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Standard Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures[1]

This standard is issued under the fixed designation E1007; 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 test method is part of a set of standards for evaluating the sound insulating properties of building elements and sound isolation between spaces. It is designed to measure in the field the impact sound isolation between rooms or to estimate lower limits for impact sound transmission through a floor-ceiling partition element installed as an interior part of a building using a standard tapping machine. Others in the set cover measurement of impact sound transmission through an isolated floor-ceiling assembly in a controlled laboratory environment (Test Method E492), the measurement of airborne sound transmission loss of an isolated partition element in a controlled laboratory environment (Test Method E90), the measurement of airborne sound isolation and airborne sound transmission loss associated with building elements in the field (Test Method E336), the measurement of sound transmission through building facades and facade elements in the field (Guide E966); and the measurement of sound transmission through a common plenum between two rooms in a controlled laboratory environment (Test Method E1414).

1. Scope

1.1 This test method covers the measurement of the transmission of impact sound generated by a standard tapping machine through floor-ceiling assemblies and associated supporting structures in field situations.

1.2 Measurements may be conducted on all types of floor-ceiling assemblies, including those with floating-floor or suspended ceiling elements, or both, and floor-ceiling assemblies surfaced with any type of floor-surfacing or floor-covering materials.

1.3 This test method defines several procedures and metrics to assess either the apparent performance of the nominally separating floor-ceiling or the isolation of a receiving room from the sound produced by the operation of the tapping machine. The receiving room may be the space directly below the tapping machine or, in some cases, any separated space that receives sound from the operation of the tapping machine. The source and receiving rooms as well as the floor-ceiling system are identified and described in the test report. All measured levels and derivative single number ratings include the effect of flanking transmission. Efforts to suppress flanking are not permitted. Available measures and their single number ratings are the impact sound pressure levels (ISPL) and impact sound rating (ISR), the reverberation time normalized impact sound pressure levels (RTNISPL) and normalized impact sound rating (NISR), and the absorption normalized impact sound pressure levels (ANISPL) and apparent impact insulation class (AIIC).

1.4 The ISPL and ISR may be measured and reported between any two specific rooms or usage areas where the source room area is large enough to accommodate the tapping machine positions and the receiving room volume is sufficiently large to accommodate the microphone positions. For all other measures and ratings in this standard, restrictions such as minimum room volume or dimensions or maximum room absorption are imposed. Thus, conditions may exist that will not allow RTNISPL (NISR) or ANISPL (AIIC) to be determined.

1.5 Where a separating floor-ceiling assembly is composed of parts that are constructed differently on the receiving room (ceiling) side, it is not possible to determine the ANISPL and AIIC of the individual elements or portions of the assembly. In this situation, the measurement will be of the composite structure, not of an individual element.

[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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1.6 Any single field measurement only represents the performance of the actual assembly tested and cannot be used alone to accurately predict how an identical or similar assembly might perform.

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

1.9 *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

E336 Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings

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

E989 Classification for Determination of Impact Insulation Class (IIC)

E1414 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

2.2 *ANSI Standards:*[3]

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

S1.40 Specifications and Verification Procedures for Sound Calibrators

S1.43 Specifications for Integrating-Averaging Sound Level Meters

2.3 *ISO Standard:*[4]

ISO 140—Acoustics—Measurement of Sound Insulation in Buildings and of Building Elements; Part VI—Laboratory Measurement of Impact Sound Insulation of Floors, and Part VII—Field Measurements of Impact Sound Insulation of Floors

2.4 *IEC Standards*[5]:

IEC 60942 Electroacoustics – Sound Calibrators

IEC 61672–1 Electroacoustics - Sound Level Meters – Part 1:Specifications

3. Terminology

3.1 *Definitions*—For definitions of terms pertaining to acoustics used in this test method, see Terminology C634.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *absorption normalized impact sound pressure level, ANISPL, (dB), n*—into a receiving room of at least 40 m^3 in a specified frequency band, the impact sound pressure level (ISPL) normalized to a reference absorption of 10 m^2 in the receiving room.

3.2.1.1 *Discussion*—10 m^2 is equivalent to 108 Sabins

3.2.2 *apparent impact insulation class, AIIC, n*—a single-number rating derived from values of ANISPL in accordance with Classification E989.

3.2.2.1 *Discussion*—field impact insulation class (FIIC) has been replaced with apparent impact insulation class (AIIC) to make clear that the quantity includes flanking and to harmonize terminology with Test Method E336.

3.2.2.2 *Discussion*—AIIC provides an estimate of the apparent sound insulating properties of a floor-ceiling assembly under tapping machine excitation where sound power from associated support structures are attributed to the floor-ceiling assembly.

3.2.2.3 *Discussion*—The absorption normalized impact sound pressure level (ANISPL) and apparent impact insulation class (AIIC) are analogous to apparent transmission loss (ATL) and apparent sound transmission class (ASTC) for airborne measurements.

3.2.3 *coupled space, n*—a secondary space which is adjacent to and partially open to the receiving room 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*—Coupled spaces are only pertinent when measuring and calculating ANISPL and AIIC.

3.2.3.2 *Discussion*—To qualify as a coupled space in this standard the space must meet requirements specified in 10.4.2.

3.2.4 *impact sound pressure level, ISPL, (dB), n*—in a specified frequency band, the average sound pressure level in a specified frequency band produced in the receiving room by the operation of the standard tapping machine on a floor-ceiling assembly, averaged over each of the specified tapping machine positions.

3.2.5 *impact sound rating, ISR, n*—a single-number rating derived from values of ISPL in accordance with Classification E989.

3.2.5.1 *Discussion*—ISR provides a measure of the isolation of the receiving room from the impact sound produced by the

[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.

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

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

operation of the tapping machine in the source room given the existing conditions (that is, sound absorption, reverberation time) in the receiving room at the time of the test.

3.2.5.2 *Discussion*—impact sound pressure level (ISPL) and impact sound rating (ISR) are analogous to noise reduction (NR) and noise isolation class (NIC) for airborne measurements.

3.2.6 *normalized impact sound rating, NISR, n*—a single-number rating derived from values of RTNISPL in accordance with Classification E989.

3.2.6.1 *Discussion*—NISR provides a measure of the potential isolation of the receiving room from the impact sound produced by the operation of the tapping machine in the source room as if the receiving room had a reverberation time of 0.5 s. This reverberation time is typical of many furnished small offices and furnished residential living rooms and bedrooms.

3.2.6.2 *Discussion*—The reverberation time normalized impact sound pressure level (RTNISPL) and normalized impact sound rating (NISR) are analogous to normalized noise reduction (NNR) and normalized noise isolation class (NNIC) for airborne measurements.

3.2.7 *receiving room, n*—a room below or near the source room in which the impact sound pressure levels are measured.

3.2.7.1 *Discussion*— Depending on the metric being measured, the impact sound pressure levels may also have to be measured in spaces that are coupled to the receiving room.

3.2.7.2 *Discussion*—The receiving room is usually the room below the floor-ceiling assembly being excited by the tapping machine but, depending on the metric being measured, it may be on the same level, diagonally below, or, in some cases, above the source room.

3.2.8 *reverberation time normalized impact sound pressure level, RTNISPL, (dB), n*—into a receiving room of less than 150 m^3, in a specified frequency band, the impact sound pressure level normalized to a reverberation time of 0.5 s in the receiving room.

3.2.9 *separating floor-ceiling, n*—the area of the floor-ceiling assembly that is common to both the source room and the room or space immediately below the source room.

3.2.10 *source room, n*—the room or space containing the tapping machine.

3.2.10.1 *Discussion*—The source room could also be an exterior location on a roof or a deck.

3.3 *Symbols:*

3.4 A_2—the total acoustical absorption in the receiving room measured in ⅓ octave frequency bands, m^2.

3.5 T_2—the reverberation time in the receiving room measured in ⅓ octave frequency bands, seconds.

4. Summary of Test Method

4.1 A standard tapping machine is placed in operation on a floor-ceiling assembly. The transmitted impact sound is characterized by the one-third octave band spectrum of the average sound pressure level produced by the tapping machine in the receiving room located beneath or near the floor-ceiling assembly.

4.2 A complete test shall consist of one background noise level measurement, and four tapping level measurements, one for each tapping machine position. The background noise measurement and each tapping level measurement are conducted in the same way, whether by a single sweep or multiple measurements at fixed microphone positions.

4.3 If appropriate, the measured impact sound levels are adjusted for the background noise.

4.4 The adjusted impact sound pressure levels can be used *(1)* without normalization, *(2)* normalized to a standard reverberation time, or *(3)* normalized to a standard amount of absorption.

4.5 If normalized values are to be reported, the reverberation time (T_2) or absorption (A_2), or both, of the receiving room must be determined. To determine absorption, the volume of the receiving room must also be calculated from measured room dimensions.

5. Significance and Use

5.1 The spectrum of the noise produced in the receiving room by the standard tapping machine is determined by *(1)* the size and the mechanical properties of the floor-ceiling assembly, such as its weight, surface properties, mounting or edge restraints, stiffness, and internal damping; *(2)* the degree of flanking transmission through associated structures; and *(3)* the acoustical response of the receiving room.

5.2 The standardized tapping machine specified in 6.1.1 produces a continuous series of uniform impacts at a uniform rate on a floor-ceiling assembly to allow accurate and reproducible measurements of impact sound pressure levels in the receiving room. The tapping machine is not designed to simulate any one type of impact, such as male or female footsteps or to simulate the weight of a human walker. Also, measurements described in this method and ratings based on the results are restricted to a specific frequency range. Thus the subjectively annoying creak or boom generated by human footfalls on a limber floor-ceiling assembly may not be adequately evaluated by this test method.

5.3 Laboratory Test Method E492 calls for highly diffuse sound fields and the suppression of flanking sound transmission in the laboratory's receiving room. This field test method does not allow efforts to suppress flanking. In field tests, acoustical measurements are much more uncertain than in the laboratory since a great variety of receiving room shapes and sizes are encountered in ordinary buildings. Highly diffuse fields are seldom found and the nature of structure-borne flanking transmission can vary widely. In addition, energy can be transmitted laterally away from the receiving room. The amount of lateral transmission of energy can vary significantly between buildings. Consequently, good agreement between laboratory tests and field tests on similar floor-ceiling assemblies should not be expected.

5.4 Several metrics are available for specific uses:

5.4.1 *absorption normalized impact sound pressure level (ANISPL) and apparent impact insulation class (AIIC)*—These metrics are intended to evaluate the performance of the

floor-ceiling assembly and adjacent structures as installed (including structure-borne flanking paths). For these metrics, sound power from associated support structures are attributed to the floor-ceiling assembly. Because these are measures of the apparent performance of the nominally separating floor-ceiling, the receiving room shall be the space directly under the tapping machine. ANISPL and AIIC may be reported if the receiving room has a volume of at least 40 m^3 and the smallest dimension is at least 2.3 m. In rooms of 150 m^3 or greater ANISPL and AIIC shall not be determined and reported unless, in all frequency bands necessary to calculate the AIIC, the receiving room absorption, A_2, is less than:

$$A_2 < 2 \times V^{(2/3)} \quad (1)$$

where:

V = the volume of the receiving room, m^3

Results are usually not identical to laboratory tests of the floor-ceiling assembly alone. Because of the uncontrollable factors mentioned in 5.1 – 5.3, caution must be used when using test results to predict the performance of other floor-ceiling assemblies with similar construction.

5.4.2 *impact sound pressure level (ISPL) and impact sound rating (ISR)*—These metrics are intended to assess the impact sound isolation as it exists at the time of the test due to the mechanical excitation of the floor-ceiling assembly by the standard tapping machine. The measurements can be performed in any space affected by the sound of the operating tapping machine. These metrics do not represent the performance of the separating floor-ceiling. They represent the impact sound isolation between the source floor and the receiving room. There are no receiving room absorption restrictions and no receiving room volume restrictions other than being sufficiently large to accommodate the microphone positions described in 11.3.

5.4.3 *reverberation time normalized impact sound pressure level (RTNISPL) and normalized impact sound rating (NISR)*—These metrics are intended to assess the impact sound isolation as if the receiving room had a reverberation time of 0.5 s. This reverberation time is typical of many furnished small offices and furnished residential living rooms and bedrooms. RTNISPL and NISR shall not be reported for receiving rooms of 150 m^3 or larger.

6. Test Machine

6.1 *Tapping Machine Specifications:*

6.1.1 This test method is based on the use of a standardized tapping machine that conforms to the specifications given in ISO 140 /part 6. The tapping machine shall have five hammers equally spaced in a line. The distance between centerlines of neighboring hammers shall be 100 ± 3 mm. Each hammer shall have an effective mass of 500 ± 6 g which falls freely from a height of 40 ± 3mm. The falling direction of the hammers shall be perpendicular to the test surface to within ± 0.5°. The part of the hammer carrying the impact surface shall be cylindrical with a diameter of 30 ± 0.2 mm. The impact surface shall be of hardened steel and shall be spherical with a curvature radius of 500 ± 100 mm. The time between successive impacts shall be 100 ± 20 ms.

6.1.2 Since friction in the hammer guidance system can reduce the velocity of the hammer at impact, the tapping machine shall be checked for friction between the hammers and the guidance system. Any friction found should be eliminated or reduced as much as possible.

6.1.3 The bottoms of the machine supports shall be at least 100 mm from the nearest hammer.

NOTE 1—Investigations (**1**)[6] involving light-frame floating floors have shown that both the resiliency of the tapping machine supports as well as their spacing from the hammers significantly affect the impact sound pressure levels in frequency bands below 400 Hz.

6.1.4 Following adjustment of the hammer drop in accordance with 6.1.1 – 6.1.3 , the tapping machine is ready for use on any floor, including those surfaced with soft or resilient materials.

6.2 *Operational Noise*—The presence of airborne sound flanking could cause extraneous noise to occur in the receiving room. The sound pressure levels in the receiving room due to airborne transmission from the operating tapping machine shall be at least 10 dB less than those due to hammer impacts transmitted structurally.

NOTE 2—A loudspeaker or other convenient airborne noise source can be used to evaluate the extent of airborne sound transmission between the rooms (see Test Method E336).

6.3 *Tapping Machine Positions*—the spectrum of the noise in the receiving room may be influenced by the location of the tapping machine on the floor assembly. For purposes of this test method, the tapping machine positions described in 6.3.1 – 6.3.4 shall be used (see Fig. 1).

6.3.1 *Position 1*—The middle hammer of the tapping machine shall be at the approximate center of the area identified in 9.4. In joist construction arrange the tapping machine so that all hammers are parallel with and aligned with the middle joist if possible.

NOTE 3—Joist locations and orientations may not be obvious in field situations. Inspection of building plans and nailing patterns may assist the determination of joist layout.

6.3.2 *Position 2*—Same as Position 1, except rotate the tapping machine 90° around the axis of the middle hammer.

6.3.3 *Position 3*—Displace the tapping machine laterally with respect to Position 1, so that the longitudinal axis of the machine is centered midway between and parallel to the central joists and to Position 1. In the case of homogeneous floors of concrete slab or solid deck construction without joists, the lateral displacement of the tapping machine shall be 0.6 m from that of Position 1.

6.3.4 *Position 4*—Position the tapping machine so that the longitudinal axis of the machine forms an angle of 45° with respect to Position 1. Displace the machine laterally so that the middle hammer is 0.6 m from the midpoint of Position 1.

7. Measuring Equipment

7.1 Microphones, amplifiers, and electronic circuitry to detect, measure, process and analyze microphone signals shall

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

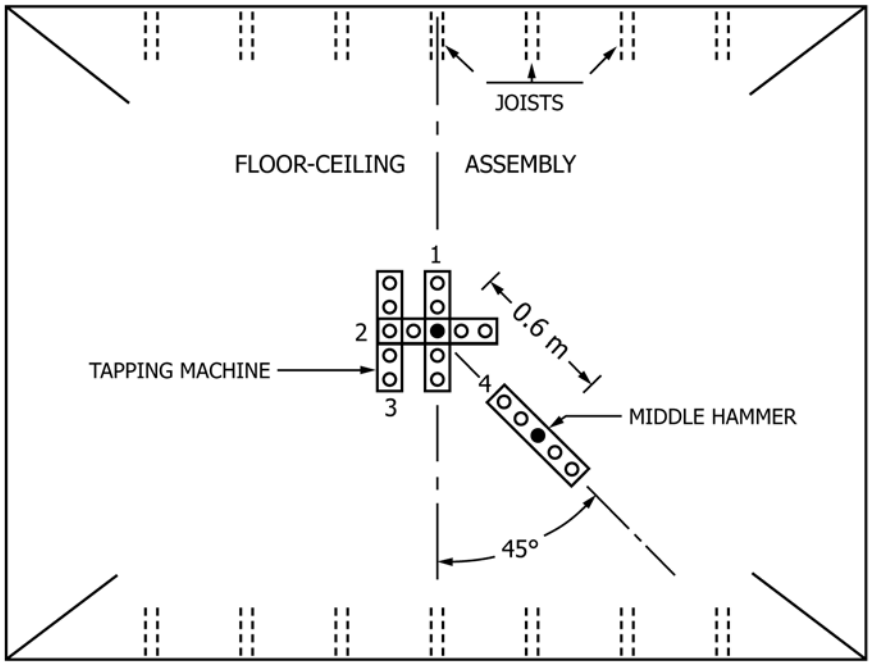

FIG. 1 Tapping Machine Positions

satisfy the requirements of ANSI S1.43 or IEC 61672-1 for class 1 sound level meters, except that B and C weighting networks are not required.

7.2 Measurement quality microphones having a diameter of 13 mm or smaller shall be used.

NOTE 4—If measurements are to be made above 5000 Hz, a diffuse field (random-incidence) microphone or corrector is preferred.

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

7.4 The measurement system filters shall for each test band conform to the specifications in ANSI S1.11 for a one-third-octave band filter set, class 1 or better.

8. Calibration and Sensitivity Checks

8.1 A thorough calibration of acoustical instrumentation shall be performed by an accredited calibration laboratory at regular intervals as this is necessary to help assure that the equipment is operating within instrument tolerances and manufacturer's specifications.

NOTE 5—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.

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

8.3 The field calibrator used for sensitivity checks shall be an acoustic or electro-acoustic calibrator meeting class 1 requirements of ANSI S1.40 or IEC 60942.

8.4 Sensitivity checks of the entire measuring setup (including the microphone, all cables, and instruments) shall be performed with the same field calibrator at the beginning and end of each test day. Additional checks may be performed as deemed necessary. If the sensitivity changes by more than 0.5 dB, the results since the last valid sensitivity check are invalid and the measurements shall be repeated.

9. Test Site Conditions

9.1 *Assembly types*—This test method is applicable to all types of floor-ceiling assemblies surfaced with any type of material, including assemblies with floating floors or suspended ceilings.

9.1.1 In all cases the test assembly shall be installed in accordance with customary field practice including normal constraint and sealing conditions at the perimeter and at the joints within the assembly.

9.2 *Aging of Assemblies*—Test assemblies that incorporate materials for which there is a curing process (for example, adhesives, plasters, concrete, mortar, and damping compound) shall age for a sufficient interval before testing. Recommended aging periods for certain common materials are summarized in Table 1.

TABLE 1 Recommended Minimum Aging Periods Before Test

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

9.3 *Installation of Floor-Surfacing Materials:*

9.3.1 Floor-surfacing materials of significant weight, such as carpets and pads, may exert a damping or restraining effect on the flexural motion of lightweight floor-ceiling structures. For this reason, it is recommended that the entire area of the floor be covered with the floor surfacing materials. Any exception to this shall be noted in the test report. A minimum area of 5 ft (1.52 m) by 5 ft (1.52 m) shall be covered with the surfacing materials under test so that all tapping positions described in 6.3 can be accommodated on the covered portion.

9.3.2 The installation or application of floor-surfacing materials shall be in accordance with manufacturer's instruction, if available, especially in regard to cleaning and priming of the subfloor.

9.3.3 Certain floor-surfacing materials (for example, sheet vinyl) are intended to be applied with adhesive. For testing purposes, such materials shall not be loosely laid. They shall be firmly adhered to the subfloor.

NOTE 6—Although most floors are ready for immediate use after being installed, it is recommended that measurements on floors with adhesive-applied surfacing materials be deferred for at least 24 h after installation to allow the adhesive to cure.

9.4 *Identification of Separating floor-ceiling and Tapping Location*—The separating floor-ceiling and location of the tapping positions as described in 6.3 will depend on whether the space below is partially divided and whether the floor-ceiling assembly (including flooring surface) is consistent over the space below.

9.4.1 *Separating floor-ceiling*—The separating floor-ceiling will be the area of the floor-ceiling assembly that is common to both the upper and lower spaces.

9.4.1.1 If either the space above or the space below is partially divided into different usage areas (such as living, dining, or kitchen areas that are largely open to each other) with some minimal but clearly identifiable partial dividers, consider each usage area to be a separate space for purposes of defining the separating floor-ceiling.

9.4.2 *Tapping Locations:*

9.4.2.1 If the floor-ceiling assembly (including flooring surface) are consistent over the separating floor-ceiling, the tapping positions described in 6.3 should be relative to the approximate center of the separating floor-ceiling.

9.4.2.2 If the floor-ceiling construction differs over the extent of the separating floor-ceiling, each construction should be considered separately. Examples of such a difference are a different flooring surface, a difference in framing, or a lowered ceiling in a portion of the space. The tapping positions described in 6.3 should be relative to the approximate center of each construction type for which results are desired.

9.4.2.3 If tapping is to be conducted on the ground floor then the boundaries of the spaces on that level shall be used to determine the location of the tapping machine.

9.4.2.4 The report must clearly and explicitly describe where the tapping was conducted.

10. Receiving Room Selection

10.1 Determine the space in which the sound level measurements will be performed.

10.1.1 In partially divided spaces, the floor-ceiling construction may be consistent over a usage area but different over adjacent areas. In those circumstances, when measuring in a specific usage area, it is possible that sound radiated over an adjacent area may be stronger than in the area under the separating floor-ceiling, and may strongly influence or even dominate the sound in the area of the measurements. This is most likely to occur with concrete floor construction when there is a separate ceiling in the receiving room space but not in the adjacent space. In such cases the measured sound levels and corresponding metrics may be greater in the adjacent area than in the area directly below the separating floor-ceiling. When such conditions are apparent the report shall clearly state that the results shown may not represent the worst case scenario.

10.2 *ISPL and ISR:*

10.2.1 The ISPL and ISR may be measured and reported between any two specific rooms or usage areas where *(1)* the source room area is large enough to accommodate the tapping positions described in 6.3 and *(2)* the receiving room volume is sufficiently large to accommodate the microphone positions described in 11.3.

10.2.2 There are no absorption limits for measuring these metrics.

10.2.3 Even in great rooms with no partial dividers between areas, if usage areas are clearly visible, measurements may be made and reported between these usage areas.

10.2.4 The report shall clearly and explicitly describe where the measurements were performed in the receiving space.

10.2.5 If there is an area directly below the tapping machine and if this area is not included in the measurements, the report shall clearly state that the results shown may not represent the worst case scenario.

10.3 *RTNISPL and NISR:*

10.3.1 RTNISPL and NISR may be measured and reported in the same circumstances as ISPL and ISR if the receiving room is less than 150 m^3. RTNISPL and NISR shall not be reported if the receiving room has a volume of 150 m^3 or greater.

10.3.2 The report shall clearly and explicitly describe where the measurements were performed in the receiving space.

10.3.3 If there is an area directly below the tapping machine and if this area is not included in the measurements, the report shall clearly state that the results shown may not represent the worst case scenario.

10.4 *ANISPL and AIIC:*

10.4.1 ANISPL and AIIC are measurements of the apparent insulating performance of the separating floor-ceiling. All coupled spaces not eliminated by closing openings shall be included in the measurements and calculations. Measurements are required to verify that a coupled space exists.

10.4.2 *Coupled Spaces*—When the receiving room immediately adjacent to the separating floor ceiling assembly is connected by an opening to a secondary space, then the existence of a coupled space must be evaluated. Multiple coupled spaces may exist adjacent to a given primary space.

For a space to be considered a coupled space for purposes of this standard, the following conditions must be met:

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

10.4.2.2 Unless one of the dimensions of a secondary space is less than 1 m, it must be demonstrated by measurement that the difference between the space-averaged A-weighted sound level in the primary and secondary spaces with the tapping machine operating is not more than 6 dB.

10.4.2.3 If either dimension of the secondary space in the plane of the opening between spaces is less than 1 m, the dimension perpendicular to that plane shall not be more than 1 m.

10.4.2.4 If a secondary space does not meet all of the conditions of 10.4.2.1 – 10.4.2.3 then it is not coupled and that space shall not be included in the measurements and its volume shall not be included in calculations even if it is left open to the primary space.

10.4.3 The measurement space shall be the enclosed space directly under the tapping machine location and associated coupled spaces.

10.4.4 When measuring and reporting ANISPL and AIIC, ideally, the receiving room should be sufficiently large and reverberant so that an approximately diffuse sound field exists in all measurement bands. For the purposes of this standard test method, sound fields are deemed acceptable if the receiving room volume is at least 40 m^3. ANISPL and AIIC shall not be reported for receiving rooms (including coupled spaces) of less than 40 m^3. The volume of enclosed cabinets and major appliances such as a refrigerator or range when present shall not be considered part of the room volume.

10.4.4.1 All doors enclosing the receiving room shall be closed unless doing so would leave the 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 space would meet the minimum volume requirement, then all doors to that coupled space shall be left fully open.

10.4.4.2 It is recommended that coupled spaces open to receiving spaces without doors 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 unless such coupled space is needed to meet minimum volume requirements.

10.4.5 In rooms of 150 m^3 or greater, ANISPL and AIIC shall not be reported unless the room absorption A_2 meets the criteria of Eq 1 in all frequency bands needed to compute the AIIC rating.

10.4.6 When the floor-ceiling construction differs over the separating floor-ceiling, it is not possible to measure the insulating properties of any one construction type because the results will be influenced by the presence of the other constructions. The report shall state that the construction is not the same over the full area and that results of such measurements represent only the performance under those specific circumstances and shall not be used to typify the performance of any part of the floor-ceiling.

The report shall clearly and explicitly describe where the measurements were performed in the receiving space.

11. Determination of Impact Sound Pressure Levels

11.1 *Intrusive noises*—during all measurements, the operator shall listen for possible intrusive noise (that is, an acoustical event that might affect the measured average sound level). If such an intrusive noise is detected during a measurement, that measurement shall be repeated.

11.2 The minimum range of measurements shall be a series of contiguous one-third-octave bands with center frequencies from 100 to 3150 Hz, inclusively.

NOTE 7—It is desirable that the frequency range be extended to include at least the 4000 and 5000 Hz bands and the 50, 63, and 80 Hz bands if possible.

11.2.1 The impact sound pressure levels are measured in a receiving room near the floor-ceiling assembly upon which a standard tapping machine operates in the positions described in 6.3. Various spatial sampling arrangements are possible. A single microphone may be moved continuously or placed sequentially at several measurement positions or an array of stationary microphones may be used. When measuring impact sound isolation (ISR or NISR), the average sound level should be measured 1 to 2 m above the floor in the receiving room while still conforming to the restrictions in 11.4.

11.3 *Measurement Space:*

11.3.1 Microphones shall be placed or scanned in the space which is more than 1 m from all major extended surfaces.

11.3.2 If the requirements of 11.3.1 prevent adequate spatial sampling of the measurement region then measurements may be made as close as 0.5 m to room surfaces **(2)**, but must never be less than 1 m from the separating floor-ceiling.

11.3.3 When coupled spaces are included in the measurement space for ANISPL and AIIC, measurements of the sound level in each space must be averaged in approximate proportion to the volume of each space.

11.3.3.1 When using manually scanned microphones or fixed microphone positions this may 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 Alternatively, the sound level can be measured separately in each space and for each ⅓ octave band, combine the measurements in proportion to the volume of each space as follows:

$$\textit{Volume weighted sound pressure level} = \quad (2)$$

$$10log\left(\left[V1*10(L1/10)+V2*10(L2/10)+\ldots+Vn*10(Ln/10)\right]/V\right)$$

where

Vn = the volume of subspace n, m^3
Ln = average sound pressure level in subspace n
V = the total volume of the defined receiving room, m^3

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

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 *Fixed Microphone Positions*—if fixed microphone positions are used, at least four positions shall be used in the receiving room for each tapping machine position. The microphone positions shall be at least 1 m apart. The distance between microphones may be reduced, if and only if the receiving room volume is too small to allow this. Do not use microphone arrangements that are obviously symmetrical (for example, all microphone positions in the same vertical or horizontal plane).

NOTE 8—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 (**2**). The provision in 11.4.1 will not provide independent samples at the lowest frequency bands specified in 11.2.

11.4.2 *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.

11.4.2.1 *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 11.4 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 9—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 2 L/λ and for a circular or closed traverse of length L is (2 L/λ) λ 1, where λ is the wavelength of interest (**3**).

11.4.2.2 *Manually Scanned Microphones*—When the size of the measurement space allows, the operator shall stand within the space and turn slowly while 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. The microphone shall be moved up and down as well as from side to side. 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 spatial sampling is essentially uniform throughout the measurement space.

11.5 *Averaging Time:*

NOTE 10—the average sound pressure level is best obtained using an instrument that computes and displays the average value. Such instruments include integrating-averaging sound level meters that meet the requirements of ANSI S1.43 or IEC 61672. Other equivalent averaging methods may also be satisfactory.

11.5.1 *Fixed Microphones*—At each sampling position and for each tapping machine position, the averaging time shall be sufficient to yield an accurate estimate of the average sound pressure level. This requires longer averaging times at low frequencies than at high frequencies. The minimum averaging time shall provide 95 % confidence limits of ±0.5 dB in each one-third octave band. For a band with center frequency, f, the minimum averaging time, T_a, in seconds, may be calculated from:

$$T_a\left(\frac{1240}{f}\right) \tag{3}$$

Thus at 100 Hz, the minimum averaging time for 95% confidence limits of ±0.5 dB shall be 12.4 s. For more information see (**4**).

11.5.2 *Moving Microphones*—for mechanically or manually swept microphones, averaging times should be sufficiently long that repeat measurements are not significantly different. The averaging time shall be at least 30 s. A typical sweep time for a small room is 30 seconds and for a larger room up to 150 m^3 is 60 s. For rooms larger than 150 m^3, it is necessary to use sweep times longer than 60 s.

11.6 *Background Noise Level:*

11.6.1 With the tapping machine shut off, measure the average background noise level in each frequency band in the receiving room. The background noise levels shall be measured the same way as the impact sound levels are measured, using the same averaging times and the same microphone positions or scan pattern. The background noise measurement can be made immediately before, immediately after, or at some time in between the measurement of the impact sound level at the four tapping machine positions.

NOTE 11—The background noise levels should be measured using the same instrument range settings as used for the measurement of the impact sound levels. A preliminary measurement with the tapping machine operating may be necessary in order to establish the appropriate instrument range to be used for measuring both the source signal and the background noise levels in the receiving room.

11.6.2 If the difference between the level due to the combination of source signal plus background and the background noise level alone exceeds 10 dB in any frequency band, then no correction to the receiving room level is necessary in that band.

11.6.3 Adjustments for background noise levels should be made for each discrete measurement period before averaging over the discrete microphone positions or over the discrete tapping machine positions. However it is deemed acceptable for this standard to make the adjustments after averaging.

11.6.4 If the difference between the combination of source signal plus background and the background noise level alone is greater than 5 dB in any frequency band, the background-noise adjusted receiving room level in that band shall be calculated as follows:

$$L_s = 10log\left(10^{(L_{sb}/10)} - 10^{(L_b/10)}\right) \tag{4}$$

where:

L_s = the background-noise adjusted receiving room level, dB

L_{sb} = the combined level of signal and background (the measured receiving room level), dB

L_b = the measured background noise level in each band, dB

11.6.5 If the background noise level is within 5 dB of the combined source signal plus background in any frequency band, then subtract 2 dB from the combined receiving room level and use the net result as the background-noise adjusted receiving room level in that band. In this case, the calculated values only provide an estimate of the lower limit of the impact insulation of the separating floor-ceiling system or of the impact sound isolation. Such values shall be identified in the test report.

11.7 *Determination of Space-Averaged Impact Sound Pressure Levels*—following the procedures given above, obtain an averaged sound pressure level corresponding to the sampling method used in the receiving room. The space-average level for the room is the ISPL and is calculated as follows:

$$ISPL = 10log\left[\frac{1}{N}\sum_{i=l}^{N} 10^{(Ls_i/10)}\right] \quad (5)$$

For stationary microphones, Ls_i is the set of background-noise adjusted space- and time-averaged sound pressure levels measured at n microphone locations for each of the four tapping machine positions and N is $4n$. For moving microphones, Ls_i is the set of background noise adjusted space and time averaged sound pressure levels measured for the four tapping machine positions and N is 4. If any data from the set of measured levels have been adjusted for background noise levels, then the adjusted levels shall be used as values for L_i.

12. Determination of Receiving Room Decay Rates, Reverberation Times and Sound Absorption

12.1 When either the receiving room sound absorption or receiving room decay rate and reverberation time is needed to determine the NISR or AIIC, the respective quantities shall be determined in accordance with Test MethodE2235. The determination of receiving room absorption (A_2) or receiving room reverberation time (Test Method E2235) shall be made with the receiving room in the same condition as for the measurement of impact sound pressure levels.

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

12.2.1 Locate the sound source such that it excites both the receiving room and coupled spaces.

12.2.2 Select measurement positions so they are in approximate proportion to the volume of the receiving room and coupled spaces. Measurements are not required in coupled spaces less than 20% of the total volume.

12.3 When coupled spaces exist and NISR results are to be reported for a portion of the complete space, the requirements of Test Method E2235 shall be met for measurements within the space for which results are to be reported.

12.4 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 room absorption.

13. Calculation of Acoustical Quantities and Associated Metrics

13.1 *absorption normalized impact sound pressure level (ANISPL) and apparent impact insulation class (AIIC)*—The receiving room should be the space directly below the tapping machine. The report shall state explicitly the location of the receiving room in relation to the source (tapping) room. The receiving room shall have a minimum volume of 40 m^3. ANISPL and AIIC shall not be reported unless the room absorption A_2 meets the criteria of Eq 1 in all frequency bands necessary to calculate the AIIC.

13.1.1 Calculate the absorption normalized impact sound pressure level, ANISPL, in each of the specified frequency bands as follows:

$$ANISPL = ISPL - 10log\left(\frac{A_0}{A_2}\right) \quad (6)$$

where:

ANISPL = absorption normalized impact sound pressure level, dB,
ISPL = impact sound pressure level in the receiving room, dB,
A_0 = reference absorption, 10 m^2
A_2 = sound absorption of the receiving room, m^2.

13.1.2 The values of ANISPL may be used to obtain a single number rating (AIIC) in accordance with Classification E989.

13.2 *impact sound pressure level (ISPL) and impact sound rating (ISR)*—may be reported for any receiving room that is affected by the sound of the operating tapping machine. The report must state explicitly the location of the receiving room in relation to the source room

13.2.1 The non-normalized impact sound pressure level, ISPL, is measured in each of the specified frequency bands in the receiving room and may be adjusted for background noise levels in accordance with section 11.7.

13.2.2 The ISPL data may be used to obtain a single number rating (ISR) in accordance with Classification E989.

13.3 *reverberation time normalized impact sound pressure level (RTNISPL) and normalized impact sound rating (NISR)*—shall not be used for receiving rooms of 150 m^3 or greater. These metrics are intended for small rooms that can be expected to have a reverberation time of 0.5 s when furnished normally. For large rooms (greater than 150 m^3) the appropriate metrics for isolation are impact sound pressure level (ISPL) and impact sound rating (ISR), measured with the spaces furnished normally. The RTNISPL and NISR may be reported for any receiving room that is affected by the sound of the operating tapping machine and meets the volume criteria stated above. The report must state explicitly the location of the receiving room in relation to the source room.

13.3.1 Calculate the reverberation time normalized impact sound pressure level, RTNISPL, in each of the frequency bands as follows:

$$RTNISPL = ISPL - 10log\left(\frac{T_2}{0.5}\right) \quad (7)$$

where:

RTNISPL = reverberation time normalized impact sound pressure level, dB,
ISPL = Impact sound pressure level in the receiving room, dB,
T_2 = reverberation time measured in the receiving room, seconds.

$$T = \frac{60}{d} \quad (8)$$

where:

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

13.3.2 The values of RTNISPL may be used to obtain a single number rating (NISR) in accordance with Classification E989.

14. Report

14.1 The report shall include the following information:

14.2 *Statement of Conformance to Standard*—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 E1007-XX" where XX indicates the last two digits of the year date of the version of the standard used.

14.2.1 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 12—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 14, including the statement of exceptions as required above, it is recommended that a statement be included at least noting that such report is not in accordance with this standard.

14.3 *Description of Test Environment:*

14.3.1 A general description of the receiving room. Include a description of walls, ceiling and floor as well as furnishings.

14.3.2 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.

14.3.3 If ANISPL and AIIC are being measured and reported, then state the key dimensions that define the volume of the receiving room.

14.3.4 A description of where the tapping machine was placed during the measurements.

14.3.5 The exact relationship between the source and receiving rooms. Clearly state the horizontal and vertical relationship between the rooms. A sketch is sometimes helpful to show this relationship.

14.3.6 Whenever ISPL or RTNISPL 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."

14.4 *Description of Test Assembly*—To the extent information is available, give a complete description of the test assembly, including the dimensions, thickness, and all of the constructional elements. This will often be based on the documented intended design, variances from the design reported, or differences observable without examining the interior of the assembly. The source of any description shall be stated.

14.4.1 Include a description of any floor-covering material and underlayment such as carpets, pads, and mats that may have been placed on top of the finished floor.

14.4.2 If the construction or installation of the floor-ceiling assembly 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 floor-ceiling assembly 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.

14.5 *Description of Test Procedure and Equipment:*

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

14.5.2 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.

14.6 *Statement of Test Results:*

14.6.1 State clearly the type of results that are being presented (ISPL, RTNISPL, ANISPL) and the associated single number rating (ISR, NISR, AIIC). All such results shall be presented in tabular form rounded to the nearest decibel and, optionally, may also be presented in a graphical format.

NOTE 13—When the results are presented in graphical form, it is recommended that the ordinate scale be 2 mm/dB and the abscissa scale be 50 mm/decade. If it is necessary to use a larger or smaller scale, the same aspect ratio as above should be used. Whenever practicable, the ordinate scale should start at 0 dB.

14.6.2 State the average values of the measured impact sound pressure levels (ISPL), the measured background noise, and, if measured, the set of A_2 or T_2 values. The sound pressure level data must be presented in tabular form, rounded to one decimal place. Values of A_2 data shall be reported to three (3) significant figures and T2 data shall be reported to hundredths of a second. These data may be placed in an appendix of the report.

14.6.3 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 11.6.5).

14.6.4 On each page of the report containing test results, place the statement "This page alone is not a complete report".

14.6.5 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 standard on

nominally identical constructions and acoustical conditions may produce different results."

14.7 Number all pages of the report, and indicate the total number pages on each page of the report.

15. Precision and Bias

15.1 *Precision*—A round robin test was performed in 2008 to evaluate Test Method E1007, and establish reproducibility limits for the data obtained. Six independent test agencies participated in the round robin by testing the same floor-ceiling assembly in a multi-family residential building. The tests were conducted using a pair of unfurnished bedrooms stacked one above the other. Both bedrooms were located adjacent to an exterior wall of the building and each unit contained an exterior window. The floor-ceiling assembly consisted of a ceramic tile finish floor over a 5 mm thick shredded rubber/polymer underlayment over an 8 inch thick PT concrete slab. A single layer of ⅝ in. type X gypsum board was installed on independent framing suspended 4 in. below the slab. The reproducibility values reported in this section are based on that round robin series.

15.1.1 For the purposes of this standard, the reproducibility, R, is the value below which the absolute difference between two single test results obtained with the same method in the identical field situation, by two different test agencies may be expected to lie with a probability of 95 %.

15.1.2 Estimates for reproducibility of absorption normalized impact sound pressure level (ANISPL) and apparent impact insulation class (AIIC), based on the results of the round robin, are listed in Table 2 together with the mean value of ANISPL at each frequency. Also, the reproducibility of the AIIC is listed along with the mean value.

15.1.3 Estimates for impact sound pressure level (ISPL) and impact sound rating (ISR), based on the results of the round robin, are listed in Table 3 together with the mean value of ISPL at each frequency. Also, the reproducibility of the ISR is listed along with the mean value.

TABLE 2 Estimates of Reproducibility, R, of the ANISPL values for the measurements of a specific field floor-ceiling assembly.

Mid Band Frequency, Hz	ANISPL, dB	R, dB
80	48.49	3.42
100	48.22	8.71
125	48.19	3.20
160	49.29	1.95
200	48.96	2.75
250	47.98	3.04
31	47.93	1.84
400	48.74	1.52
500	49.02	1.53
630	50.16	2.56
800	51.26	1.59
1000	55.48	1.83
1250	55.80	1.54
1600	57.74	1.52
2000	60.41	1.86
2500	55.59	2.91
3150	46.94	3.79
4000	43.67	2.64
5000	40.14	4.43
AIIC	46.17	2.10

TABLE 3 Estimates of Reproducibility, R, of the ISPL values for the measurements of a specific field floor-ceiling assembly.

Mid-band frequency, Hz	ISPL, dB	R, dB
80	49.86	3.32
100	50.81	8.71
125	51.27	2.46
160	52.42	1.70
200	52.48	2.69
250	51.74	2.47
315	52.26	1.94
400	53.59	1.65
500	53.82	1.55
630	54.83	2.15
800	55.84	2.04
1000	59.68	2.39
1250	59.81	2.03
1006	61.36	2.20
2000	63.55	2.80
2500	58.75	3.89
3150	50.30	4.74
4000	46.97	3.68
5000	43.13	5.44
ISR	43.00	3.07

15.1.4 Estimates for reverberation time normalized impact sound pressure level (RTNISPL) and normalized impact sound rating (NISR), based on the results of the round robin, are listed in Table 4 together with the mean value of ISPL at each frequency. Also, the reproducibility of the ISR is listed along with the mean value.

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

16. Keywords

16.1 absorption normalized impact sound pressure level; apparent impact insulation class; impact sound insulation; impact sound pressure level; impact sound rating; normalized impact sound rating; reverberation time normalized impact sound pressure level; tapping machine

TABLE 4 Estimates of Reproducibility, R, of the RTNISPL values for the measurements of a specific field floor-ceiling assembly.

Mid-band frequency, Hz	RTNISPL, dB	R, dB
80	47.64	3.38
100	47.50	9.68
125	47.66	3.16
160	48.71	1.63
200	48.33	2.67
250	47.43	2.94
315	47.26	1.69
400	47.99	1.32
500	48.32	1.44
630	49.24	1.48
800	50.50	1.07
1000	54.75	1.51
1250	55.05	1.09
1600	56.96	1.18
2000	59.73	2.06
2500	55.09	3.10
3150	46.48	3.99
4000	43.08	2.91
5000	39.68	4.80
NISR	46.60	2.50

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