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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 E 492; 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—Keywords were added editorially in April 1996.

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, and the laboratory and field methods of measuring airborne sound transmission loss of building partitions such as walls, floor-ceiling assemblies, doors, and other space-dividing elements.

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 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 *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:*

C423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method ASTM Standards:[2]

C 634 Terminology Relating to Environmental Acoustics

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

E 548 Guide for General Criteria Used for Evaluating Laboratory Competence[3]

E 717 Guide for the Preparation of the Accreditation Annex of Acoustical Test Standards

E 989 Classification for Determination of Impact Insulation Class (IIC)[2] Classification for Determination of Impact Insulation Class (IIC)

E 2235 Test Method for the Determination of Decay Rates for Use in Sound Insulation Test Methods

2.2 *ANSI Standards:*

[1] This test method is under the jurisdiction of ASTM Committee E-33 E33 on 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* , Vol 04.06.volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Annual Book of ASTM Standards, Vol 14.02.

[3] Withdrawn

S1.11 Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters[4]
S1.26 Method for the Calculation of the Absorption of Sound by the Atmosphere[4]
2.3 *ISO Standard:*
ISO 140/6 Acoustics—Measurement of Sound Insulation in Buildings and of Building Elements Part 6: Laboratory Measurements of Impact Sound Insulation of Floors[4]

3. Terminology

3.1 The acoustical terminology used in this method is consistent with Terminology C 634 except for the following special usages.

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.2 *source room*—the room containing the tapping machine.

4. Summary of Test Method

4.1 A standard tapping machine is placed in operation on a test-floor specimen that forms a horizontal separation between two rooms, one directly above the other. (See Section 6.) The transmitted impact sound characterized by the spectrum of the space-time average one-third octave band sound pressure levels produced by the tapping machine is measured in the receiving room below.

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 evaluation of the impact sound-insulating performance of a floor-ceiling assembly begins with the measurement of the sound pressure levels in the room below the test specimen. The spectrum of the noise in the room below 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, and

5.1.3 Inevitably, the characteristics and placement of the object or device producing the impacts and the nature or degree 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 8.1.1 and 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 sufficiently high to make accurate and reproducible measurements possible. The tapping machine itself, however, is not designed to simulate any one type of impact, such as produced by male or female footsteps.

NOTE 1—**Caution:** Because of its portable design, the tapping machine does not simulate the weight of a human walker. Therefore, the creak or boom of a limber floor assembly caused by such footstep excitation may not be 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 overall field performance of floors under typical conditions of domestic impact excitation may be subject to some variation, depending on both the type of floor construction and the nature of the impact excitation.

6. Test Rooms

6.1 *Flanking Transmission*:

6.1.1 The test rooms shall be so constructed and arranged that the test specimen constitutes the only important transmission path between them. The impact sound pressure level transmitted through the test structure shall be at least 10 dB greater than that transmitted into the receiving room by all other paths.

6.1.2 The limit of impact sound levels that can be measured in the receiving room without being biased by flanking transmission must be determined for each test facility. A suggested method is to build and install in the usual manner a test specimen and to measure the vibration acceleration levels of the test specimen in the receiving room and the receiving room walls. If the former exceeds the latter by 10 dB, one may consider the flanking transmission due to vibrating room surfaces as negligible. The amount of energy radiated from a structure depends upon its radiating efficiency as well as its amplitude of vibrations.

NOTE 2—The amount of flanking transmission may also be determined by using sound intensity techniques to measure the contribution of the radiating surfaces and any possible airborne leaks.

6.2 *Size and Shape of Receiving Room*—To produce an acceptable approximation to the assumed diffuse sound fields, especially in the lowest test frequency band, the receiving room should meet the following requirements.

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[4] Available from American National Standards ~~Institute, 11~~ Institute (ANSI), 25 W. ~~42nd~~43rd St., ~~13th~~4th Floor, New York, NY 10036.

6.2.1 *Volume of Receiving Room*—The recommended minimum volume of the receiving room is 125 m^3 (4415 ft^3). Laboratories that use a volume smaller than 125 m^3 must report the room volume in their test report (**1, 2**).[5]

6.2.2 *Room Shape*—It is recommended that no two dimensions of the receiving room be the same or in the ratio of small whole numbers. The ratio of largest to smallest dimension of the room should be less than two.

NOTE 3—Theoretical studies of rectangular rooms (**2, 3, 4**) suggest that the proportions $1:2^{1/3}:2^{2/3}$ provide an optimum distribution of modes in the lowest bands. Minor deviations in construction, or the presence of diffusers, will alter the actual distribution.

6.3 *Sound Diffusion*— Even in receiving rooms meeting the requirements of 6.2, measurements in the lower test bands are likely to depend critically on microphone locations. Space/time variations in measured sound pressure levels can be minimized by using a diffusing panel system that incorporates stationary or moving diffusing panels, or both. For this reason it is suggested that the receiving room should be fitted with diffusing panels. It has been found that diffusing panels meeting the following requirements have been effective in diffusing sound fields. This is not to say that other diffusing panels are more or less effective. Each laboratory should select and install diffusing elements such that they meet the precision requirements of 11.3.

6.3.1 The recommended minimum dimension of any diffusing panel is 1 m excluding thickness and recommended minimum surface mass of the panels is 5 kg/m^2 (1 lb/ft^2).

6.3.2 Fixed diffusing panels should be suspended in random orientations throughout the room space. The distribution of the panels should be determined experimentally in order to provide an acceptably uniform sound which satisfies the precision requirements of 11.3.

6.3.3 Moving diffusers usually comprise a set of rotating or oscillating panels set at oblique angles relative to the room surfaces. These devices are known to be particularly effective in producing a uniform sound field.

6.3.4 The recommended total single-sided area of fixed plus moving panels should be greater than 10 to 15 % of the total surface of the receiving room.

6.4 *Room Absorption*:

6.4.1 The sound absorption in the receiving room should be low in order to achieve the best possible simulation of the ideal diffuse field condition, and in order to minimize the region dominated by the direct field of the test specimen. It is recommended that in the frequency range that extends from $f = 2000/V^{1/3}$ to 2000 Hz that the Sabin absorption in the receiving room (as furnished with diffusers) and corrected for air absorption be no greater than the following:

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

where:

V = the room volume, m^3, and
A = the room absorption in metric sabins.

For frequencies below $f = 2000/V^{1/3}$, (where the number 2000 is an empirical constant with the units (metres/seconds) somewhat higher absorption may be desirable to accommodate other test requirements (for example, ANSI S1.32, ISO 3741); in any case, the absorption should be no greater than three times the value given by Eq 1.

NOTE 4—To minimize errors related to atmospheric absorption, the temperature and humidity in the receiving room should be kept constant during both the transmission and absorption measurements; for monitoring purposes, temperature and humidity should be measured and recorded during each day's testing. (See ANSI S1.26 on air absorption correction.)

6.5 The information and recommendations of 6.2-6.4 are provided so that the closest possible approximation to a diffuse sound field will exist in the receiving room. The spatial variations measured in the receiving room shall be such that the precision requirements in 11.3 are satisfied at all frequencies.

7. Test Specimens

7.1 *Size and Mounting*—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 in order to fit each laboratory's test opening. In the case of precast or preformed solid concrete slabs or hollow-masonry panel structures, it is recommended that the test specimen include two or more complete slabs or panel units. It is recommended that the area of the test specimen be at least 10 m^2 and have a minimum dimension of 2.4 m. The test specimen shall be sealed and structurally isolated from the receiving room to avoid significant flanking transmission.

7.2 *Aging of Specimens*:

7.2.1 Test specimens that incorporate materials for which there is a curing process (for example: adhesives, plasters, concrete, mortar, damping compound) shall age for a sufficient interval before testing. Aging periods for certain common materials are specified in Annex A1. Shorter aging periods may be used if test data indicate that additional aging does not affect acoustical performance (see Note 5).

7.2.2 In the case of materials whose aging characteristics are not known, repeated tests over a reasonable time shall be made on at least one specimen to determine an appropriate aging period.

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

NOTE 5—A suggested procedure for determining if a specimen has aged sufficiently is to conduct a series of tests on the specimen after 2, 4, 7, 14 or 28 days of aging. If for two consecutive tests on different days the change in the one-third octave band sound pressure levels at each test frequency is within the range of repeatability for laboratory tests on the same specimen using identical facilities and equipment, then the specimen can be considered to have aged sufficiently.

7.3 *Installation of Floor-Surfacing Materials*:

7.3.1 Floor-surfacing materials of significant weight, such as carpets and pads, especially when installed with adhesive, may significantly affect the response of the test specimen to impacter, both during test and in normal use. Consequently, such materials should be deemed parts of the test specimen. The materials and the manner of installing them should be fully described (see also 7.3.2 and 7.3.3). The floor-surfacing material should cover the whole test specimen, not merely the portions under the impact machine.

7.3.2 The installation or laying of floor-surfacing materials shall be in accordance with manufacturer's instruction, especially in regard to cleaning and priming of the subfloor. It is recommended that flooring materials, including underlayments and adhesives, be stored in an environment similar to that of the source room for at least 72 h before installation, preferably with bundles or cartons broken open. It is recommended that the environmental conditions be regulated to a temperature of 15 to 25°C and a relative humidity of 30 to 60 %. The environmental conditions in both the source and receiving rooms should be controlled and recorded.

7.3.3 The foregoing procedure is recommended for installation of any flooring material whether by nailing or adhesive techniques. Although most floors are ready for immediate use after being installed, it is recommended that measurements on floors with adhesive-applied surfacing materials be tested no sooner than 24 h after installation to allow the adhesive to cure. For adhesives with undetermined aging periods see Note 3.

8. Tapping Machine

8.1 *Specifications*:

8.1.1 This test method is based on the use of a standardized tapping machine that conforms to the specifications given in ISO 140/6~~. It shall have five hammers equally spaced in a line, the distance between the two end hammers shall be 400 mm. The machine shall deliver 10 impacts/s at equal intervals, such that the time between successive impacts shall be 100 ms ± 5 ms. The effective mass of each hammer shall be 0.5 ± 0.012 kg. The drop of a hammer on a flat hard floor shall be equivalent to a free drop without friction of 40 ± 1 mm. The part of the hammer that strikes the floor shall be a cylinder of steel, 30 mm in diameter with a spherical end having a radius of 500 ± 10 mm. Check both the hammer drop and the radius of curvature of the hammer heads with a gage or template for conformance with the given specifications.~~

~~8.1.2~~. The tapping machine shall have five hammers equally spaced in a line. The distance between centerlines of neighboring hammers shall be100 ± 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 º. 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 tapping machine shall be self driven. The time between successive impacts shall be 100 ± 20 ms.

8.1.2 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. If the friction can not be eliminated, then the hammer weight or drop height can be increased to compensate for this friction. In any event, the hammer weight and drop height shall not exceed the limits given in 8.1.1.

8.1.3 In addition, cap the bottoms of the machine mountings or feet with soft sponge-rubber pads about 5 mm thick, and space the feet at least 100 mm from the nearest hammer.

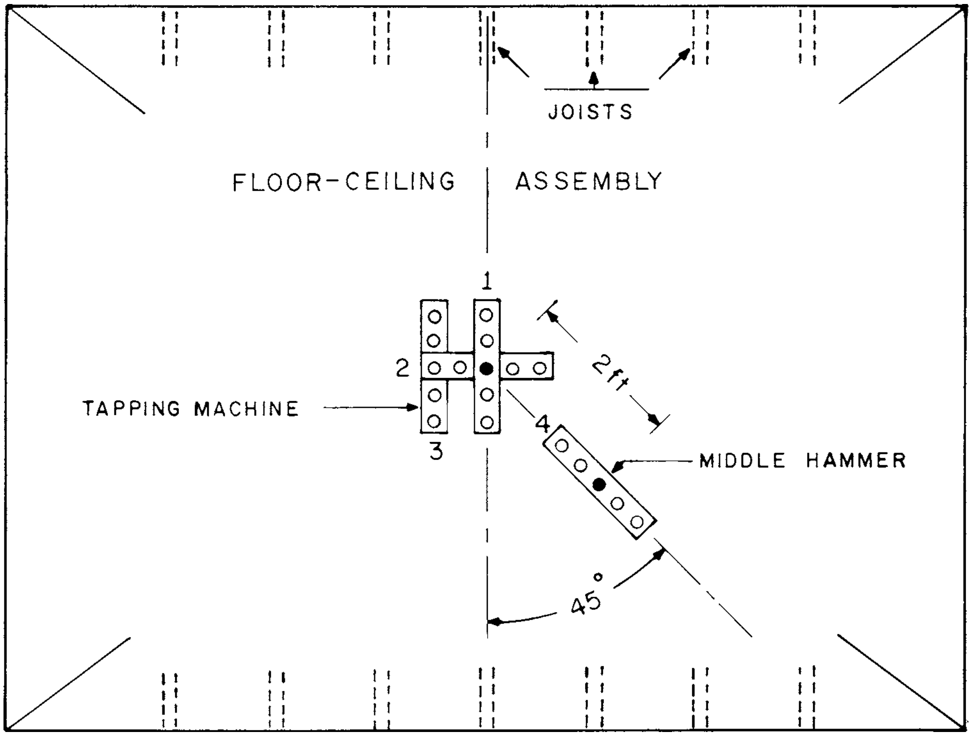
NOTE 6—Investigations involving light frame floating floors show that the resiliency of the tapping machine mountings as well as their spacing from the hammers significantly affect the sound pressure levels in the frequency band below 400 Hz. (**5**). The machine may be effectively decoupled from the floor by the use of the sponge rubber pads described in ~~8.1.2~~8.1.3. To determine whether these pads are functioning adequately, place a strip of soft resilient material under the impacting hammers. If, in each frequency band, there is at least a 10 dB reduction in the sound pressure level in the receiving room, the spurious vibrational transmission is negligible. If the reduction is less than 10 dB, the supports must be redesigned and the hammer drop readjusted to conform with the specifications in 8.1.

8.1.~~3~~4 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.

8.2 *Airborne Noise*— The airborne noise radiated by the tapping machine, (in the source room) including that due to the impacting of hammers on the floor surface, shall not contribute to or influence the one-third octave band sound pressure levels measured in the receiving room due to impact noise radiated by the floor/ceiling assembly. One method of dealing with this is to distribute enough sound absorbing material about the source room so that the level of the reverberant sound field is sufficiently reduced. Alternatively, the airborne noise transmission through the specimen under test can be measured to demonstrate that airborne noise does not affect the measurements.

8.3 *Tapping Machine Positions*—For conformity, the tapping machine positions and orientations illustrated in Fig. 1 and described below must be used.

8.3.1 *Position 1*—The middle hammer of the tapping machine shall be coincident with the midpoint of the floor area, that is,



NOTE 1—2 ft = 0.6 m

FIG. 1 Tapping Machine Positions

the point of intersection of floor diagonals. In joist construction, adjust this point to the center line of the closest joist or other support member, and arrange the tapping machine so that all hammers fall on the joist.

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

8.3.3 *Position 3*—Similar to position 1, except displace the tapping machine laterally, such that the long dimension of the machine is centered midway between and parallel to the central joists. 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.

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

9. Measurement of One-Third Octave Band Sound Pressure Levels

9.1 The procedure for this method of test is to measure the sound pressure levels in a receiving room located directly below a floor specimen (see 5.1). Measurements of the sound pressure levels shall be made in a specified series of frequency bands for each of the tapping machine positions as designated in 8.3.

9.2 *Test Frequency Bands*:

9.2.1 The sound pressure levels shall be measured in the 16 contiguous one-third octave bands with center frequencies as follows: 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, and 3150 Hz. It is suggested that additional one-third octave band measurements be made at 50, 63, 80, 4000, and 5000 Hz to accumulate research data.

9.2.2 The overall frequency response of the filters used in the microphone system shall, for each test band, conform to the specifications in ANSI S1.11 for a one-third octave band filter set, Order 3 or higher, Type 1 or better.

9.3 *Averaging Time*— For each tapping machine position and fixed microphone positions the impact sound pressure levels in a receiving room shall be averaged over a time interval of at least 10 s at frequencies of 400 Hz and below and at least 5 s at frequencies above. If a rotating vane is used, the time average sound pressure level shall be determined during a sufficient time period to take account of variations with vane position.

9.4 *Microphone Requirements*—Since absolute rather than relative measurements of impact sound pressure levels are required, the calibration and frequency response of the microphones are important. Microphones are preferred that have a flat frequency response and are stable, omnidirectional, and small in size, such as random incidence response condenser microphones, are preferred.

9.4.1 *Calibration*— All microphones and associated instrument systems used in the measurements must be calibrated. This includes all amplifiers and other instrumentation up to the point at which the microphone signals are observed and recorded. It is recommended that the calibration of the measurement system be checked before and after each set of measurements to safeguard against small errors in system sensitivity. Such checks may be performed with an acoustic calibrator that generates a known sound pressure level at the microphone diaphragm.

9.4.2 *Orientation and Response*—The orientation of the microphone in a diffuse sound field is not considered to be critical for the frequency range specified above.

9.4.3 *Location*—The perpendicular distance from any microphone position to any major extended surface shall be no less than 1 m. The same limit applies relative to any fixed diffuser, if a perpendicular can be drawn to the diffuser surface (excluding edges) and relative to any possible position of a rotating diffuser.

9.4.4 *Number of Microphone Locations* —The number and location of microphone positions required for a space average to a given precision (see Section 11) should be determined initially by a detailed survey of the receiving room, especially at the lowest test frequencies. A reduced number of locations that yield the same average result as the detailed survey and meet the precision requirements of Section 11 may be selected for day-to-day measurements. No fewer than four (4) microphone positions, however, shall be used for each tapping machine location.

9.4.5 If the estimates of precision of average sound pressure levels are to be reliable the observation points should be sufficiently far apart to provide independent samples of the sound field. This requires, if fixed microphone positions are used, that they be spaced at least half a wavelength apart. A single microphone continuously moving along a defined traverse may be used instead of stationary microphones provided that the above restrictions are met.

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

$$\bar{L}_p = 10 \log \left(\frac{1}{n} \sum_{i=1}^{n} 10^{L_{pi/10}} \right) \tag{2}$$

where:

n = number of microphone positions or readings, and

L_{pi} = sound pressure level measured at a microphone position for one location of the tapping machine, dB.

9.6 *Background Noise Level*—Measurements of the background noise levels shall be made during each test to ensure that the observations are not affected by extraneous airborne or electrical noise in the receiving system.

9.6.1 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. 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.

9.6.2 *Adjustment for Background Noise Level*—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:

$$L_s = 10 \log (10^{L_{sb/10}} - 10^{L_{b/10}}) \tag{3}$$

9.6.3 At those frequencies where the background noise level is less than 5 dB below the combined level, subtract 2 dB from the combined level and identify those data with an asterisk to indicate the background noise level was too high.

9.7 The average one-third octave band sound pressure level ($\bar{L}_{P4}$) for the four individual sound pressure levels measured for each tapping machine position is given by the following:

$$\bar{L}_{P4} = 10 \log (0.25 \sum_{j=1}^{4} 10^{L_{pj/10}}) \tag{4}$$

where:

$\bar{L}_{pj}$ = The average one-third octave band sound pressure level, decibels re 20 Pa, for each tapping machine position.

9.8 The normalized sound pressure level, L_p, in each of the specified frequency bands may be obtained from the following relationship:

$$L_n = \bar{L}_{P4} - 10 \log (A_0/A_1) \tag{5}$$

where:

$\bar{L}_{P4}$ = the average of the one-third octave band sound pressure levels, in decibels re 20 Pa, in the receiving room for the four tapping machine positions,

A_1 = sound absorption of the receiving room, expressed in units of metric sabins, and measured in the same frequency band used for the measurement of $\bar{L}_{4p}$, and

A_0 = reference absorption of 10 metric sabins.

9.9 *Determination of Receiving Room Sound Absorption*:

9.9.1 The required method of determining the sound absorption is to measure the decay rate, *d,* in the receiving room using a sound source in the receiving ~~room (see Test Method C423).~~room. The determination of the sound absorption in the receiving room is to be made with the room in the same condition and with microphones in the same positions as for the measurement of sound