Designation: E 2249 – 02

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

This standard is issued under the fixed designation E 2249; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This standard test method is part of a set for evaluating the sound transmission loss of a partition or partition element under laboratory conditions. It differs from Test Method E 90 in that the sound power radiated by the element under test is measured directly using an intensity probe rather than indirectly from the space averaged receiver room sound pressure and the room reverberation time. This test method is especially useful when the receiver room requirements of Test Method E 90 can not be achieved, or flanking sound involving the receiver room surfaces is present but its influence is to be circumvented **(1)**[2], as discussed in Annex A3.

Others test methods to evaluate sound insulation of building elements include: Test Method E 90, airborne transmission loss of an isolated partition element in a controlled laboratory environment, Test Method E 492, laboratory measurement of impact sound transmission through floors, Test Method E 336, measurement of sound isolation in buildings, Test Method E 1007, measurement of impact sound transmission in buildings, Guide E 966, measurement of sound transmission through building facades and facade elements.

1. Scope

1.1 This test method covers the measurement of airborne sound transmission loss of building partitions such as walls of all kinds, operable partitions, floor-ceiling assemblies, doors, windows, roofs, panels and other space-dividing building elements. It may also be have applications in sectors other than the building industry, although these are beyond the scope.

1.2 The primary quantity reported by this standard is Intensity Transmission Loss (ITL) and shall not be given another name. Similarly, the single-number rating Intensity Sound Transmission Class (ISTC) derived from the measured ITL shall not be given any other name.

1.3 This test method may be used to reveal the sound radiation characteristics of a partition or portion thereof.

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

NOTE 1—The method for measuring the sound intensity radiated by the building element under test defined by this ASTM standard meets or exceeds those of ISO 15186-1. Special consideration will have to be given to requirements for the source room and specimen mounting if compliance with ISO 15186-1 is also desired as they differ from those of this standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C 634 Terminology Relating to Environmental Acoustics[3]

E 90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements[3]

E 336 Test Method for Measurement of Airborne Sound Insulation in Buildings[3]

E 413 Classification for Rating Sound Insulation[3]

2.2 *ANSI Standards:*[4]

S1.9 Instruments for the Measurement of Sound Intensity

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

2.3 *ISO Standards:*[4]

ISO 140-3 Acoustics—Measurement of Sound Insulation in Buildings and of Building Elements—Part 3: Laboratory Measurements of Sound Insulation of Building Elements

ISO 9614-1 Acoustics—Determination of Sound Power

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

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

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

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

Levels of Noise Sources Using Sound Intensity—Part 1: Measurement at Discrete Points

ISO 9614-2 Acoustics—Determination of Sound Power Levels of Noise Sources Using Sound Intensity—Part 2: Measurement by Scanning

ISO 15186-1 Acoustics—Measurement of Sound Insulation in Buildings and of Building Elements Using Sound Intensity—Part 1: Laboratory Conditions

ISO 15186-2 Acoustics—Measurement of Sound Insulation in Buildings and of Building Elements Using Sound Intensity—Part 2: In-Situ Conditions

2.4 *IEC Standard:*[5]

IEC 1043 Instruments for the Measurement of Sound Intensity

3. Terminology

3.1 The acoustical terminology used in this method is intended to be consistent with the definitions in Terminology C 634 and Test Method E 90. Unique definitions of relevance to this test method are presented here:

3.1.1 *sound intensity, I*—time averaged rate of flow of sound energy per unit area in the direction of the local particle velocity. This is a vector quantity which is equal to:

$$\vec{I} = \frac{1}{T}\int_0^T p(t)\cdot\vec{u}(t)\cdot dt\,\frac{W}{m^2} \quad (1)$$

where:

$p(t)$ = instantaneous sound pressure at a point, Pascals,

$\vec{u}(t)$ = instantaneous particle velocity at the same point, m/s, and

T = averaging time, s.

3.1.2 *normal sound intensity, I_n*—component of the sound intensity in the direction normal to a measurement surface defined by the unit normal vector $\vec{n}$:

$$I_n = \vec{I}\cdot\vec{n}\,\frac{W}{m^2} \quad (2)$$

where:

$\vec{n}$ = unit normal vector directed out of the volume enclosed by the measurement surface.

3.1.3 *normal unsigned sound intensity level, $L_{|In|}$*—ten times the common logarithm of the ratio of the unsigned value of the normal sound intensity to the reference intensity I_o as given by:

$$L_{|In|} = 10\log\frac{|I_n|}{I_o}\text{ dB} \quad (3)$$

where:

$$I_o = 10^{-12}\frac{W}{m^2} \quad (4)$$

3.1.4 *normal signed sound intensity level, L_{In}*—ten times the common logarithm of the ratio of the signed value of the normal sound intensity to the reference intensity I_o as given by:

$$L_{In} = sgn(I_n)\,10\log\frac{|I_n|}{I_o}\text{ dB} \quad (5)$$

where:

$sgn(I_n)$ = takes the value of negative unity if the sound intensity is directed into the measurement volume, otherwise it is unity.

3.1.5 *pressure-residual intensity index, δ_{pI_o}*—the difference between the sound pressure level, L_p, and the unsigned normal sound intensity level when the intensity probe is placed and oriented in a sound field where the sound intensity is zero, expressed in decibels,

$$\delta_{pI_o} = L_p - L_{|In|} \quad (6)$$

Additional details can be found in IEC 61043.

3.1.6 *measurement surface*—surface totally enclosing the building element under test on the receiving side, scanned or sampled by the probe during the measurements. This surface has an area S_m expressed in m^2.

3.1.7 *measurement distance, d_m*—distance between the measurement surface and the building element under test in a direction normal to the element.

3.1.8 *measurement subarea*—part of the measurement surface being measured with the intensity probe using one continuous scan or a series of discrete positions. The *k*th measurement subarea has an area S_{mk} expressed in m^2.

3.1.9 *measurement volume*—the volume that is bounded by the measurement surface(s), the building element under test, and any connecting non-radiating surfaces.

3.1.10 *measurement array*—a series of fixed intensity probe positions where each position represents a small subarea of the sub-divided area of a measurement surface.

3.1.11 *discrete point method*—a method of integrating the sound intensity over the entire measurement surface where a series of stationary microphone positions are chosen to adequately sample the test partition.

3.1.12 *scanning method*—a method of integrating the sound intensity over the entire measurement surface whereby a series of subareas are scanned by moving the intensity probe in a methodical fashion to adequately sample the test partition.

3.1.13 *field indicators*—a series of indicators used to assess the quality of the measurement conditions, and ultimately the accuracy, of the intensity measurement.

3.1.13.1 *dynamic capability index, L_d*—a measure of the usable dynamic range of an intensity measuring system (which is a function of the phase mismatch of the system and the bias error factor, *K*), expressed in decibels.

3.1.13.2 *surface pressure-intensity indicator*—the difference between the sound pressure level, and the normal sound intensity level on the measurement surface, both being time and surface averaged. F_2 is used for the discrete point method and F_{pI} and for the scanning method.

3.1.13.3 *negative partial power indicator, F_3*—the difference between the average sound pressure level integrated over a measurement surface and signed (accounting for direction) average normal intensity level.

3.1.13.4 *field non-uniformity indicator, F_4*—this measure is only applicable to the discrete point method and assess the suitability of the selected measurement array.

NOTE 2—The field indicators and criteria used by this standard are based on those of ISO 9614 and are a more stringent superset of those

[5] Available from International Electrotechnical Commission (IEC), 3 Rue de Varembe, CH 1211, Geneva 20, Switzerland.

required by ISO 15186-1. Functional definitions are given in Annex A1 and Annex A2.

3.1.14 *flanking transmission*—transmission of sound from a source to a receiving location other than directly through the element under consideration.

3.1.15 *sound transmission loss, TL*—In a specified frequency band, ten times the common logarithm of the ratio of the incident sound power, W_i, to the sound power transmitted though the specimen under test, W_t, expressed in decibels.

$$TL = 10 \log_{10}\left[\frac{W_i}{W_t}\right] \quad (7)$$

NOTE 3—For this standard, *TL* is operationally defined by Eq 13 and differs from the definitions given in Test Method E 90 only in the way that the transmitted sound power is estimated.

NOTE 4—Transmission loss is a property of the specimen and to a first approximation, is independent of the specimen area and dimension. Nevertheless, results of specimens that have significantly different dimensions and aspect ratios can vary significantly, especially at low frequencies, as this will hinder comparison. It is for this reason that this standard requires a minimum area for the test specimen.

4. Summary of Test Method

4.1 The building element under test is installed between two spaces creating two spaces as conceptually shown in Fig. 1. The source space is a well-defined room satisfying the criteria of Test Method E 90 while the other, the receiver room, has no specific physical requirements for size or absorption condition. It is assumed that the sound field in the source room is approximately diffuse since the incident sound power is estimated from the space averaged sound pressure level. The sound power transmitted into the receiver space is estimated from direct measurement of the radiated sound intensity over a measurement surface that completely encloses the portion of the building element in the receiver room. The transmission loss of the building element is then estimated using the incident and transmitted sound powers. Because transmission loss is a function of frequency, measurements are made in a series of frequency bands.

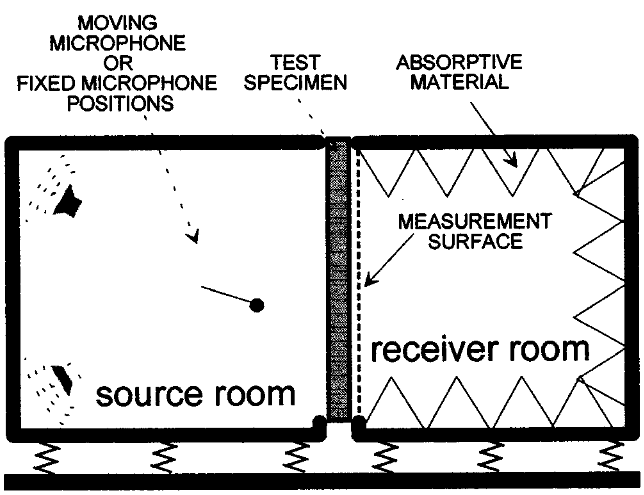


FIG. 1 Conceptualized Testing Arrangement Showing the Source and Receiving Rooms

5. Significance and Use

5.1 This test method can be used to obtain an estimate the transmission loss of building elements in a laboratory setting where the source room and the specimen mounting conditions satisfy the requirements of Test Method E 90. The acceptability of the receiving room will be determined by a set of field indicators that define the quality and accuracy of the intensity estimate.

5.2 By appropriately constructing the surface over which the intensity is measured it is possible to selectively exclude the influence of sound energy paths including the effects from joints, gaps as well as flanking sound paths. This method may be particularly useful when accurate measurements of a partition can not be made in an Test Method E 90 facility because the partition sound insulation is limited by flanking transmission involving facility source and receiver room surfaces, (for example, the path from the source room floor to the receiver room floor via the isolators and the slab supporting the two). Annex A3 discusses this in detail.

5.3 The discrete point method allows the mapping of the radiated sound intensity which can be used to identify defects or unique features **(2)** of the partition.

5.4 Current research reported in the literature indicate that there exists a bias between measures of transmission loss obtained using the intensity technique and those obtained using the conventional two room reverberation technique (for example, Test Method E 90, **(3)** and **(4)**). Appendix E provides estimates of the bias that might be expected. Despite the presence of a bias, no corrections are to be applied to the measured data obtained by this test method.

6. Test Rooms

6.1 *Source Room*—The source room shall possess the following properties:

6.1.1 It shall comply with the relevant sections of Test Method E 90. In particular, it shall possess the appropriate room size, shape, volume, diffusion, absorption characteristics.

6.1.2 Flanking paths involving source room surfaces and the specimen shall be insignificant relative to direct transmission through the specimen under test. The procedure and criterion of Annex A3 shall be followed and satisfied.

6.2 *Receiving Room or Space*—The receiving room may be any space meeting the requirements for background noise and the field indicators and associated field criteria (Annex A1 for the discrete point method, and Annex A2 for the scanning method).

7. Test Partitions

7.1 *Size, Mounting and Ageing*—Specimens shall be installed in full compliance with all relevant requirements of Test Method E 90.

8. Test Signal Sound Sources

8.1 *Signal Spectrum*—The sound signals used for these tests shall be in full compliance with the requirements of Test Method E 90.

8.2 *Sound Sources*—The number, characteristics, orientation and location of loudspeakers shall be in full compliance with the requirements of Test Method E 90.

8.3 *Standard Test Frequencies*—As a minimum, measurements should be made at all of the one-third-octave bands stated in Test Method E 90.

9. Measurement Surface

9.1 The measurement surface shall define a measurement volume that (*1*) completely encloses the portion of the specimen under test, (*2*) contains no extraneous or flanking sources, (*3*) contains no absorbing materials that are not part of the specimen, and (*4*) satisfies the field indicator criteria.

9.1.1 An absorptive material is defined as a material having an absorption coefficient greater than 0.1 in any of the frequency bands for which data will be reported.

NOTE 5—The measurement surface must be chosen so that all the radiated sound power of the portion of the building element under test passes through the measurement surface. Failure to do so will cause a significant underestimation in the radiated sound power.

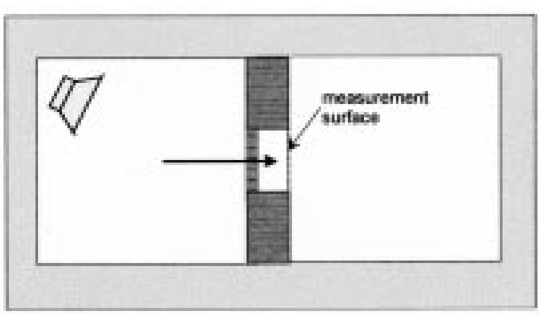
9.2 Define one or more flat hypothetical surfaces that satisfy the conditions of 9.1. Measurement distances shall be no less than 0.1 m. Initially, select a distance between 0.1 and 0.3 m. Longer distances are usually undesirable since the proportion of direct to reverberant field decreases with increasing measurement distance. Measurement positions inside a niche shall be avoided.

NOTE 6—Measurement points closer than 0.1 m are to be avoided because of near field effects. Measurement conditions in a niche are usually unfavorable due to the presence of standing waves.

9.2.1 The number of surfaces needed to construct the measurement surface can be reduced if the building element under test is bounded by a rigid non-absorbing surface as shown in Figs. 2 and 3. A rigid non-radiating surface is defined as one having, in all frequency bands for which data are to be reported, a transmission loss in excess of 20 dB, and a radiated sound power that is at least 10 dB lower than the power radiated by the building element under test.

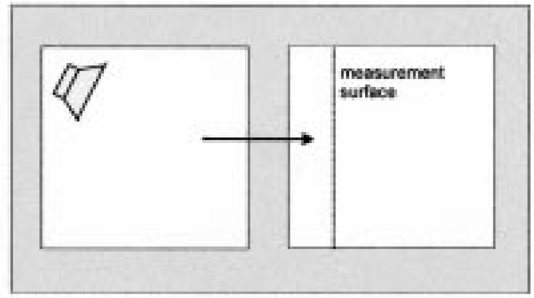
9.2.2 Typically small building elements, such as windows, require the use of a five-sided box as shown in Fig. 4, and the measurement distance shall be no more than 0.3 m.

NOTE 7—As shown in Fig. 4, four of the five faces of the box-shaped measurement surface intersect the perimeter of the element under test. These side surfaces will have a depth equal to 0.1 to 0.3 m; the distance between the frontal face and the specimen. Thus, complete sampling of the side surfaces may include the effect of near-field radiation. This situation can be avoided by providing an offset of 0.1 m for the four sides of the box-shaped measurement surface when the sound power radiated by the building element under test is considerably greater than that radiated by non-specimen surfaces contained in the measurement volume. Radiation from the non-specimen surfaces can be viewed as being unwanted flanking and this alternate configuration can only be deemed acceptable if the sound power is 10 dB lower than that radiated by the partition.



A single measurement surface can be used when the specimen is mounted in a niche as shown above.

FIG. 2



A single measurement surface can be used when the specimen is bounded on all sides as shown above.

FIG. 3

9.3 Once an appropriate measurement surface has been defined, each face of the surface may be subdivided into smaller subareas arranged in rows and columns, which establish the measurement array.

NOTE 8—For convenience it is recommended to make each subarea of equal area although the subareas may be smaller on the side faces of a box surface than the frontal face.

9.4 When the discrete point method of measurement is used, the probe shall be placed in the geometric centre of each subarea with the probe axis normal to the subarea, and transported either by mechanical means or by a human operator.

9.5 When the scanning method of measurement is used, the probe will be passed over the entire surface of each subarea, and transported either by mechanical means or by a human operator.

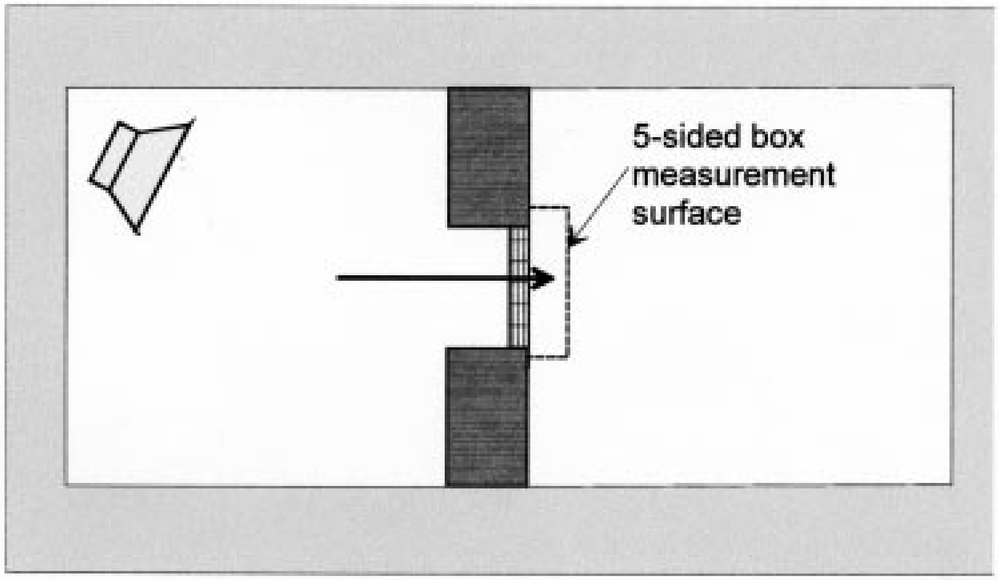
10. Microphone and Intensity Probe Requirements

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

10.2 *Source Room Microphones*—Microphones are used to measure average sound pressure levels in the source room. The electrical characteristics and calibration procedures shall comply with the relevant sections of Test Method E 90.

10.3 *Source Room Microphone Positions*—Stationary microphone positions or a moving microphone may be employed to determine the space-average sound pressure level in the source room. The system adopted shall comply with the relevant sections of Test Method E 90.

10.4 *Intensity Probe*—The intensity probe shall comply with the requirements of ANSI S1.9 and shall allow determination of the sound intensity in a known direction. The probe shall consist of two pressure-sensing microphones spaced a known distance apart.



A five-sided measurement surface forming a box may be used to completely enclose a small specimen that is mounted in a larger partition.

FIG. 4

10.5 *Probe Calibration*—Using a sound intensity probe calibrator and following the manufacturers instructions, conduct the following before each test:

10.5.1 Calibrate both microphones for sound pressure.

10.5.2 Calibrate the probe for sound intensity.

10.5.3 Measure the pressure-intensity residual index, δ_{pI_0}.

NOTE 9—δ_{pI_0} is a measured by exposing the microphone pair to a sound field where the sound intensity is zero. Increasing values indicate increased phase matching between the measurement channels.

10.6 *Probe Microphone Spacing*—The spacing between the two microphones of an intensity probe affects the usable lower and upper frequency range limits. Errors due to phase mismatch between measurement channels increase as the spacing is decreased. The spacing shall be as large as possible, consistent with acceptable inherent finite difference errors that appear at high frequencies **(5)**. Refer to manufacturer's specifications for the usable frequency range for a particular spacing. It may be necessary to perform complete measurements using more than one microphone spacing (usually two) to cover the frequency range of interest.

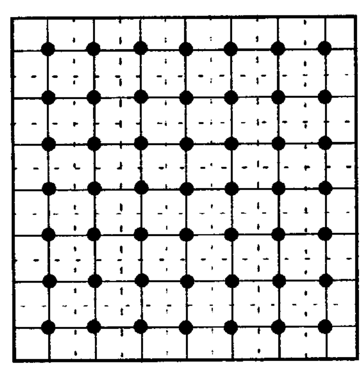
10.7 *Probe Field Check*—Before beginning measurements, verify proper operation of the probe. Place the probe in the receiving room near the center of building element under test at distance of 0.1 to 0.3 m from the surface. Fix the probe position by securing it with a stand and align the longitudinal probe axis normal to the specimen surface. With the sound sources turned on, measure and record the intensity level over the frequency range of interest. Rotate the probe 180° about the acoustic centre of the microphone pair and re-measure the intensity level. For the probe and measurement instrumentation to be deemed acceptable the following shall be satisfied: (*1*) the direction of the intensity level shall reverse sign, and (*2*) the magnitude of the difference in the undirected intensity measured for the two probe orientations shall not be greater than 1.5 dB in any one-third-octave band.

NOTE 10—If this can not be attained then it is likely the field criteria will not be satisfied using the surface average values. Check probe calibration. If this fails to rectify the problem, check that Criterion 1 is satisfied. (Use Annex A1 for the discrete point method, and Annex A2 for the scanning method). Add absorption if this condition is not met.

11. Intensity Measurement Methods

11.1 There are two acceptable sampling methods for measuring the average sound intensity radiated by the building element under test: the discrete point method and the scanning method **(5)**. The scanning method is often very much faster than the discrete point method and is also the most suitable method when measurement surface is large. The disadvantage to the scanning method is that it is less reproducible than the discrete point method.

11.2 *Discrete Point Method*—This method uses a set of fixed points to sample the intensity field normal to one or more measurement surfaces. (See Fig. 5). The probe may be supported by a device or held by an operator. Sampling uncertainty



Typical construction of the measurement grid for discrete point measurements. The dots indicate the sampling locations while the dashed lines define the area sampled by each point.

FIG. 5

is a function of the spatial variation of the normal intensity over the measurement surface, the distribution of sample points and the level of background noise in the receiving space. For the initial measurement, the spacing between measurement points should be equal to the probe distance. The side faces of a five-sided box surface, as shown in Fig. 4, will often require a higher density of measurement points than the frontal surface.

11.3 *Scanning Method*—This method is based on sweeping the probe over the surface at a uniform speed so that the integration time is proportional to the area of the surface. A typical scan pattern is a line segment that has been folded several times to cover the subarea as shown in Fig. 6. The straight portions of the scan pattern are referred to as the scan lines. The average distance between adjacent scan lines shall be equal for all intensity measurements made on the same surface. The probe shall be moved continuously and at uniform speed of 0.1 to 0.3 m/s along the selected scan pattern while maintaining the probe axis perpendicular to the measurement surface. It is acceptable to move the probe by mechanical means as long as extraneous noise or intensity does not interfere with the measurement.

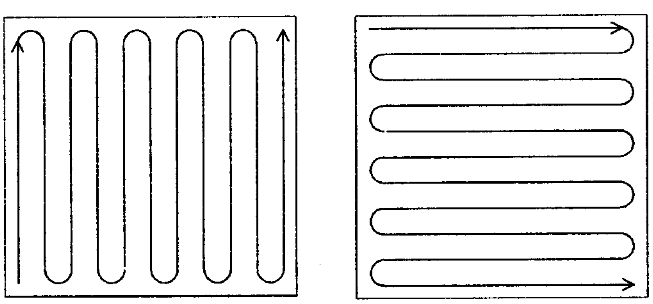
NOTE 11—Repeated scans are also required to ensure adequate measurement reproducibility which my also be a function of the operator's ability to maintain a constant scan speed, especially when the surface has a non-uniform radiation pattern.

11.3.1 Make two separate scans on each subarea of the measurement surface. The two individual scan paths shall be orthogonal (scan pattern rotated by 90°). See Fig. 6. Record the intensity levels $L_{In_k}(1)$ and $L_{In_k}(2)$. Use Criterion 3 in Annex A2 to determine the adequacy of the scan line density for frequency band. If the criterion is satisfied the intensity of the subarea is given by the arithmetic mean of the two scans:

$$L_{In_k} = \frac{L_{In_k}(1) + L_{In_k}(2)}{2} \text{ dB} \tag{8}$$

11.3.2 If Criterion 3 of Annex A2 is not satisfied, repeat the two scans again and check if the repeat measurements satisfy the criterion. If it is impossible to comply with these requirements then no results shall be given for these frequency bands. This may prevent the single number ratings from being calculated and reported.

NOTE 12—A2.5 provides guidance on how to change the scan line density to satisfy Criterion 3.



Scan patterns for the first and second scans differ in orientation by 90°. The measured intensities are L_{In_k} (*1*) and L_{In_k} (*2*), respectively. The difference in the measured intensity levels is used to determine the adequacy of the scan line density and the measurement reproducibility.

FIG. 6

11.3.3 Scan each subarea according to Fig. 6. If a box shaped measurement surface is chosen, ensure that the sides of the box are carefully scanned by moving the probe no closer than 0.1 m to the junction between the box and the building element under test.

11.3.4 During manual scanning, the operator shall not stand in front of the subarea being scanned but shall stand to one side so the person's body does not impede, reflect or diffract sound towards the probe. Similarly, automated scanning mechanisms shall present a minimum of interference to the sound field.

12. Measurement Procedure

12.1 *General*—Measure the average sound pressure level in the source room. Ensure the probe is operating correctly by calibrating it and performing the field check (see 10.7). Once satisfactory, obtain an initial estimate of the receiving room conditions (see 12.2) and add treatments to the receiving room as required. (See Annex A1-Annex A3 for a discussion of possible treatments). Check that the flanking transmission is not adversely affecting the measurement (see 12.3). If satisfactory, measure the average sound intensity level and sound pressure level for each subarea and compute the field indicators for the measurement method (discrete point A1.3 and scanning A2.3). If each subarea meets the background noise criterion (see 12.5) and also meets the field criteria then compute the average sound intensity and sound pressure levels for the complete measurement surface (see 12.6). Compute the field indicators for the complete measurement surface and evaluate the field criteria. Compute the intensity transmission loss for all frequency bands satisfying the criteria (see 12.12).

12.2 *Initial Test for Receiving Room Suitability*—To test the suitability of the receiving room for intensity measurements, switch on the sound sources and scan with the intensity probe diagonally across the building element under test at a distance of 0.1 to 0.3 m.

12.2.1 Check that there is sufficient signal by using the background noise criterion of 12.5.

12.2.2 If there is sufficient signal, check that all frequency bands Criterion 1 is satisfied. Use Annex A1 for the discrete point method and Annex A2 for the scanning method.

NOTE 13—If this condition is not satisfied then it is highly likely that the field criteria will not be satisfied for surface averaged values so remedial actions should be taken before beginning the detailed measurements. Annex A2 and Annex A3 provide methods to improve the measurement conditions.

12.3 *Flanking Transmission Check*—The flanking criterion of Annex A3 shall be satisfied since acoustic radiation from building elements adjacent to the measurement surface can adversely effect the accuracy of the measurements. Failure to satisfy the flanking criterion can cause a significant underestimation of the sound insulation **(6)**.

12.4 *Measurement of the Average Sound Intensity Level on the Receiving Side*—Measure the average sound intensity and sound pressure levels for each subarea of the measurement surface. For each subarea, if the background noise criterion is satisfied, calculate the field indicators and evaluate the field criteria according to the type of measurement (Annex A1 for the discrete point method, Annex A2 for the scanning method) for all frequency bands of measurement. If the field criteria are fulfilled for each surface and each frequency band, compute the average values for the complete measurement surface.

12.4.1 If the field criteria of Annex A1 for the discrete point method or Annex A2 for the scanning method, are not satisfied for all frequency bands of interest then take one of the following alternative courses of action:

12.4.1.1 Make a statement in the report to the effect that the accuracy of the sound intensity measurements do not meet the requirements at these frequency bands and do not report data for these bands, or,

12.4.1.2 Take remedial action according to A1.5 (discrete point method) or A2.5 (scanning method) to increase the accuracy and repeat the measurements.

NOTE 14—The single number rating ISTC can not be reported if the Criteria of A1.4 for the discrete point method or A2.4 for the scanning method are not satisfied for all frequency bands required for the computation defined in Classification E 413.

12.5 *Background Noise*—Sources of background noise contained within the measurement volume will bias the intensity results and can not be adequately detected by the field criteria of Annex A1 and Annex A2. Consequently, average background levels are determined at one or more points on each face of a measurement surface when the sound source is turned off but all other test conditions are maintained. The average background level of sound pressure level and undirected intensity level should be more than 10 dB below the levels obtained when the sound source is turned on at any measurement point for each frequency band.

NOTE 15—These requirements may be tested by applying the following procedure: If the criteria for the field indicators are satisfied then lower the source level by 10 dB. If F_2(discrete point method) or F_{pI} (scanning method) is changed less than 1 dB then the background noise requirement is fulfilled.

12.6 *Computing Average Levels from Multiple Subareas*—If the measurement surface is divided into *M* subareas, each with the area, S_{mk}, evaluate the surface averaged signed sound intensity, $\bar{I}_n$, for the measurement surface from:

$$\bar{I}_n = \frac{I_0}{S_m} \sum_{k=1}^{M} \left[S_{m_k} \left(10^{0.1 L_{In_k} \text{dB}}\right) sgn(I_{nk}) \right] \frac{W}{m^2} \quad (9)$$

where *k* indicates the subarea, and $sgn\ (I_{nk})$ takes the value of negative unity if the sound intensity for a measurement subarea is directed into the measurement volume otherwise it is unity, and the total area of the measurement surface, S_m, is given by:

$$S_m = \sum_{k=1}^{M} S_{M_k} \quad (10)$$

It is possible for $\bar{I}_n$, evaluated using Eq 9, to take a negative value indicating that the average intensity flow through the measurement surface is toward the specimen under test. In this case transmission loss is not defined and shall not be reported.

NOTE 16—A negative intensity may occur when the receiving room is excessively reverberant or when there are extraneous noise sources (such as flanking surfaces) exterior to the measurement volume.

12.7 The surface average estimate of the signed normal sound intensity level of the measurement surface, $\bar{L}_{In}$, is obtained using:

$$\bar{L}_{In} = sgn(\bar{I}_n)\ 10 \log\left(\frac{|\bar{I}_n|}{I_0}\right) \text{dB} \quad (11)$$

where $(\bar{I}_n)$ takes the value of negative unity if $\bar{I}_n$ is negative otherwise it is unity.

12.8 Similarly, calculate the average pressure level over the measurement surface, $\bar{L}_p$, using:

$$\bar{L}_p = 10 \log \left[\frac{1}{S_m} \sum_{k=1}^{M} S_{m_k}\ 10^{0,1 L_{p_k} \text{dB}} \right] \text{dB} \quad (12)$$

where $\bar{L}_{p_k}$ is the surface averaged sound pressure level over subarea *k*.

12.9 Compute the relevant field indicators for the measurement method (discrete point Annex A1, scanning Annex A2) using the results averaged over the complete measurement surface.

12.10 *Measurement of the Average Sound Pressure Level in the Source Room*—Measure the average sound pressure level in the source room according to the procedures given in Test Method E 90.

12.11 *Multiple Measurement Scans*—When the frequency range of interest exceeds the frequency range for a particular probe microphone spacing, perform additional complete sets of intensity measurements at appropriate probe microphone spacing. For the frequency range where the usable ranges overlap take the arithmetic mean of the intensity levels if they differ by less than 1.5 dB, otherwise take the higher value.

12.12 *Computing the Intensity Transmission Loss*—For all frequency bands for which $\bar{L}_{In}$ is positive, and the Field Criteria for the measurement method (discrete point Annex A1, scanning Annex A2) are satisfied when using surface averaged data, compute the transmission loss for the test partition in each one-third-octave band from:

$$ITL = [L_1 - 6 + 10 \log (S_s)] - [\bar{L}_{In} + 10 \log (S_m)] \quad (13)$$

where:

ITL = intensity transmission loss, dB,
L_1 = average source room sound pressure level, dB,
$\bar{L}_{In}$ = surface averaged transmitted sound intensity normal to the measurement surface, W/m^2,
S_m = total area of the measurement surface, m^2, and
S_s = area of the specimen, or portion thereof, contained in the measurement volume, m^2.

NOTE 17—The first bracket represents an estimate of the incident sound power on the specimen under test in the source room expressed in dB re 10^{-12} Watts assuming a diffuse field, while the second term represents an estimate of the total sound power radiated by the portion of the specimen in the receiving room expressed in dB re 10^{-12} Watts.

13. Report

13.1 A test report shall include the following information:

13.1.1 At the bottom of each page of the test report add the following statement. "The measurements reported herein were made using the intensity method for measurement of sound transmission loss ASTM E 2249 and must not be used to demonstrate compliance with a specification calling for the use of ASTM E 90 (Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements). Details as to the expected differences between the two standard test methods are presented in ASTM E 2249."

13.1.2 A statement, if true in every respect, that the tests were conducted according to this test method.

13.1.3 A description of the partition or test specimen in accordance with Test Method E 90. Report the area of the specimen that is being tested.

NOTE 18—The specimen area is not the same as the area of the measurement surface.

13.1.4 Indicate which sampling method was used. Include a description and dimensions of the final measurement surface that bounds the test partition. Report the distance from the surface of the partition to the acoustic center of the intensity probe. Report the number of measurement scans made and the microphone spacing used for each scan.

13.1.5 A description of the type of intensity probe used and a summary of the calibration procedure.

13.1.6 The Field Indicators determined for each test frequency.

13.1.7 The temperature, barometric pressure and relative humidity in the rooms or spaces.

13.1.8 The volumes of all enclosed rooms.

13.1.9 Report the average one-third octave sound pressure levels in the source room accurate to one decimal place for each test frequency.

13.1.10 Report surface-averaged one-third octave intensity levels and corresponding sound pressure levels accurate to one decimal place for each test frequency. When multiple measurements have been made with different microphone spacing, provide the intensity data for all frequencies which are used to compute transmission loss.

13.1.11 *Intensity Transmission Loss* shall only be reported for one-third octave bands where the measured intensity and pressure satisfy the field criteria for the measurement method (discrete point Annex A1, scanning Annex A2), the signed intensity averaged over the complete measurement surface is positive, flanking satisfies the criterion of 12.3, background noise satisfies the criterion of 12.5, the source room requirements satisfy the requirements of Test Method E 90, and the specimen mounting conditions and aging satisfy Test Method E 90.

13.1.11.1 Values shall be given accurate to one decimal place. Values limited by flanking transmission involving source room surfaces shall be clearly noted. See Annex A2.

NOTE 19—If results are presented in graphical form, the abscissa length for a 10:1 frequency ratio should equal the ordinate length for 25 dB. Whenever practicable, the scales should be 50 mm for a 10:1 frequency ratio and 20 mm for ten decibels, and the ordinate scale should start at zero decibels. Contour maps showing intensity level data in individual bands across one or more measurement faces may be included.

13.1.12 *Single Number Ratings* shall only be reported when there are valid intensity transmission loss data in each third octave band used to compute the single number ratings.

13.1.12.1 *Intensity Sound Transmission Class*—Compute the single number rating Intensity Sound Transmission Class by applying Classification E 413 to the measured transmission loss data obtained using this standard. The single number rating shall be identified as being Intensity Sound Transmission Class or ISTC. It shall not be given any other name or descriptor.

13.1.12.2 *Intensity Outdoor-Indoor Transmission Class*—Compute the single number rating Intensity Outdoor-Indoor Transmission Class by applying Classification E 1332 to the transmission loss measured using this standard. The single number rating shall be identified as being Intensity Outdoor-Indoor Transmission Class or OITC. It shall not be given any other name or descriptor.

14. Precision and Bias

14.1 *Precision*—The precision of this test method has not been established. Since the source room and specimen mounting requirements are identical to those Test Method E 90 it is expected that the precision of this standard will be the same or similar to Test Method E 90.

NOTE 20—Precision for ISO 15186-1 is expected to be equal to or better than that of ISO 140-3 (the ISO laboratory two room method functionally similar to Test Method E 90).

14.2 *Bias*—The bias of this test method has not been thoroughly determined. Appendix X1 provides initial estimates based on limited results published in the open literature and from private communications.

ANNEXES

(Mandatory Information)

A1. DISCRETE POINT METHOD—FIELD INDICATORS AND CRITERIA

A1.1 *General*—When the discrete point method is used, evaluate the following field indicators and evaluate the suitability of the measurement using the criteria for each measurement surface and each measurement array, in each frequency band of interest.

A1.2 *ISO Compatibility*—All of the field indicators and criteria defined in this annex are based on those used in ISO 9614-1 and represent a more stringent superset of those used in ISO 15186-1. The criteria appearing here have been extended to allow for a non-uniform spacing of the measurement positions. In the limit that each measurement position represents the same area, then the equations in this annex are identical to those of ISO 9614-1. Refer to 9614-1 for a list of references used to develop the material in this Annex. Reference **(5)** cited at the end of this standard contains valuable information relative to the development of the material presented in this Annex. ISO 9614-1 field indicator F1, the temporal variability indicator of the sound field, is not used in this test method since it is assumed that the sound source operated in the source room is stationary over the measurement time.

A1.3 *Field Indicators*—Three field indicators are used for the discrete point method.

A1.3.1 L_d, *Dynamic Capability Index* indicates the dynamic capability of the measurement system:

$$L_d = \delta_{pI_0} - K \quad \text{(A1.1)}$$

where:

δ_{pI_0} = pressure-residual intensity index, dB, and
K = 10, dB.

NOTE A1.1—This field indicator is compatible with ISO 9614-2and ISO 15186-1.

NOTE A1.2—δ_{pI_0} is obtained during the calibration of the intensity measuring system (see 10.5).

A1.3.2 F_2, surface pressure-intensity indicator, is defined as the level difference between the average pressure integrated over a measurement surface and unsigned (disregard direction) average normal intensity level:

$$F_2 = \overline{L_p} - \overline{L_{|In|}} \quad \text{(A1.2)}$$

where:

$$\overline{L_p} = 10 \log\left[\frac{1}{S_m}\sum_{k=1}^{N} S_{m_k} 10^{\left(\frac{L_{p_k}}{10}\right)}\right] \quad \text{(A1.3)}$$

is the surface sound pressure level, in decibels, and

$$\overline{L_{|In|}} = 10 \log\left[\frac{1}{S_m}\sum_{k=1}^{N} S_{m_k} 10^{\left(\frac{|L_{n_k}|}{10}\right)}\right] \quad \text{(A1.4)}$$

is the undirected surface normal intensity level, in decibels, and

$$S_m = \sum_{k=1}^{N} S_{m_k} \quad \text{(A1.5)}$$

where there are N subareas used to sample the measurement surface.

NOTE A1.3—This field indicator is compatible with ISO 9614-2 and ISO 15186-1.

A1.3.3 F_3—The negative partial power indicator is the level difference between the average pressure integrated over a measurement surface and signed (accounting for direction) average normal intensity level:

$$F_3 = \overline{L_p} - \overline{L_{In}} \quad \text{(A1.6)}$$

where:

$\overline{L_{In}}$ = is given by Eq 11.

NOTE A1.4—This field indicator is compatible with ISO 9614-1, but is not required by ISO 15186-1.

A1.3.4 F_4—The field non-uniformity indicator is a measure of the suitability of the selected measurement array:

$$F_4 = \frac{1}{|\overline{I_n}|}\sqrt{\frac{1}{N-1}\sum_{k=1}^{N}(I_{n_k} - \overline{I_n})^2} \quad \text{(A1.7)}$$

NOTE A1.5—This field indicator is compatible with ISO 9614-1 and ISO 15186-1.

A1.4 *Field Criteria*—Two criteria that must be satisfied for a measurement to be considered acceptable.

A1.4.1 *Adequate Dynamic Range*—For a measurement array to qualify as being suitable for the determination of sound power radiating from the receiving side of a test partition using the discrete point method, Criterion 1 shall be satisfied for each frequency band of measurement:

Criterion 1:

$F_2 < L_d$	Reflective test specimen
$F_2 < 6$ dB	Absorptive test specimen

A1.4.1.1 A test specimen shall be considered absorptive for any one-third octave band if the absorption coefficient exceeds 0.5.

NOTE A1.6—Criterion 1 is compatible with ISO 15186-1. ISO 9614-1 does not differentiate between reflective and absorptive surfaces.

A1.4.2 *Adequate Measurement Array*—The number of N probe positions uniformly distributed over a chosen measurement surface is shall be sufficient if Criterion 2 is satisfied for each frequency band of measurement:

Criterion 2: $N > C F_4^2$

where C, a correction factor is given in Table A1.1.

NOTE A1.7—This field indicator is compatible with ISO 9614-1 and ISO 15186-1.

A1.5 *Remedial Actions*

TABLE A1.1 Values for factor *C*

One-third Octave Band Center Frequency (Hz)	*C* factor (dimensionless)
50 to 160	19
200 to 630	29
800 to 5000	57
6300	19

A1.5.1 *Criterion 1*—If either Criterion 1 or $F_3 - F_2 \leq 3$ dB is not satisfied, perform either of the following remedial actions:

A1.5.1.1 *Action a*—In the presence of significant extraneous noise and/or strong reverberation, reduce the distance of the measurement surface from the test partition. In the absence of significant extraneous noise and/or strong reverberation, increase the distance of the measurement surface from the test partition;

A1.5.1.2 *Action b*—Shield the measurement surface from extraneous noise or reduce the adverse influence of the reverberant sound field by introducing additional absorption into the receiving space at locations remote from the test partition.

A1.5.2 *Criterion 2*—If Criterion 2 is not satisfied, perform either of the following remedial actions:

A1.5.2.1 *Action c*—If $1 \text{ dB} \leq (F_3 - F_2) \leq 3$ dB: increase the density of measurement positions uniformly;

A1.5.2.2 *Action d*—If $(F_3 - F_2) \leq 1$ dB: increase the average distance of measurement surface from test partition using the same number of measurement positions, or increase the density of measurement positions uniformly on the same surface.

A2. SCANNING METHOD—FIELD INDICATORS AND CRITERIA

A2.1 *General*—When the scanning method is used, evaluate the following field indicators and evaluate the repeatability of the measurement and the measurement using the criteria for each measurement surface, in each frequency band of interest.

A2.2 *ISO Compatibility*—All of the field indicators and criteria defined in this annex are based on those used in ISO 9614-2 and represent a superset of those used in ISO 15186-1. Refer to ISO 9614-1 for a list of references used to develop the material in this Annex. Reference **(5)** cited at the end of this standard contains valuable information relative to the development of the material presented in this Annex.

A2.3 *Field Indicators*—Three field indicators are used for the scanning method.

A2.3.1 L_d, *Dynamic Capability Index*—Indicates the dynamic capability of the measurement system:

$$L_d = \delta_{pI_0} - K \tag{A2.1}$$

where:

δ_{pI_0} = pressure-residual intensity index, dB, and
K = 10, dB.

NOTE A2.1—This field indicator is compatible with ISO 9614-1 and ISO 15186-1.

NOTE A2.2—δ_{pI_0} is obtained during the calibration of the intensity measuring system.

A2.3.2 F_{pI}—The surface pressure-intensity indicator:

$$F_{pI} = \bar{L}_p - \bar{L}_{|In|} \tag{A2.2}$$

where:

$$\bar{L}_p = 10 \log_{10}\left[\frac{1}{S_m}\sum_{k=1}^{N} S_{m_k} 10^{\left(\frac{L_{Pk}}{10}\right)}\right] \tag{A2.3}$$

is the surface-average sound pressure level, in decibels, and where:

$$S_m = \sum_{k=1}^{N} S_{m_k} \tag{A2.4}$$

is the total area of measurement surface.

NOTE A2.3—F_{pI} has been expressed in terms of the measured quantity, intensity, rather than sound power and an area term, which is used in ISO 9614-2.

NOTE A2.4—This field indicator is compatible with ISO 9614-2 and ISO 15186-1.

NOTE A2.5—F_{pI} is equivalent to F_3 in the special case of uniform subarea areas.

A2.3.3 $F_{\pm}$—The negative partial power indicator:

$$F_{\pm} = 10 \log\left[\frac{\sum_{k=1}^{N} S_{m_k} 10^{\left|\frac{L_{In_k}}{10}\right|}}{\sum_{k=1}^{N} S_{m_k} 10^{\frac{L_{In_k}}{10}}}\right] \tag{A2.5}$$

NOTE A2.6—This field indicator is compatible with ISO 9614-2, but is not required by ISO 15186-1.

NOTE A2.7—$F_{\pm}$ is equivalent to $F_3 - F_2$ in the special case of uniform subareas.

A2.4 *Field Criteria*—Three criteria that must be satisfied for a measurement to be considered acceptable.

A2.4.1 *Adequate Dynamic Range*—For a measurement to qualify as being suitable for the determination of sound power radiating from the receiving side of a test partition using the scanning method, Criterion 1 shall be satisfied for each measurement surface and for each frequency band:

Criterion 1:	
$F_2 < L_d$	Reflective test specimen
$F_2 < 6$ dB	Absorptive test specimen

NOTE A2.8—Criterion 1 is compatible with ISO 15186-1. ISO 9614-1 does not have a separate requirement for radiating surfaces that are absorptive.

A2.4.1.1 A test specimen shall be considered absorptive for any one-third octave band if the absorption coefficient exceeds 0.5.

A2.4.2 *Limit on Negative Partial Power*—To check the suitability of the measurement conditions, the following shall be satisfied for each frequency band of measurement:

Criterion 2: $F_{\pm} \leq 3$ dB

NOTE A2.9—This field indicator is compatible with ISO 9614-1, but is not required by ISO 15186-1.

A2.4.3 *Partial-power Repeatability Check*—To check the suitability of the scan-line pattern, the following shall be satisfied for each frequency band of measurement:

$$\text{Criterion 3: } L_{Ink}(1) - L_{Ink}(2) \leq 1 \text{ dB}$$

NOTE A2.10—$L_{Ink}(1)$ and $L_{Ink}(2)$ are defined in 11.3. The 1 dB maximum deviation is compatible with ISO 15186-1 which is more stringent the requirement of ISO 9614-1.

A2.5 *Remedial Actions*

A2.5.1 *Criterion 1*—If Criterion 1 is not satisfied, perform either of the following remedial actions:

A2.5.1.1 *Action a*—Reduce by half the distance from the measurement surface to the test partition to not less than 0.1 m and double the scan-line density.

A2.5.1.2 *Action b*—Reduce the adverse influence of the reverberant sound field by introducing additional absorption into the receiving space at locations remote from the test partition.

A2.5.2 *Criterion 1 and 2*—If Criterion 1 and 2 are not satisfied, perform any of the following remedial actions:

A2.5.2.1 *Action a*—Reduce by half the distance from the measurement surface to the test partition to not less than 0.1 m and double the scan-line density.

A2.5.2.2 *Action b*—Reduce the adverse influence of the reverberant sound field by introducing additional absorption into the receiving space at locations remote from the test partition.

A2.5.2.3 *Action c*—Shield the measurement surface from strong extraneous noise sources by means of a screen.

A2.5.3 *Criterion 3*—If Criterion 3 is not satisfied, perform the following remedial actions:

A2.5.3.1 *Action a*—double the scan-line density on the same subarea.

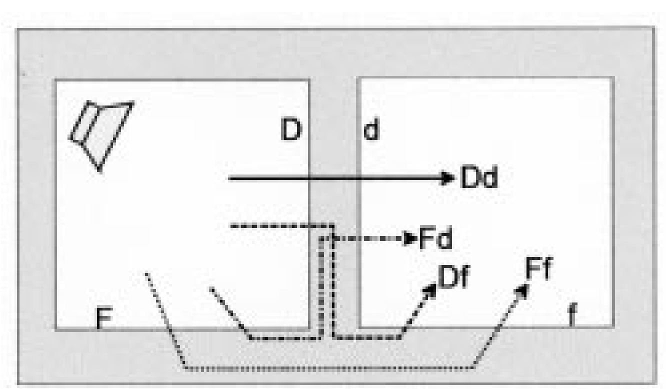
A2.5.3.2 *Action b*—If $F_{\pm} \leq 1$ dB, double the distance from the measurement surface to the test partition keeping the same scan-line density.

A3. MEASUREMENT AND THE EFFECT OF FLANKING TRANSMISSION

A3.1 *General*—Flanking transmission can be suppressed but not eliminated. The effect of flanking transmission on the quality of the measure of transmission loss is a function of the sound insulation and construction details of the element under test.

A3.1.1 Fig. A3.1, which shows only the first-order flanking paths involving the junction between source and receiving rooms at the bottom of the specimen, illustrates that all receiving rooms surfaces, even the test specimen will have a flanking component. (A first-order flanking path is one that involves a single source surface, a single junction, and a single receiving room surface). The magnitude of the flanking component is complex function of the structural isolation between the rooms and the specimen.

A3.1.2 Since the intensity method measures the sound power of all sources contained in the measurement volume, the effect of flanking transmission involving receive room surfaces (paths D_f and F_f of Fig. A3.1) can often be circumvented by selecting a measurement surface that excludes such sources.



Idealized sketch for monolithic constructions showing the direct transmission and the first-order flanking paths at the wall/floor junction between two rooms sharing a common partition. There will also be higher order flanking paths, which have been omitted for clarity.

FIG. A3.1

A3.1.3 It is undesirable to have flanking surfaces interior or adjacent to the measurement volume. A criterion is given to assess their effect. This annex provides a method to assess the effect of flanking surfaces contained in, and adjacent to, the measurement volume. It also provides a set of mandatory procedures and criteria which will allow the operator to establish a flanking limit for paths involving source room surfaces whose effect can not be limited by the selection of the measurement surface in the receive space, (for example, path F_d of Fig. A3.1), namely paths involving a source room surface and the test specimen.

A3.1.4 The effect of source room flanking paths that involve the partition under test can not be eliminated by selection of the measurement surface and hence represent inherent flanking involving all measurements using this standard. This inherent flanking must be quantified.

NOTE A3.1—Flanking transmission will increase the amount of extraneous noise in the receiving room and it may be necessary to add significant absorption to the receiving room in order to obtain a satisfactory measurement environment (that is, to satisfy the requirements of A1.4 and A2.4). In extreme cases, it may also be necessary to shield one or more receiving room flanking surfaces.

A3.2 *Flanking from Surfaces Contained in the Measurement Volume*—For surfaces contained in the measurement volume, the contribution to the radiated sound power of source room flanking paths must be 10 dB lower than the direct path though the partition under test.

NOTE A3.2—Typically, an extraneous noise source contained in the measurement volume will cause an underestimation of the intensity transmission loss of the specimen under test **(6)**.

A3.2.1 Before conducting measurements, the operator shall identify the acoustic sources close to the measurement surface, particularly those that might be contained in the measurement volume. Fig. A3.2 shows how a portion of a flanking surface can be included in the measurement volume. For the portion of the flanking surface contained in the measurement volume to have a negligible effect on the estimate of the transmission loss of the partition, the sound power radiated by the partition must be considerably greater than the sound power radiated by the extraneous noise source (that is, portion of the flanking surfaces) contained in the measurement volume.

A3.3 The following procedure shall be used to determine if an adjacent radiating surface is likely to affect the estimate of the transmission loss estimate for the surface under test.

A3.4 Select the measurement surface and the measurement distance, d_m. Use the normal component of the intensity along a diagonal line across the surface (from 12.2, Initial Test for Receiving Room Suitability) to obtain an crude estimate of the surface intensity, $L_{In,Ms}$. Next, orient the probe toward the flanking surface and measure the intensity along a line in the plane of the measurement surface that is a distance, d_m, from the flanking surface. This intensity is defined as $L_{In,Fs}$.

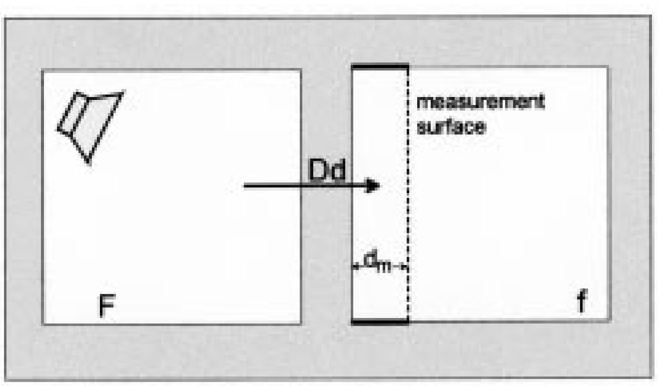
NOTE A3.3—If in measuring $L_{In,Ms}$ or $L_{In,Fs}$ the measurement field was unsatisfactory (that is, Criterion 1 was not satisfied) then try to improve the field by placing additional absorption in the measurement room. Sound absorbing material must not be placed within the measurement volume.

A3.5 The following shall be satisfied for all flanking surfaces contained in the measurement volume:

$$L_{In,Ms} - L_{In,Fs} + 10 \log\left[\frac{S_m}{S_F}\right] > 10 \text{ dB} \quad \text{(A3.1)}$$

where S_F is the area of portion of the flanking surface contained in the measurement volume, and S_m is defined by Eq 10.

A3.5.1 If this condition is not achieved then the portion of the flanking surface contained in the measurement volume shall be shielded. In most instances adequate shielding can be achieved by using 13 mm gypsum board placed over 50 mm of fibrous sound absorbing material. Edges and joints of the shielding contained in the measurement volume should be taped to avoid unwanted absorption. After shielding the surface(s) the test should be repeated to ensure the effectiveness of the applied treatment(s).



A sketch showing a measurement surface used to sample the partition wall. The dark lines indicate the portion of flanking surfaces that are contained in the measurement volume. Using the indicated measurement surface, and without the shielding of any surfaces, the following paths will be measured D_d, F_d and a fraction of D_f and F_f.

FIG. A3.2

A3.6 *Flanking Involving Source Room Surfaces*—Because the effect of flanking transmission involving source room surfaces can not be minimized by selecting the measurement surface, it is necessary to establish the limit on transmission loss measurement due to flanking. The procedure used shall be as follows:

A3.6.1 In the test opening, build a partition expected to have high transmission loss. Since the magnitude of these flanking paths is a function of the specimen construction and its mounting, the specimen and mounting shall be representative of those typical for the laboratory. This procedure shall be repeated for each specimen or mounting condition that is significantly different.

NOTE A3.4—A concrete specimen should not be used for evaluation flanking paths if normally the laboratory tests lightweight double leaf partitions, and vice versa.

A3.7 Measure the transmission loss following procedure defined in the main body of this test method.

A3.8 Increase the expected transmission loss by making a substantial improvement to the partition, for example, by adding a heavy shielding structure in front of the test partition. Improvements to the test partition shall be made on the source room side of the partition.

A3.9 Measure the transmission loss again.

A3.10 Repeat steps A3.8 and A3.9 until significant additions to the test partition no longer significantly increase the measured transmission loss. The transmission loss measured than then be ascribed to flanking paths involving source room surfaces and the test specimen. This is the flanking limit of the facility using this standard. Unless steps are taken to eliminate them, these paths will always exist and will reduce the measured transmission loss for partitions whose inherent transmission loss values are within 10 dB of the flanking limit.

NOTE A3.5—The facility flanking limit as measured using the Annex of this test method will typically be higher than that measured by the corresponding procedure of Test Method E 90. The reason being that the flanking limit for the intensity method is largely determined by a single path, namely F_d, while for Test Method E 90 there are two additional paths (F_f and D_f). These two additional paths involve receive room surfaces and are assumed to be made negligible by either selection of the measurement surface or by shielding.

A3.11 When the transmission loss measured for a test specimen in a particular frequency band is within 10 dB of the flanking limit established for the laboratory, the transmission loss value must be clearly identified in the test report as being potentially limited by the laboratory. The true value may be higher than that measured.

A3.12 Records of the flanking limit and of the procedure shall be maintained by the laboratory. These shall be made available, upon request, when the reported results are potentially limited by flanking transmission involving the laboratory.

APPENDIX

(Nonmandatory Information)

X1. BIAS

X1.1 *General*—Currently there is much discussion regarding the precision with which intensity transmission loss standards can reproduce the results of the traditional two-room methods. Within the international community there appears to be a general consensus that there is a bias between the two methods **(3,4)**. However, agreement on the cause has not been achieved. The following is a general discussion of some of the most obvious factors followed by a range of biases reported by European and North American laboratories. Possible sources of bias can be broken into two frequency ranges, high and low.

X1.1.1 In the high frequencies when the spacing between the microphones of the probe (typically 12 or 50 mm) becomes a significant fraction of a wavelength the method of estimating the particle velocity from the pressure gradient breaks down. The error is often referred to as the "finite difference error" which, in the high frequencies, causes the measured intensity to be underestimated and hence the transmission loss to be overestimated **(5)**.

X1.1.2 In the low frequencies room effects may play prominently. There is a tendency for the ISO and ASTM two-room test methods to underestimate the transmission loss in the low frequencies because of the assumption that the sound field in the receive room is diffuse (that is the energy density is uniform throughout the room). In reality this is only approximated despite making the rooms as large as possible and the using diffusing elements. In rooms where the wavelength in the lower third-octave bands may be of comparable length to the largest room dimension there is a pressure build-up in the central volume of the room which leads to the overestimation of the radiated sound power and an underestimation of the transmission loss. Intensity test methods obtain estimates of the radiated sound power directly and hence are not prone to the same problem at low frequencies. Thus, when comparing the two methods a correction needs to be applied to transmission loss results of the standard two-room method.

X1.1.3 Waterhouse has provided a mathematical formulation to describe the apparent underestimation of the transmission loss for the two-room test method. Such a correction helps improve the low frequency agreement between the two methods but can not fully account for the difference; the intensity-based method still predicts a higher transmission loss.

X1.1.4 Other possible factors affecting the low frequency agreement include the highly directional sound fields and the directionality of the intensity probe, the presence of extraneous noise sources such as flanking.

X1.1.5 Thus, any bias will likely be a function of the volume of the receive room that was used for the two-room method, spacing between the microphones of the probe, and possibly many other factors.

X1.1.6 This Annex provides an estimate of the precision with which this standard can reproduce laboratory the results of Test Method E 90 and field results of Test Method E 336 when measuring the same building element with the same mounting and boundary conditions.

X1.1.7 It should be noted that unless shielding is used, the transmission loss as measured by Test Method E 336 includes flanking paths to the receiving room and in order to make a fair comparison the intensity measurements must be conducted so that the same paths are measured and included in the estimate. Failure to adequately sample all significant radiating surfaces will result in a large and negative bias term, K_1. Thus, the bias term can be used to provide guidance when deciding if all significant sources have been sampled.

X1.2 *Estimated Bias Term, K_1*—It is defined as the difference between the measured transmission loss obtained using the reverberation room technique (Test Method E 90 for laboratory conditions and Test Method E 336 for field conditions) and the intensity technique described in this standard:

$$K_1 = TL_{reverberation\ method} - TL_{intensity\ method}\ \text{dB} \quad \text{(X1.1)}$$

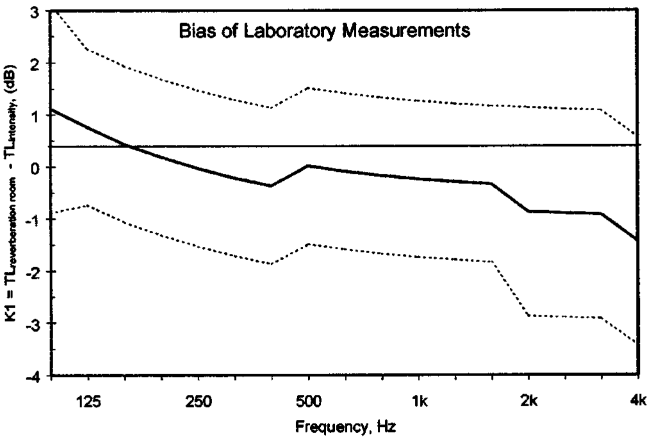
NOTE X1.1—The cause of the bias is not known.

X1.2.1 It is realistic to expect the bias and precision of this standard to be a function of both the specimen under test and the receiving room environment. For this reason it is not possible to provide a single bias estimate that is applicable to all situations that can be encountered when applying this standard. However, it is possible to define a range for the values.

X1.2.2 It is expected that the highest precision and lowest bias will be observed when comparing results of the two methods that were obtained under laboratory conditions. In this situation there are preferred receiving room conditions (suppressed flanking, large receiving room providing adequate modal density, and a well defined room volume, etc.). Fig. X1.1 shows the precision and bias when applied to a series of doors, windows and walls[6] under laboratory conditions.

X1.2.3 It is expected that the precision and bias of field measurements, applicable to in-situ measurements, will not be as good as the laboratory counterpart. Thus, this can be viewed

[6] Jonasson, Hans, G., "Measurements of Sound Reduction Index with the Intensity Technique," *Nordtest Project 746-88*, Swedish National Testing and Research Institute, Report SP 23, 1991.



Estimate of the precision with which this standard can reproduce reverberation room results obtained in a laboratory. The results[6] were obtained for ISO 140-3, the ISO counterpart to Test Method E 90, and are expected to compare very favorably with those from Test Method E 90, if they were available. The data are an average of the measured results made in three laboratories for a series of, doors, windows, and walls. The bias is expressed in terms of K_1, (solid line) and precision is expressed by the standard deviation (dashed line).

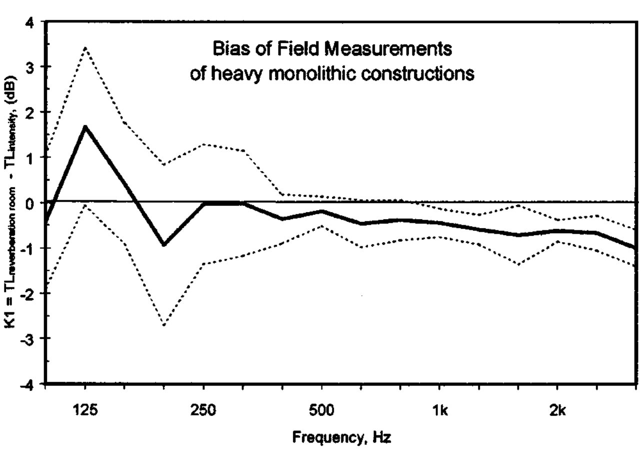
FIG. X1.1

as defining a best case for field measurements, which might apply when the receiving room is large, well defined, and radiation from these surfaces is suppressed.

NOTE X1.2—The 95 % confidence interval will be given by plus/minus twice the standard deviation.

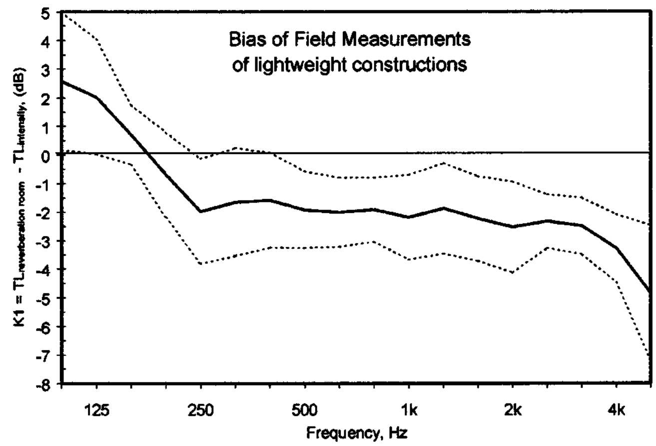
X1.2.4 Field measurements made in the presence of strong flanking and in small receiving rooms should represent the worst case for bias and precision. Results from two flanking facilities are shown in Figs. X1.2 and X1.3.

X1.2.5 The data shown in Fig. X1.2 are the results of fourteen measurements of heavy monolithic constructions made in the same laboratory. They exhibit a similar bias term K_1 relative to those for traditional measurements of separating partitions under laboratory conditions shown in Fig. X1.1. Comparing the standard deviations shown in Figs. X1.1 and X1.2 it is evident that the standard deviation is smaller for the set of measurements in the single laboratory (Fig. X1.2). This implies that there may be significant variation in K_1 between laboratories, which is presumably due to differences in receiving room conditions and the type of specimens tested.



Estimate of the precision with which field measurements using the intensity method can reproduce those obtained using the reverberation room method when measuring heavy monolithic constructions. The data are for 14 cases measured in the same laboratory. The bias is expressed in terms of K_1, (solid line) and precision is expressed by the standard deviation (dashed line).

FIG. X1.2



Estimate of the precision with which field measurements using the intensity method can reproduce those obtained using the reverberation room method when measuring lightweight constructions. The data are for 34 cases measured in the same laboratory. The bias is expressed in terms of K_1, (solid line) and precision is expressed by the standard deviation (dashed line).

X1.2.6 The data shown in Fig. X1.3 are the results of thirty-four measurements of lightweight double-leaf constructions. For this situation the bias term is larger than those shown in Figs. X1.1 and X1.2. However, all three bias terms agree if a confidence interval of approximately one standard deviation is taken.

X1.2.7 The data comprising Fig. X1.3 were analyzed to determine if the bias term was a function of the surface being measured; partition or flanking element. The bias term proved to be nearly identical. However the uncertainty in the estimate for flanking surfaces is greater, especially for frequencies below 250 Hz. This might be due to the combination of several factors, including:

X1.2.7.1 High sound insulation shielding is necessary due to the fact that well below the critical frequency (approximately 2500 Hz for these cases) the flanking surfaces radiate very little sound power;

X1.2.7.2 Reduced pressure-residual intensity index in the low frequencies will reduce precision of intensity estimates;

X1.2.7.3 A low mode count in the receive room will reduce accuracy for the reverberation room measures in the low frequencies; and

X1.2.7.4 Sampling errors might be introduced by the pronounced gradient in the radiated intensity of flanking surfaces as the measurement position is moved away from the excitation junction.

X1.2.8 Comparison of all three figures indicates that expected bias will be a function of the measurement situation (determined by the degree of flanking, room volumes, amongst others) and it is not feasible to specify a single bias and precision. However, it is expected that measurements will typically fall in the range defined by Figs. X1.1-X1.3.

X1.3 *Precision*—The estimated standard deviation associated of the precision with which the intensity transmission loss will reproduce the transmission measured by the two reverberation room methods of Test Methods E 90 and E 336 for large or small building elements is expected to fall in the range defined by Figs. X1.1-X1.3.

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