOTE 12—The uncertainty of the space average sound pressure level increases with decreasing frequency and with decreasing room volume.

9.3.2 When measuring NNR, all doors present enclosing the source and receiving rooms shall be closed unless doing so would leave primary space too small to meet volume requirements. In that case, if leaving the doors to an adjacent space open would create a coupled space meeting the requirements of 8.4 such that the room including coupled spaces would meet the minimum volume requirement, then all the doors to that coupled space shall be left fully open. However, if doing so increases flanking between the source room and receiving room, this shall be reported.

9.4 *Apparent Transmission Loss and Field Transmission Loss*—ATL and FTL measurements are allowed only when certain requirements on the room volume, dimensions, and absorption are met, with more stringent requirements for FTL.

9.4.1 ATL of a partition may be measured only if the following requirements are met:

9.4.1.1 The volume of the source room (including coupled spaces, if any) and the volume of the receiving room (including

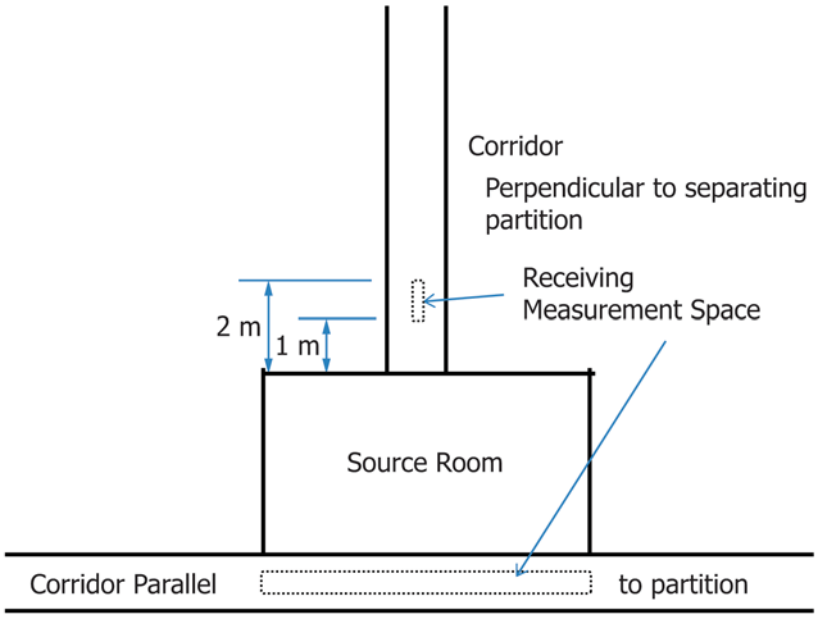


FIG. 5 Receiving Measurement Space in Corridors

coupled spaces, if any), excluding spaces not considered coupled, must each be at least 25 m^3, and the smallest dimension of the primary spaces of each must be at least 2.3 m. The volume and dimensions of individual coupled spaces may be less than these minimums.

9.4.1.2 If the volume of the source room (including coupled spaces, if any) or the volume of the receiving room (including coupled spaces, if any) is 150 m^3 or more, the sound absorption, A, for each room must be measured in accordance with Test Method E2235 in each one-third-octave band from 125 to 4000 Hz inclusive and shown to be less than:

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

where:

V = the room volume. If V is in m^3, then A is in m^2.

9.4.2 FTL may be measured only if all the requirements of Annex A1 are met.

9.4.3 All the requirements of the remainder of 9.4 must be met in measuring ATL or FTL.

9.4.4 If a corridor must be used as one of the spaces for measurement of ATL or FTL, it shall be used as the source space.

9.4.5 When the partition separating spaces is not the same in all areas (for instance a portion of a wall is covered with permanently installed cabinets or there are soffits, or the ceiling is lowered in some areas of a floor-ceiling being evaluated) then the ATL or FTL of the complete partition including the covered or thicker sections shall be reported. The overall area of the partition in the plane of the partition including the area of the partition that is covered by cabinets or soffits or thicker areas shall be used in the calculation. The area of extensions perpendicular to the plane of the partition shall not be included in the area.

9.4.6 All doors present enclosing the source and receiving spaces shall be closed unless doing so would leave primary space too small to meet volume requirements. In that case, if leaving the doors to an adjacent space open would create a coupled space such that the total volume would meet the minimum volume requirement, then all the doors to that coupled space shall be left fully open. A door shall not be opened if doing so would increase flanking between the source room and the receiving room.

9.4.7 *Coupled Spaces*—When either the source or the receiving space immediately adjacent to the separating partition is connected by an unblocked opening to a secondary space that may be coupled, (see Fig. 2), then the existence of a coupled space must be evaluated in accordance with 8.4, and if such exists, the requirements of 9.4.8 – 9.4.11 shall be met. If a space is not found to be coupled, then that space shall not be included in the measurements and its volume shall not be considered in calculations even if it is left open to the primary space.

NOTE 13—Unless needed to meet minimum volume requirements, it is recommended that coupled spaces with all dimensions greater than 1 m and that are open to receiving spaces without doors (such as areas D and F in Fig. 4) be eliminated from the measurement space by blocking openings with sheets of solid material such as gypsum board or plywood if such materials are available.

9.4.8 All coupled spaces on the receiving side not eliminated by the closure of openings shall be included in the measurements and calculations and all coupled spaces on the source side shall be excluded from the measurements, except in the following two cases:

9.4.8.1 The volume of the coupled spaces on the source side is needed to meet minimum volume requirements, or

9.4.8.2 The coupled space on the source side is immediately adjacent to a partition separating it from either the primary or a coupled space on the receiving side (see Fig. 3 and space E in Fig. 4).

9.4.9 When a coupled space exists on only one side of a partition, that side with the coupled space shall be used as the source side whenever all the following conditions exist:

9.4.9.1 The coupled space is not partially bounded by that partition (see Fig. 2),

9.4.9.2 A measurement is to be made in only one direction, and

9.4.9.3 There is no other driving reason to select one direction or the other.

9.4.10 When a coupled space on the source side is immediately adjacent to the receiving space or a space coupled to the receiving space (Fig. 3 or space E in Fig. 4) and must be included in source side measurements in accordance with 9.4.8.2, the overall A-weighted sound level in the coupled space shall be within ± 3 dB of the level in the primary space. If necessary a sound source shall be placed in the coupled space to achieve the required uniformity of sound levels.

9.4.11 The ATL or FTL can be determined for a segment of a partition between the source and receiving space by dividing the source or receiving space into a smaller volume with a temporary partition provided the minimum volume requirements are still met.

10. Sound Sources

10.1 *Location*—Place the sound source(s) at least 5 m from the separating partition unless the room dimensions prohibit this.

10.1.1 If measuring isolation of a vertical partition, and the room is not large enough to permit sound sources 5 m from the partition, place them in the corners of the room most distant from the separating partition. Aim directional sources into the corners.

10.1.2 If measuring the isolation of a floor-ceiling with the source room below, place the sound source(s) on the floor. Aim directional sources into corners.

10.1.3 If measuring the isolation of a floor-ceiling with the source room above, support the sound source(s) so the radiating surfaces are at least 1.5 m (and if practical 2 m in rooms greater than 100 cubic meters volume) above the floor. Aim directional sources toward the nearby reflective surface but not downward. Take steps to provide structural isolation of the source from the floor.

NOTE 14—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. (When the isolating partition is a vertical wall, sources are usually placed in corners away from the isolating partition. When the isolating partition is a floor ceiling structure, the source usually should be placed in the lower room.) Pointing loudspeakers into corners reduces the direct field from the loudspeakers in the source room and is generally recommended even in large rooms. However, it has been observed that the combination of placing speakers within 1 m of the apex of the corner and aiming them horizontally into the corner can introduce a weakness in part of the sound spectrum in the range of measurement, becoming severe as room size increases. Either spacing the speaker at least 1 m from the corner apex or aiming the speaker at least 20° above horizontal will greatly reduce this effect in the frequency range of concern. When this weakness in the spectrum is significant, the NR is reduced in the frequency region of the weakness, but the single number ratings are typically not reduced more than one point even in severe cases.

10.2 If more than one source position is used, the distance between positions shall be at least 2 m. If more than one source is used simultaneously, they shall be driven by separate noise generators and amplifier channels so the outputs are uncorrelated.

NOTE 15—Multiple sources may be necessary to achieve an even sound distribution for noise reduction measurements in some large irregular absorptive spaces.

NOTE 16—It is highly desirable to use more than one source location as results, especially at low frequencies, may be influenced by the position of the source in the room. If desired, measurements may be repeated for several loudspeaker positions and the values averaged to provide a less biased result.

11. Measurement of Average Sound Pressure Levels and Decay Rates

11.1 The test method requires two sets of average sound pressure levels with the source(s) operating in the source room. The first are those in the source room. The second are those in the receiving room measured with the effect of background noise removed if necessary.

11.2 *Averaging Time*—When measuring sound pressure levels in all frequency bands simultaneously at fixed locations, the minimum averaging time shall be 10 s for measurements down to 125 Hz. If frequency bands are measured sequentially, the averaging time may be 5 s at 250 Hz and above. The minimum averaging time, T_a, at frequency f that is less than 250 Hz must be computed from:

$$T_a = \frac{1240}{f}\ \text{s} \tag{4}$$

NOTE 17—This provides 95 % confidence limits of ± 0.5 dB. For more information, see Ref (**4**).

11.2.1 When using mechanically or manually scanned microphones, integration times shall be at least 30 s. Longer times may be required to cover the entire volume to be measured.

11.3 *Measurement Space*—Measurements shall be obtained at suitable minimum distances from the sources, the separating partition, and other room surfaces. These distances are determined by the size of the space and the results that are to be reported.

11.3.1 The requirements stated in this section shall be met for measurements of NNR, ATL and FTL in all cases, and for measurements of NR where conditions permit unless otherwise explained in the report.

11.3.1.1 Microphones shall be placed or scanned in an area at least 1 m from all major extended surfaces.

11.3.1.2 The distance from all sources shall be at least 1 m when the room volume is less than 25 m^3, at least 1.5 m when the room volume is 25 m^3 or larger but less than 100 m^3, and at least 2 m in rooms that are 100 m^3 or larger.

11.3.1.3 If the requirements of 11.3.1.1 and 11.3.1.2 prevent adequate sampling of the measurement region then measurements shall be made at least 0.5 m from room surfaces (**5**), but must never be less than 1 m from the separating partition in the receiving room except as allowed in 11.3.2 or A2.3.1.

11.3.2 When only NR is being measured, measurements may be closer to surfaces than described above if the purpose of the measurement requires it or if it is necessary due to dimensions of the space. See the reporting requirements in 13.2.3.

11.3.3 When coupled spaces are included in the measurement space, measurements of the sound level in each space must be spatially averaged in approximate proportion to the volume of each space by one of the following two methods:

11.3.3.1 When using manually scanned microphones or fixed microphone positions and if the method of 11.3.3.2 including Eq 5 is not used, this shall be accomplished by making the time in each space or the number of microphones in each space in approximate proportion to the volume of each space.

11.3.3.2 When using mechanically scanned microphones (or alternatively with manually scanned or fixed microphones if the method of 11.3.3.1 is not used) measure the sound level in each space and for each one-third-octave band combine the measurements in proportion to the volume of each space as follows:

$$\textit{Volume weighted sound pressure level} = 10log\left(\left[V_1 * 10^{(L1/10)} + V_2 * 10^{(L2/10)} + \ldots + V_n * 10^{(Ln/10)}\right]/V\right) \quad (5)$$

Where:

V_n = is the volume of the primary or coupled subspace n,
L_n = is average sound pressure level in subspace n, and
V = is the total volume of the defined source or receiving room including the primary and coupled spaces.

11.4 *Spatial Sampling Method*—There are three permissible methods to spatially sample the measurement space: fixed microphone positions, mechanically operated microphones, and manually scanned microphones.

11.4.1 When measuring background noise, the same methods, microphone positions, sweep pattern, measurement periods and instrument range settings as used for the measurement of level in the receiving room due to the sound source shall be used.

11.4.2 *Fixed Microphone Positions*—If fixed microphone positions are used, at least six positions shall be used in each room. The positions shall be at least 1 m apart. If and only if the space is too small to allow this, the distance between microphones or number of microphone or both may be reduced. Do not use microphone arrangements that are obviously symmetrical, such as all in the same vertical or horizontal plane.

NOTE 18—To provide independent samples of the sound field, stationary microphones in an ideal diffuse sound field would be spaced at least one-half wavelength apart at the lowest frequency of interest (**5**).

11.4.2.1 *Determination of Space-Average Levels*—When multiple measurements are made in the same room, use the following equation to obtain the average sound pressure level which is a space and time average level:

$$\bar{L} = 10\log\left[\frac{1}{n}\sum_{i=1}^{n} 10^{L_1/10}\right] \quad (6)$$

where:

L_1 = the level measured at the *i*th microphone position and there are *n* locations in the room.

11.4.3 *Moving Microphones*—Moving microphones may be used in conjunction with sound level meters or the equivalent that give integrated levels in accordance with ANSI S1.43 or IEC 61672. Whether mechanically or manually moved, the microphone speed shall not exceed 0.5 m/s.

11.4.3.1 *Mechanically Operated Microphones*—A single microphone continuously moving along a defined traverse such as a circular path may be used if the restrictions given in 11.3 are met at all points on the path. The radius of a circular path must be at least 1 m, and larger if the dimensions of the room allow. The plane of the path shall not be parallel to any surface of the room.

NOTE 19—The minimum radius is required to achieve the equivalent of the minimum required number of points at low frequencies. 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 (**6**).

11.4.3.2 In larger rooms, multiple locations of the microphone traverse may be necessary to adequately sample the room. Avoid patterns that overlap; the size of the path and the number of locations should be adjusted to give adequate coverage. The results of multiple scans shall be averaged using Eq 6.

11.4.3.3 *Manually Scanned Microphones*—When the size of the measurement space allows, the operator shall stand within the space and turn slowly moving the microphone to sample as much of the measurement space as possible without going outside the measurement space. The microphone shall be held well away from the operator's body (a boom serves to increase the distance). For larger rooms, the operator shall walk slowly moving the microphone in a circular path of at least 0.5 m diameter in front to evenly sample as much as practical of the measurement space. For very small rooms where it is impractical for operator to stand within the measurement space and hold the microphone away from the body, the operator shall stand to the side of the measurement space and extend the microphone into the measurement space. The microphone speed shall remain as constant as practical. The operator shall take care to assure that the path does not significantly sample any part of the room volume for more time than other parts. Take care when moving the microphone and its cable, and when walking, especially when measuring sound in the receiving room. The measured data can be contaminated by footstep sounds or extraneous signals due to inadvertent contact between the microphone and the operator's body.

11.5 *Receiving Room Level*—With the sound source(s) operating at a constant level, measure the average sound pressure level at each frequency in the receiving room.

11.5.1 When measurements are made in areas with fluctuating background noise, the operator shall listen to the noise in the receiving room during measurements of the receiving room level. If any intermittent interfering sounds are heard during the measurements, the measurements must be repeated until no such sounds are heard during the collection period.

11.6 *Source Room Level*—With the sound source(s) operating at a constant level, measure the average sound pressure level at each frequency in the source room taking care to avoid the direct field of the sound sources, see 11.3.

11.7 *Background Noise Level*—With the sound source(s) shut off, measure the average sound pressure level at each

frequency in the receiving room using the same instrument range setting used to measure receiving room levels and a minimum averaging time of 30 s at each microphone position.

NOTE 20—A longer integration time is needed for the measurement of background noise since its level may vary significantly with time.

11.7.1 Compare the receiving room levels and background noise levels. If at any frequency the background noise level is within 10 dB of the receiving room level, increase the source level if possible to achieve at least a 10 dB difference at each frequency and repeat all level measurements.

11.7.2 It may be necessary to filter the spectrum of the noise source to concentrate the available sound power in a few bands to increase the source room sound pressure level. In such cases, the bandwidth of the filter applied to the source signal shall extend at least one-third-octave band above and below the frequency band(s) measured in the receiving room.

11.8 *Corrected Receiving room Levels*—If the difference between the background and the combined level in the receiving room due to source and background is more than 10 dB at all frequency bands then no corrections to the receiving room levels are necessary.

11.8.1 If, after increasing the source level, the difference between the background and the receiving room level is between 5 and 10 dB, the adjusted value of the receiving room level shall be calculated as follows:

$$L_s = 10\log\left(10^{L_{sb}/10} - 10^{L_b/10}\right) \tag{7}$$

where:

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

11.8.2 If the background level is within 5 dB of the receiving room level, then subtract 2 dB from the receiving room level and use the result as the corrected receiving room level. In this case, the measurements shall only be used to provide an estimate of the lower limit of the noise reduction or other derivative result. Identify such measurements in the test report.

11.9 *Sound Absorption*—When sound absorption or reverberation time must be established to verify acceptable conditions or to determine the NNR, FTL or ATL, the sound absorption or decay rate shall be measured in accordance with Test Method E2235.

11.9.1 The volume of enclosed cabinets and major appliances such as a refrigerator or range when present shall not be included in the volume used to calculate the sound absorption in the space.

11.9.2 When coupled spaces exist and results are to be reported for combination of primary and coupled spaces, the measurements must represent the full volume.

11.9.2.1 Locate the sound source such that it uniformly excites both the primary and coupled spaces.

11.9.2.2 Select the number of decay rate measurement positions to be in approximate proportion to the volume of the primary and coupled spaces. Decay rate measurements are not required in coupled spaces having volumes that are less than 20 % of the combined volume or the primary and coupled spaces.

11.9.3 When coupled spaces exist and NNR results are to be reported for a portion of the complete space, the requirements of Test Method E2235 shall apply to that partial space.

12. Calculation of Acoustical Quantities and Associated Metrics

12.1 Where both rooms are less than 150 cubic meters, calculate the noise reduction as the difference between the average sound pressure levels obtained in the source and receiving rooms, using:

$$NR = \bar{L}_1 - \bar{L}_2 \tag{8}$$

where:

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

12.1.1 If required, normalized noise reduction values for rooms less than 150 cubic meters shall be calculated as follows:

$$NNR = \bar{L}_1 - \bar{L}_2 + 10\log\left(\frac{T}{0.5}\right) \tag{9}$$

where:

T = the reverberation time in the receiving room, s,

$$T = \frac{60}{d} \tag{10}$$

and:

d = the rate of decay of sound pressure level, dB/s measured in accordance with Test Method E2235.

NOTE 21—This normalization adjusts the noise reduction to values that would be expected in a room with reverberation times of 0.5 s.

12.2 If required, apparent transmission loss values shall be calculated from measurements in the two rooms as follows:

$$ATL = \bar{L}_1 - \bar{L}_2 + 10\log\left(\frac{S}{A_2}\right) \tag{11}$$

where:

S = the area of the test partition, m^2, and
A_2 = the sound absorption in the receiving room, m^2, measured in accordance with Test Method E2235.

12.3 This test method specifies the use of one-third-octave bands for measurement and calculation of noise reduction and all derivative quantities. It does not allow measurement of octave band noise reductions because these are very sensitive to the shape of the source and receiving room spectra. In applications where octave band values are required, they shall be calculated using the expression:

$$NR_{oct,f_c} = -10\log\left[\frac{1}{3}\sum_{B=B_c-1}^{B_c+1} 10^{-NR_B/10}\right] \tag{12}$$

where:

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

12.3.1 The summation is made over three one-third-octave bands *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.

NOTE 22—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 A complete report in accordance with this standard shall include all the elements listed below in this Section 13.

13.1.1 Number all pages of the report, and indicate the total number of pages on each page of the report. Place the following statement on each page of the report that contains results: "This page alone is not a complete report."

13.1.2 Include in the report the following statement if true: "The testing described, the results calculated, and this report fully comply with the requirements of ASTM E336–XX" where XX indicates the last two digits of the year date of the version of the standard used.

13.1.2.1 If there are any exceptions, add the phrase, "with the following exceptions:" and list the exceptions. Such exceptions would include deviations from the required measurement procedures, failure of the measurement spaces to meet the conditions required for a result to be reported, or required elements not included in the report.

NOTE 23—If the results of a test in accordance with this standard are reported in a way that is not in accordance with most of the requirements of this Section 13, including the statement of exceptions to reporting requirements as required above, it is recommended that a statement be included at least noting that such report is not in accordance with this standard.

13.1.3 Include in the report the following statement, "The results stated in this report represent only the specific construction and acoustical conditions present at the time of the test. Measurements performed in accordance with this test method on nominally identical constructions and acoustical conditions may produce different results."

13.1.4 Depending on the results reported include one or more of the following notes in the report for each kind of result reported:

13.1.4.1 If noise reduction is reported: "Noise reduction (NR) and the noise isolation class (NIC) are measurements of the overall sound isolation between two rooms or spaces as found, including the effects of partition size and sound absorption in the receiving room as well as other potential factors in addition to flanking and the sound insulation property of the separating partition."

13.1.4.2 If normalized noise reduction is reported: "Normalized noise reduction (NNR) and the normalized noise isolation class (NNIC) are measurements of the overall sound isolation between two rooms or spaces each less than 150 m^3 in volume but where the receiving space is at least 25 m^3, adjusted to represent an approximation of the performance if the receiving space were normally furnished, including the effect of partition size in addition to flanking and the sound insulation property of the separating partition."

13.1.4.3 If the apparent transmission loss is reported: "Apparent transmission loss (ATL) and the apparent sound transmission class (ASTC) are measurements of the apparent sound insulating property of the separating partition between two spaces each at least 25 m^3 in volume and meeting a limit on absorption if either space is 150 m^3 or greater in volume, including the effects of flanking which distinguishes such results from laboratory results."

13.1.4.4 If the field transmission loss or minimum field transmission loss are reported: "Field transmission loss (FTL) and field sound transmission class (FSTC) are measurements of the sound insulating property of the separating partition between two spaces each at least 40 m^3 in volume and meeting a stringent limit on absorption in the spaces and other requirements, with special efforts to eliminate flanking sound around the partition. If flanking sound is not fully eliminated, the results are referred to as the minimum FTL and minimum FSTC."

13.1.5 If either source or receiving space is less than 25 m^3 or has a dimension less than 2.3 m, identify such measurements clearly and include one of the following notes as appropriate in the report referenced to such measurements:

13.1.5.1 If the receiving space is less than 25 m^3 or has a minimum dimension less than 2.3 m: "NR and NIC results are reported for a space that is too small for reliable and precise measurement of the apparent transmission loss (ATL) of the separating partition or the appropriate reporting or the NNR between spaces. While NR measurements are inherently more precise than ATL or NNR measurements, they are still less precise in small spaces. For the same construction, NR in small spaces, especially small receiving spaces, is typically less than for larger spaces. The reported results cannot and shall not be used as an indicator of the ATL or apparent sound transmission class (ASTC) of the partition or the NNR or normalized NIC (NNIC) between spaces."

13.1.5.2 If the source space only is less than 25 m^3 or has a dimension less than 2.3 m: "Results are reported for a source space that is too small for reliable and precise measurement of the apparent transmission loss (ATL) of the separating partition and which has an influence on the precision of a measurement of the normalized noise reduction (NNR) and resulting normalized NIC (NNIC). While NR measurements are inherently more precise than ATL or NNR measurements, they are still less precise in small spaces. For the same construction, NR and NNR in small spaces, especially small receiving spaces, are typically less than for larger spaces. The reported results cannot and shall not be used as indicators of the ATL or apparent sound transmission class (ASTC) of the partition."

13.2 *Description of Test Environment and Separating Partition*—Provide the following:

13.2.1 A general description of the source and receiving spaces and their environs, including furnishings, and clearly indicating which is the source and which is the receiving room if measurements are made in only one direction.

13.2.2 The major dimensions and volumes of the test rooms. Provide a sketch showing the layout unless the two rooms are similar rectangular parallelepipeds. Whenever NR or NNR are reported for portions of an enclosed space less than the total

enclosed space such as a dining or living area of a great room, clearly indicate the boundaries of the space measured with the dimensions and volumes of those spaces and qualify any such result with the following statement, "These results are specifically for the measurement space described in this report which is less than the total enclosed space."

13.2.3 If NR is reported in accordance with 11.3.2 or A2.3.1, clearly describe the measurement space used and proximity of measurements to surfaces.

13.2.4 A clear indication of any coupled spaces included or not included in the measurements and any openings to adjacent spaces not closed off with doors or otherwise even if such spaces are not coupled.

13.2.5 To the extent information is available give a complete description of the separating partition, including all of the essential constructional elements, the thickness, and dimensions. This will often be based on the documented intended design, variances from the design reported, or differences observable without examining the interior of the partition. The source of any description shall be stated.

13.2.6 If the construction or installation of the separating partition is observed to be different from the documented design by intent or due to construction defect, such that the results do not represent performance of the separating partition as shown in the design, state these differences. Where such differences occur, place an indication on each page with results so affected indicating the specific results affected.

13.3 *Description of Test Procedure and Equipment:*

13.3.1 Report the method of measurement for sound levels (scanning or fixed microphone), number of fixed microphones if used, and number of sources.

13.3.2 Note specifically if the procedures of Annex A1 or Annex A2 were used.

13.3.3 Describe the procedures, if used, to evaluate possible flanking transmission.

13.3.4 List all sound source and measurement equipment including microphones and field calibrators by make, model, and serial number where applicable, and for the measurement equipment including microphones and field calibrators also list the date of the last complete laboratory calibration.

13.3.5 If tests were conducted with the source room above the receiving room, describe the method used to isolate the sound source(s) from the floor.

13.4 *Statement of Test Results:*

13.4.1 State clearly the type of results that are being presented (NR, NNR, ATL, FTL or a minimum value of the FTL). All such data presented must be in tabular form rounded to the nearest decibel and may be in graphical form. If the ATL or FTL are measured in both directions, report the result for each direction clearly indicating the direction for each. If desired, the results in two directions may be arithmetically averaged and the average result reported in addition to but not instead of the results in each direction. The average shall be performed using results to one decimal place and the average result reported to the nearest decibel.

13.4.2 State the values of $\bar{L}_1$, $\bar{L}_2$, and background noise, accurate to one decimal place, and if measured state A_2 to three significant figures or T to hundredths of a second.

13.4.3 Clearly indicate in the stated results the frequencies at which receiving room sound pressure levels were within 5 dB of the background noise levels (see 11.7.2).

13.4.4 If minimum values of the FTL are being estimated according to Annex A1, clearly mark those frequencies where the room volume, shape or absorption requirements of A1.4 are not satisfied and explain.

13.4.5 If shielding as described in Annex A1 was applied in several steps, report the ATL before shielding and the minimum values of FTL measured at each step. If all possible flanking surfaces were covered in each room and all room volume, shape, and absorption requirements of A1.4 are satisfied, the values obtained under this condition may be presented as FTL values.

13.5 *Single Number Ratings:*

13.5.1 Report the NIC unless measurements were made for ATL or FTL in large spaces such that appropriate data are not available.

13.5.2 If required for the purposes of the test, report the NNIC.

13.5.3 If required for the purposes of the test, and where applicable if the requirement of 9.4.1 is met in all frequency bands required to compute the rating, report the ASTC.

13.5.4 If required for the purposes of the test, and if all requirements of Annex A1 were met in all frequency bands necessary to compute the rating, but not all potential flanking surfaces were shielded, report the values measured as minimum estimates of FSTC.

13.5.5 If all surfaces in both rooms were shielded, except for the test specimen, the result for that case shall be reported as the FSTC.

14. Precision and Bias

14.1 *Precision*—Repeatability for this test method may be thought of as the variation that might be seen if the same measurement team repeated the measurements between the same two rooms using the same equipment with perhaps some minor variations in microphone and loudspeaker positions. The study described in Ref (**7**) has been used to obtain estimates of repeatability standard deviations under conditions suitable for the measurement of FTL. They are as follows: 2 dB for the frequency bands 100 to 200 Hz and 1 dB for the bands above that. The corresponding 95 % repeatability limits are 5.6 and 2.8 dB. The repeatability standard deviation for FSTC from this work was estimated as 1.3 dB. The 95 % repeatability limit for FSTC is thus 3.6 dB. Reproducibility for this test method may be thought of as the variation that might be seen if different measurement teams with different equipment were to repeat the measurements between the same two rooms. Based on an analysis of the same study in Ref (**7**), the reproducibility standard deviations are 3 dB (100 to 160 Hz), 2 dB (200 to 400 Hz), and 1 dB at 500 Hz and above. The corresponding 95 % reproducibility limits are 8.4, 5.6, and 2.8 dB. The reproducibility standard deviation for FSTC from this work is estimated as 1.9 dB and the 95 % reproducibility limit is thus 5.3 dB. The repeatability and reproducibility data obtained from this study apply only to the spaces where the repeat measurements were made; other pairs of rooms with different acoustical conditions

will have different values. Reproducibility limits are likely to be greater for spaces with complex geometries or where volumes are not clearly defined. Repeatability and reproducibility may be reduced in spaces with volumes less than 40 m^3, and especially in spaces with volumes less than 25 m^3. Measurements of NR are inherently more repeatable and reproducible than measurements of ATL or NNR that require measurement of the sound absorption.

14.2 *Bias*—The bias in this method is unknown since there is no known true value.

15. Keywords

15.1 airborne sound transmission loss; apparent sound transmission class; apparent transmission loss; field sound transmission class; field 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 TRANSMISSION LOSS

A1.1 *Scope*—It may be necessary to demonstrate that a partition meets criteria for field transmission loss or field sound transmission class. Measuring sound transmission loss of a partition in the field is much more difficult than in a laboratory.

A1.1.1 This annex describes the room and partition conditions and shielding procedures necessary to measure the field transmission loss or to establish a minimum value of it.

A1.2 *Significance*—In most cases, it will be enough to demonstrate that the partition sound insulation is at least as good as a stated criterion by establishing a minimum value of the FTL or FSTC. If these lower minimum values satisfy the sound insulation criteria, then testing can cease before all possible flanking paths have been shielded, or possibly without any shielding.

A1.2.1 If the field transmission loss of the test specimen is required, it is necessary to reduce flanking transmission to a negligible level so measured levels in the receiving room correspond only to that sound which is transmitted directly through the partition under test. This requires shielding all surfaces in both rooms except the specimen under investigation.

A1.3 *Summary of Procedure*:

A1.3.1 Verify that the room volume and shape, partition size, and temperature meet the requirements in this annex.

A1.3.2 Verify by measurement according to Test Method E2235 that the room absorptions are low enough.

A1.3.3 Measure apparent transmission loss values according to the main part of the standard.

A1.3.4 Shield room surfaces, if necessary, and repeat measurements (including sound absorption measurements) until minimum values of the FSTC or FTL meeting a stated criterion are met.

A1.3.5 When all surfaces except the test specimen are shielded, the results are FTL and FSTC values.

A1.4 *Required Conditions*—To make acceptable measurements of field transmission loss, the following conditions must be met:

A1.4.1 *Room Volume*—The volume of each room shall be not less than 60 m^3 for measurements down to 100 Hz, 40 m^3 for measurements down to 125 Hz, and 25 m^3 for measurements down to 160 Hz. Where these criteria are not satisfied, no attempt shall be made to determine field transmission loss. The field sound transmission class shall not be reported unless the volume of each room is at least 40 m^3.

NOTE A1.1—The minimum room volume requirement at 125 Hz is obtained by assuming 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. 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.

A1.4.2 When a coupled space or any adjacent space open to the measurement space is present, the requirements of 9.4.4 – 9.4.11, 11.3.3, 11.9.1, and 13.3.5 shall be met.

A1.4.3 *Room Shape*—In addition to the minimum volume requirement in A1.4.1, it is preferable to avoid extreme ratios of room dimensions for both source and receiving rooms. Therefore, for each room the ratio of the maximum to minimum dimension shall be less than or equal to three. The room height shall be 2.3 m or greater and no lateral room dimension shall be less than 2.75 m, the wavelength of the center frequency of the 125 Hz one-third-octave band. When coupled spaces are included within the measurement space for either source or receiving room, these restrictions apply to the overall space including the coupled spaces.

A1.4.4 *Room Absorption*—At all frequencies, the room absorption, A, for each room shall be less than:

$$A = V^{2/3} \quad \text{(A1.1)}$$

where:

V = the room volume. If V is in cubic meters, then A is in square meters.

NOTE A1.2—This condition corresponds to a minimum reverberation time in the range 0.6 to 1.0 s for room volumes ranging from 50 to 250 m^3.

A1.4.4.1 Sound absorption shall be measured in each room using the procedures of Test Method E2235.

NOTE A1.3—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.

A1.4.5 *Partition Area*—The dimensions of the part of the test partition common to both source and receiving rooms shall be at least 2.3 by 2.4 m, unless a door or window is being evaluated.

NOTE A1.4—Very small partitions often yield different transmission loss values from large ones of nominally identical construction. Comparisons of measurement results for partitions of significantly different dimensions can be misleading.

A1.4.5.1 If the purpose of the test is to evaluate typical performance of a partition, the size and mounting conditions of the test specimen shall be representative of the type of partition under study. Any unusual feature not characteristic of the structure under test shall be avoided.

A1.4.6 *Temperature*—Measure and report the room temperature in each room. Maintain the temperature in each room in the range of 17 to 27°C.

A1.5 If the two rooms on opposite sides of the partition are very dissimilar in size, the larger room is usually the better choice as receiving room especially if the smaller room is less than 50 m^3. However, specific conditions such as a lower background sound level in the smaller room or particular concern about transmission from the larger to smaller room may make the smaller room the better choice as the receiving room.

A1.6 *Shielding Room Surfaces*—To shield a room surface, apply materials that will increase the transmission loss by at least 10 dB. The shielding shall be sealed at joints and around the perimeter with tape, gaskets or caulking compound, so as to form a complete auxiliary wall.

NOTE A1.5—A suitable construction consists of a layer of plywood or gypsum board weighing at least 10 kg/m^2, freestanding or lightly supported from the surface and spaced at least 100 mm from it, with soft sound-absorbing material such as glass fiber batts in the space. It may be convenient to arrange the panels in a splayed, ziz-zag configuration so that, when the edges are taped together to form a hinge, the array is free-standing, like a decorative screen.

A1.6.1 Ensure that the shielding does not cover any of the structural elements making up the specimen under test. For example, in the case of a door or 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.

A1.7 *Unshielded Measurement of Apparent Transmission Loss*—Measure the apparent transmission loss as described in the main body of the standard with no shielding applied. If the requirements of this annex are met, and the ATL and ASTC meet the stated sound insulation criteria for the test, no further testing may be necessary and it may be stated that the FTL and FSTC are at least as good as the ATL and ASTC values measured.

A1.8 *Shielded Measurements to Establish Field Transmission Loss or a Minimum Value of it*—If the sound insulation criteria are not met, then select one or more room surfaces suspected of being flanking paths and shield them as described in A1.6.

A1.8.1 Measure the results for this shielded condition. If the sound insulation criteria are met, no further testing may be necessary and it may be stated that the FTL and FSTC are at least as good as the values measured. Continue covering additional surfaces and measuring at least until the stated sound insulation criteria are met.

A1.9 Results may be stated as actual FTL and FSTC values only if all surfaces in both rooms, except for the test specimen, are shielded. Otherwise, results should be clearly stated as minimum values of the FTL and FSTC.

A1.10 No changes to measured data shall be made to account for differences between field data and laboratory values.

NOTE A1.6—After the apparent and field transmission loss measurements have been made, data may be compared with laboratory transmission loss data for a similar type of partition. One should not necessarily expect close agreement. Substantial differences may exist for similar partitions when measured in the two situations, even though efforts are made to minimize leaks and flanking transmission (**2**). Widely divergent trends may indicate the existence of undiscovered flanking paths, of leaks, or of deviations from the nominal construction of the test specimen.

A2. MEASUREMENT OF NOISE REDUCTION BETWEEN LARGE SPACES

A2.1 *Scope*—This annex describes modified procedures for measurement of noise reduction in cases where at least one of the rooms has a volume of 150 m^3 or more. In such cases, sound fields often have significant gradients in level as the distance from the specimen is increased or across the surface of the specimen. Additional measurement procedures and a restriction of the measurement regions are necessary to deal with these problems.

A2.1.1 This annex shall not be applied if both rooms have volumes less than 150 m^3 but must be applied to all measurements of noise reduction if either room has a volume of 150 m^3 or greater.

A2.1.2 ATL and FTL also may be measured when a room has a volume of 150 m^3 or greater under limited circumstances. This annex does not apply to such measurements.

A2.2 *Significance*—It is assumed in this annex that the sound fields in the rooms are not diffuse. The only measurements appropriate for such spaces are close to the partition. The noise reduction and noise isolation class values obtained relate most directly to the isolation observed not too far from the partition.

A2.3 *Measurement Space*—The measurement space wherever possible shall be the region 1 to 2 m from the partition, and at least 1 m from other surfaces on each side of the partition. For vertical partitions, measurements shall be confined to the space 1 to 2 m from the floor.

A2.3.1 Measurements may be closer to surfaces than decribed above if the purpose of the measurement requires it or if it is necessary due to dimensions of the space. See the reporting requirements in 13.2.3.

A2.4 *Source Side Sound Field Uniformity*—The sound field across the test partition on the source room side must be shown to be uniform if the width is more than twice the height for vertical partitions or length is more than twice the width for floor-ceilings.

NOTE A2.1—To achieve sufficient sound level in large rooms, it is permissible to face speakers toward the separating partition.

A2.4.1 Scan the measurement space on the source side, measuring and observing the A-weighted slow sound level. If the difference between the maximum and minimum such level is no more than 4 dB, the sound field is satisfactory, and measurements may proceed.

A2.4.2 If the difference observed in A2.4.1 is more than 4 dB, divide the surface of the partition into approximately square areas with each side of the squares equal to the smaller dimension of the partition. Temporarily mark the divisions in any convenient manner.

A2.4.2.1 Measure the average A-weighted sound level in the region in front of each square of the partition, in the source side measurement space. In these measurements, each region shall be treated as though it were a separate room. Any of the methods for determining average sound pressure level in a room described in 11.4 is acceptable for this measurement.

NOTE A2.2—An integrating-averaging sound level meter meeting the requirements of ANSI S1.43 or IEC 61672 and scanned manually will be most convenient for this procedure.

A2.4.2.2 The difference between the maximum and minimum of the average A-weighted sound levels for all regions shall not exceed 3 dB. If this is not the case, the loudspeaker arrangement shall be improved and the measurements repeated until this requirement is satisfied. Once the sound field on the source room side has been shown to be satisfactory, the measurements may proceed.

NOTE A2.3—The sound field uniformity can be improved by adding more loudspeakers. Some improvement may also be possible by empirically adjusting the orientation of the loudspeakers.

A2.5 *Source and Receiving Room*—Measure the average sound pressure level at each frequency in the measurement space on each side of the partition using fixed microphones, mechanically scanned microphones, or a manually scanned microphone.

A2.5.1 If fixed microphones are used, use enough microphone positions to completely sample the measurement space as defined in A2.3. The distance between microphone positions shall not be more than 3 m. In all cases, at least six positions shall be used.

A2.5.2 If mechanically scanned microphones are used, use enough scans to completely sample the measurement space defined in A2.3. The distance between centers of scans shall not be more than 4 m. The radius of a circular scan shall be between 0.5 and 0.7 m. In all cases, at least three scans shall be used.

A2.5.3 If a manually scanned microphone is used, follow the procedure in 11.4.3.3 to sample the measurement space defined in A2.3.

A2.6 *Background Noise Levels*—With the sound sources shut off, measure the background noise at each frequency in the receiving room following the same procedures used to measure the receiving room level. Follow the procedures in 11.7 and 11.8 to obtain the corrected receiving room levels.

A2.7 *Calculations*—When multiple measurements are made on each side, calculate for each frequency the average level on the source side $\bar{L}_1$ and on the receiving side $\bar{L}_2$ according to 11.4.2.1.

A2.7.1 Calculate the noise reduction according to:

$$NR = \bar{L}_1 - \bar{L}_2 \qquad \text{(A2.1)}$$

A2.7.2 Report only the noise reduction, NR, and the noise isolation class, NIC, for these measurements. No other metrics contained in this test method shall be calculated or reported based on these measurements.

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