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Standard Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine[1]

This standard is issued under the fixed designation E492; 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.

ε1 NOTE—Editorially corrected 14.1 in April 2016.

INTRODUCTION

This test method is one of several for evaluating the sound insulating properties of building elements. It is designed to measure the impact sound transmission performance of an isolated floor-ceiling assembly, in a controlled laboratory environment. Others in the set deal with field measurement of impact sound transmission through floor-ceiling assemblies (Test Method E1007), measurement of sound isolation in buildings (Test Method E336), the measurement of sound transmission through a common plenum between two rooms (Test Method E1414), and the laboratory measurement of airborne sound transmission loss of building partitions such as walls, floor-ceiling assemblies, doors, and other space-dividing elements (Test Method E90).

1. Scope

1.1 This test method covers the laboratory measurement of impact sound transmission of floor-ceiling assemblies using a standardized tapping machine. It is assumed that the test specimen constitutes the primary sound transmission path into a receiving room located directly below and that a good approximation to a diffuse sound field exists in this room.

1.2 Measurements may be conducted on floor-ceiling assemblies of all kinds, 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 prescribes a uniform procedure for reporting laboratory test data, that is, the normalized one-third octave band sound pressure levels transmitted by the floor-ceiling assembly due to the tapping machine.

1.4 *Laboratory Accreditation*—The requirements for accrediting a laboratory for performing this test method are given in Annex A2.

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

1.6 *This standard does not purport to address 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]

C423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method
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

[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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[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.

E989 Classification for Determination of Impact Insulation Class (IIC)
E1007 Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures
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]
S1.10 Pressure Calibration of Laboratory Standard Pressure Microphones
S1.11 Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters
S1.43 Specification for Integrating-Averaging Sound-Level Meters
S12.51 Acoustics—Determination of Sound Power Levels of Noise Sources Using Sound Pressure—Precision Methods for Reverberation Rooms

2.3 *ISO Standards:*[3]
ISO 140/6 Acoustics—Measurement of Sound Insulation in Buildings and of Building Elements Part 6: Laboratory Measurements of Impact Sound Insulation of Floors
ISO 3741 Determination of Sound Power Levels of Noise Sources Using Sound Pressure—Precision Methods for Reverberation Rooms

2.4 *IEC Standards:*[4]
IEC 60942 Electroacoustics—Sound Calibrators
IEC 61672 Electroacoustics—Sound Level Meters—Part 1: Specifications

3. Terminology

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

airborne sound
average sound pressure level
background noise
decay rate
decibel
diffuse sound field
impact insulation class
one-third octave band
receiving room
reverberant sound field
reverberation room
sound absorption
sound pressure level

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *receiving room*—a reverberation room below the floor specimen under test in which the sound pressure levels due to the tapping machine are measured.

4. Summary of Test Method

4.1 A standard tapping machine is placed in operation on a floor specimen that is intended to represent a horizontal separation between two rooms, one directly above the other. The average spectrum of the sound pressure levels produced by the tapping machine is measured in the receiving room below in one-third octave bands.

4.2 Since the spectrum depends on the absorption of the receiving room, the sound pressure levels are normalized to a reference absorption for purposes of comparing results obtained in different receiving rooms that differ in absorption.

5. Significance and Use

5.1 The spectrum of the noise in the room below the test specimen is determined by the following:

5.1.1 The size and the mechanical properties of the floor-ceiling assembly, such as its construction, surface, mounting or edge restraints, stiffness, or internal damping,

5.1.2 The acoustical response of the room below,

5.1.3 The placement of the object or device producing the impacts, and

5.1.4 The nature of the actual impact itself.

5.2 This test method is based on the use of a standardized tapping machine of the type specified in 8.1 placed in specific positions on the floor. This machine produces a continuous series of uniform impacts at a uniform rate on a test floor and generates in the receiving room broadband sound pressure levels that are sufficiently high to make measurements possible beneath most floor

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

types even in the presence of background noise. The tapping machine itself, however, is not designed to simulate any one type of impact, such as produced by male or female footsteps.

5.3 Because of its portable design, the tapping machine does not simulate the weight of a human walker. Therefore, the structural sounds, i.e., creaks or booms of a floor assembly caused by such footstep excitation is not reflected in the single number impact rating derived from test results obtained by this test method. The degree of correlation between the results of tapping machine tests in the laboratory and the subjective acceptance of floors under typical conditions of domestic impact excitation is uncertain. The correlation will depend on both the type of floor construction and the nature of the impact excitation in the building.

5.4 In laboratories designed to satisfy the requirements of this test method, the intent is that only significant path for sound transmission between the rooms is through the test specimen. This is not generally the case in buildings where there are often many other paths for sounds— *flanking sound transmission*. Consequently sound ratings obtained using this test method do not relate directly to sound isolation in buildings; they represent an upper limit to what would be measured in a field test.

5.5 This test method is not intended for field tests. Field tests are performed according to Test Method E1007.

6. Test Rooms

6.1 The test facility shall be so constructed and arranged that the test specimen constitutes the only important transmission path for the tapping machine sound.

NOTE 1—Common methods for ensuring that this requirement is satisfied include mounting the specimen resiliently in the test opening, mounting the specimen in a resiliently supported test frame, and supporting rooms resiliently. In general, all rigid connections between the specimen and the test rooms should be avoided.

6.2 The spatial variations of sound pressure level measured in the receiving room shall be such that the precision requirements in Annex A1 are satisfied at all frequencies.

6.3 *Volume of Receiving Room*—The recommended minimum volume of the receiving room is 125 m^3.

NOTE 2—See Test Method E90 for recommendations for new construction.

6.4 *Room Absorption*—The sound absorption in the receiving room should be low to achieve the best possible *simulation* of the ideal diffuse field condition, and to minimize the region dominated by the direct field of the test specimen. In the frequency range that extends from $f = 2000/V^{1/3}$ to 2000 Hz, the absorption in the receiving room (as furnished with diffusers) should be no greater than:

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

where:

V = the room volume, m^3, and
A = the sound absorption of the room, m^2.

6.4.1 For frequencies below $f = 2000/V^{1/3}$, somewhat higher absorption may be desirable to accommodate requirements of other test methods (for example, ISO 3741); in any case, the absorption should be no greater than three times the value given by Eq 1.

NOTE 3—For frequencies above 2000 Hz, atmospheric absorption may make it impossible to avoid a slightly higher value than that given in Eq 1.

6.5 During the sound pressure level and sound absorption measurements in the receiving room the average temperature shall be in the range 22 ± 5°C and the average relative humidity shall be at least 30 %.

6.6 During the sound pressure level and the corresponding sound absorption measurements, variations in temperature and humidity in the receiving room shall not exceed 3°C and 3 % relative humidity respectively. Temperature and humidity shall be measured and recorded as often as necessary to ensure compliance.

6.6.1 If a relative humidity of at least 30 % can not be maintained in the receiving room, users of the test method shall verify by calculation that changes in the 10 log A_1 term (see 12.4) due to changes in temperature and humidity do not exceed 0.5 dB.

NOTE 4—Procedures for calculating air absorption are described in Test Method C423.

7. Test Specimens

7.1 The test specimen shall be prepared and described in the test report in accordance with Annex A1 of Test Method E90.

7.2 *Size and Mounting*—The test specimen shall have a minimum lateral dimension of 2.4 m. An area of at least 10 m^2 is recommended. The test specimen shall include all of the essential constructional elements and surfacing materials normally found in an actual installation. Some elements may have to be reduced in size to fit each laboratory's test opening. The test specimen shall be sealed to prevent tapping machine operational sounds from entering the room below. The specimen shall be structurally isolated from the receiving room to avoid significant transmission of vibration from the specimen through the supporting structure to the room below.

7.3 Floor-surfacing materials, such as vinyl, carpets and pads, especially when installed with adhesive, significantly affect the response of the test specimen to impacts, both during test and in normal use. Consequently, such materials shall be deemed parts of the test specimen. The materials and the manner of installing them shall be fully described in the test report. The floor-surfacing material shall cover the whole test specimen, not merely the portion under the impact machine.

8. Tapping Machine

8.1 This test method is based on the use of a standardized tapping machine that conforms to the following specifications:

8.1.1 The tapping machine shall be motor-driven.

8.1.2 The tapping machine shall have five hammers equally spaced in a line. The distance between centerlines of neighboring hammers shall be 100 ± 3 mm.

8.1.3 Each hammer shall have an effective mass of 500 ± 6 g and shall fall freely from a height of 40 ± 3 mm.

8.1.4 The falling direction of the hammers shall be perpendicular to the test surface to within ± 0.5°.

8.1.5 The part of the hammer carrying the impact surface shall be cylindrical with a diameter of 30 ± 0.2 mm.

8.1.6 The impact surface shall be of hardened steel and shall be approximately spherical with a curvature radius of 500 ± 100 mm.

NOTE 5—The mean curvature radius for each hammer face may be determined using a spherometer or other means.

8.1.7 The time between successive impacts shall be 100 ± 20 ms.

8.1.8 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.

8.1.9 Following adjustment of the hammer drop in accordance with the specifications, the tapping machine is ready for use on any floor structure, including those surfaced with soft or resilient materials.

NOTE 6—The above requirements are a subset of the ISO 140/6 requirements.

8.2 *Tapping Machine Positions*—The tapping machine positions and orientations described in the following must be used. Fig. 1 illustrates one case.

8.2.1 *Position 1*—The middle hammer of the tapping machine shall be coincident with the midpoint of the floor area, that is, the point of intersection of floor diagonals. In framed construction, adjust this point to the centerline of the closest structural member or other support member, and arrange the tapping machine so that all hammers fall on the joist.

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

8.2.3 *Position 3*—Displace the tapping machine laterally from position 1, such that the long dimension of the machine is centered midway between and parallel to the central structural member. In the case of homogeneous concrete slab floors or solid deck construction without joists, the lateral displacement of the tapping machine shall be 0.6 m from that of position 1.

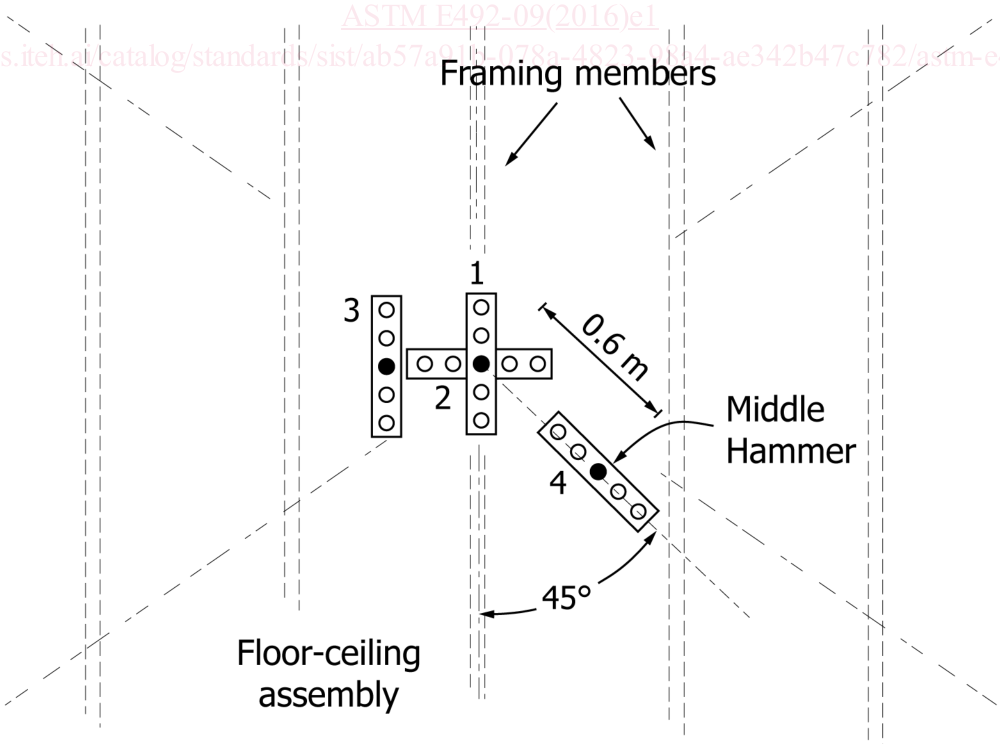

FIG. 1 Tapping Machine Positions on a Floor with Structural Members 610 mm o.c.

8.2.4 *Position 4*—Position the tapping machine so that all hammers fall on a 45° radial line extending from the middle hammer point of position 1. Locate the middle hammer 0.6 m from the midpoint of position 1.

9. Instrumentation Requirements

9.1 The measurement process must account for level fluctuations caused by spatial and temporal variations. Various systems of data collection and processing are possible, ranging from a single microphone moving continuously, a single microphone placed in sequence at several measurement positions, to several microphones making simultaneous measurements.

9.2 *Microphone Electrical Requirements*—Use microphones that are stable and substantially omnidirectional in the frequency range of measurement, with a known frequency response for a random incidence sound field. (A 13-mm random-incidence condenser microphone is recommended.) Specifically, microphones, amplifiers and electronic circuitry to process microphone signals must satisfy the requirements of ANSI S1.43 or IEC 61672 for class 1 sound level meters, except that A, B and C weighting networks are not required since one-third octave filters are used. Where multiple microphones are used, they shall be of the same model.

9.3 *Calibration*—Calibrate each microphone over the whole range of test frequencies as often as necessary to ensure the required accuracy (see ANSI S1.10). A record shall be kept of the calibration data and the dates of calibration (see A2.4.1).

9.4 The calibration of the entire measurement system shall be checked before each set of measurements using an acoustical calibrator that generates a known sound pressure level at the microphone diaphragm and at a known frequency. The Class of Calibrator shall be class 1 or better per ANSI S1.40 and/or IEC 60942. Data resulting from calibration shall be analyzed by the control chart method described in Part 3 of ASTM STP 15D. The analysis shall be according to the subsection entitled "Control—No Standard Given". If changes are made to the microphones or measurement system that result in changes in calibration values, a new control chart should be started.

9.5 *Standard Test Frequencies*—Measurements shall be made in all one-third-octave bands with mid-band frequencies specified in ANSI S1.11 from 100 to 3150 Hz. Additional one-third octave band measurements should be made at 50, 63, and 80 Hz to accumulate research data.

9.6 *Bandwidth*—The overall frequency response of the filters used to analyze the microphone signals 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.

10. Measurement of Sound Pressure Levels

10.1 Measurements of the average sound pressure levels shall be made in the receiving room directly below the floor specimen using a procedure that satisfies the requirements in Annex A1. The measurements shall be in a series of frequency bands specified in 9.4 for each of the tapping machine positions designated in 8.2.

10.2 *Background Noise Level*—Measurements of the background noise levels shall be made during each test to ensure that measurements of sound pressure level are not affected by extraneous airborne noise or electrical noise in the receiving system. These measurements shall be made at the same microphone positions using the same analyzer gain settings used to measure sound pressure levels generated by the tapping machine.

10.2.1 If the background noise level is more than 10 dB below the combined level of signal plus background, then no correction is to be made.

10.2.2 If the background noise level is between 10 and 5 dB below the combined level, then adjustments must be made for the background noise level as follows. If L_{sb} is the level of the signal and background combined, and L_b is the level due to background noise only, then the adjusted signal level, L_s, in the absence of background noise is the following:

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

10.2.3 At those frequencies where the background noise level is less than 5 dB below the combined level, subtract 2 dB from the combined level. In this case, the measurements can be used only to provide an estimate of the upper limit of the impact sound transmission. Identify such measurements in the test report.

11. Determination of Receiving Room Sound Absorption

11.1 Measure the mean value of the receiving room absorption at each frequency in accordance with Test Method E2235. The determination of room absorption shall be made with the receiving room and the specimen in the same condition as for the measurement of the average sound pressure levels.

12. Calculations

12.1 *Averaging Sound Pressure Levels*—For each tapping machine position, a set of sound pressure levels corresponding to each microphone position in the receiving room will be obtained. The space-time average sound pressure level ($\bar{L}_p$) for one tapping machine position is given by:

$$\bar{L}_p = 10\log\left(\frac{1}{n}\sum_{i=1}^{n} 10^{L_i/10}\right) \tag{3}$$

where:

n = number of microphone positions, and
L_i = sound pressure level measured at a microphone position for one location of the tapping machine, dB re 20 μPa.

12.2 The average one-third octave band sound pressure level ($\bar{L}_0$) of the four average sound pressure levels measured for each tapping machine position is given by:

$$\bar{L}_0 = 10\log\left(0.25\sum_{p=1}^{4} 10^{\bar{L}_p/10}\right) \tag{4}$$

12.3 The standard deviation of the means for four tapping machine positions is given by:

$$s_0 = \left[\frac{1}{3}\sum_{p=1}^{4}\left(\bar{L}_p - \bar{L}_0\right)^2\right]^{1/2} \tag{5}$$

12.4 The normalized sound pressure level, L_n, in each of the specified frequency bands shall be obtained from the following relationship:

$$L_n = \bar{L}_0 - 10\log(A_0/A_1) \tag{6}$$

where:

A_1 = sound absorption of the receiving room (m^2) measured in the same frequency band used for the measurement of $\bar{L}_0$, and
A_0 = reference absorption of 10 m^2.

12.5 *Variation in Sound Pressure Level Due to Tapping Machine Position*—Many floor/ceiling assemblies are not homogeneous, thus there can be a variation in the average sound pressure levels measured for each tapping machine location. Since it is desirable to have some measure of the variability, the 95 % uncertainty limits for the normalized sound pressure levels shall be determined from:

$$\Delta L_n = 1.6\left[s_0^2 + s^2(f)/n\right]^{1/2} \tag{7}$$

where *s(f)* is determined according to Annex A3.

NOTE 7—Strictly, the uncertainty due to variation in room absorption should be included in this equation. In practice, however, this can be neglected.

13. Report

13.1 The report shall include the following information:

13.1.1 A statement, if true in every respect, that the tests were conducted in accordance with the provisions of this method.

13.1.2 In conformance with 7.1, a detailed description of the test specimen. The specimen area, total thickness, and the average weight per square meter shall be reported. A description furnished by the sponsor of the test may be included in the report provided that it is attributed to the sponsor. The curing period, if any, and the final condition of the sample (shrinkage, cracks, etc.) shall be reported.

13.1.3 The dates of construction and testing.

13.1.4 The minimum and maximum temperature and relative humidity in the receiving room.

13.1.5 The volume of the receiving room.

13.1.6 The normalized impact sound pressure levels (L_n) to the nearest 1 dB, for the one-third octave frequency bands given in 9.5. Results may be presented in graphical form.

13.1.7 Identify data affected by flanking transmission or background noise.

13.1.8 The calculated 95 % uncertainty limit (ΔL_n) of the impact noise test data at each frequency (see Eq 7).

13.1.9 If a single number ratings are given, the impact insulation class (IIC) described in Classification E989 shall be included.

14. Precision and Bias

14.1 *Precision*—Measurements at one laboratory give some information on repeatability standard deviation for the test method. A wood joist floor was installed and re-tested seven times over a period ~~often~~ of ten days without disturbing the floor. The standard deviation of the sound pressure levels is given in column A of Table 1. Using different materials, eight nominally identical wood-joist floors were constructed and tested over a period of one year. The repeatability standard deviation in this case includes the effects of normal variations in materials but there were no changes in construction techniques (Column B of Table 1). A 150-mm concrete slab was installed in a test frame and tested fifteen times over a period of 11 years. The repeatability standard deviation for re-installation is given in column C of Table 1. Reproducibility data for this test method will become available when an inter-laboratory study is completed.

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