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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 ~~measured.~~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 ~~measure~~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 ~~a~~ 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.

[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.

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 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:

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

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.

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

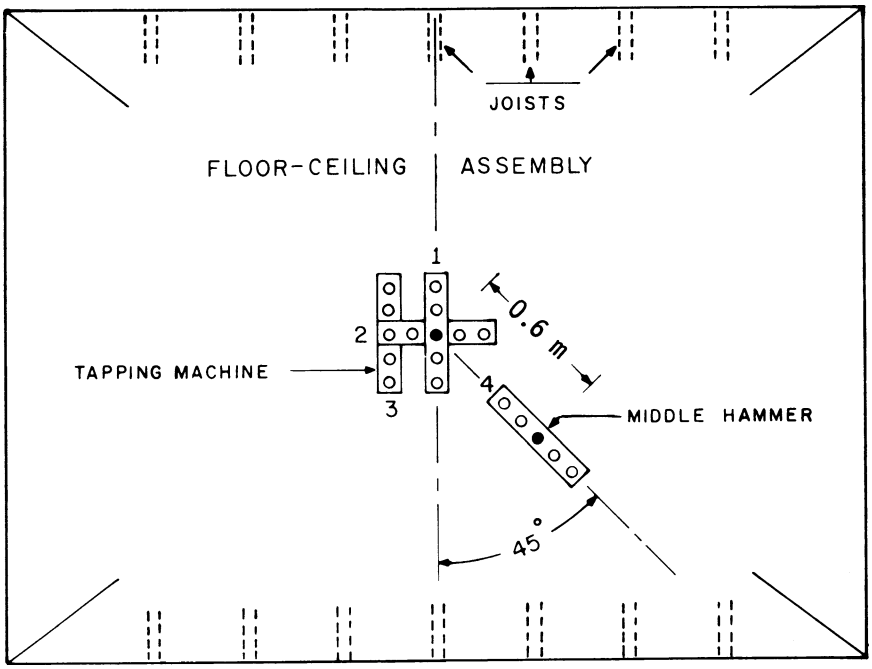

FIG. 1 Tapping Machine Positions

7. Measuring Equipment

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