~~Designation:C423–08~~ Designation: C 423 – 08a

Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method[1]

This standard is issued under the fixed designation C 423; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the measurement of sound absorption in a reverberation room by measuring decay rate. Procedures for measuring the absorption of a room, the absorption of an object, such as an office screen, and the sound absorption coefficients of a specimen of sound absorptive material, such as acoustical ceiling tile, are described.

1.2 *Field Measurements*—Although this test method primarily covers laboratory measurements, the test method described in 4.1 can be used for making field measurements of the absorption of rooms (see also 5.5). A non-standard method to measure the absorption of rooms in the field is described in Appendix X2.

1.3 This test method includes information on laboratory accreditation (see Annex A1), asymmetrical screens (see Annex A2), and reverberation room qualification (see Annex A3).

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 634 Terminology Relating to Building and Environmental Acoustics

E 548 Guide for General Criteria Used for Evaluating Laboratory Competence

E 795 Practices for Mounting Test Specimens During Sound Absorption Tests

2.2 *ANSI Standards:*

S1.6 Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements[3]

S1.11 Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters[3]

S1.26~~Method for the Calculation of the Absorption of Sound by the Atmosphere[3]~~ Method for the Calculation of the Absorption of Sound by the Atmosphere[3]

S1.43 Specifications for Integrating Averaging Sound Level Meters[3]

IEC 61672 Electroacoustics–Sound Level Meters–Part 1: Specifications[3]

2.3 *ASTM Adjuncts:*

Historical Applications Note on Sound Absorber[4]

3. Terminology

3.1 Except as noted in 3.3, the terms and symbols used in this test method are defined in Terminology C 634. The following definition is not currently included in Terminology C 634:

3.1.1 *sound absorption average, SAA* —a single number rating, the average, rounded off to the nearest 0.01, of the sound absorption coefficients of a material for the twelve one-third octave bands from 200 through 2500 Hz, inclusive, measured according to this test method.

3.1.1.1 *Discussion*—The sound absorption coefficients shall be rounded off to the nearest 0.01 before averaging. If the unrounded average is an exact midpoint, round to the next higher multiple of 0.01. For example, report 0.625 as 0.63.

---

[1] This test method is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.01 on Sound Absorption.

Current edition approved ~~March~~Oct. 1, 2008. Published ~~March~~October 2008. Originally approved in 1958. Last previous edition approved ~~2007~~2008 as ~~C423–07a.~~C 423 – 08.

[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] A drawing of this specimen is available at a nominal charge from ASTM International Headquarters. Order Adjunct No. ADJC0423.

3.2 In previous versions of this test method a single number rating, called the noise reduction coefficient (NRC), was defined as follows:

> ″Round the average of the sound absorption coefficients for 250, 500, 1000, and 2000 Hz to the nearest multiple of 0.05. If the unrounded average is an exact midpoint, round to the next higher multiple of 0.05. For example, 0.625 and 0.675 would be reported as 0.65 and 0.70, respectively.″

The noise reduction coefficient shall be reported in order to provide comparison with values reported in the past see 12.1.3).

3.3 *Definition of Term Specific to This Standard*—The following term has the meaning noted for this test method only:

3.3.1 *output interval,* Δ*t, [T], s— of a real-time analyzer*, the time between successive outputs; this time is not necessarily the same as the integration time.

4. Summary of Test Method

4.1 *Measurement of the Sound Absorption of a Room*:

4.1.1 A band of random noise is used as a test signal and turned on long enough (about the time for 20 dB decay in the test band with the smallest decay rate) for the sound pressure level to reach a steady state. When the signal is turned off, the sound pressure level will decrease and the decay rate in each frequency band may be determined by measuring the slope of a straight line fitted to the sound pressure level of the average decay curve. The absorption of the room and its contents is calculated, based on the assumptions that the incident sound field is diffuse before and during decay and that no additional energy enters the room during decay, from the Sabine formula:

$$A = 0.9210 \frac{Vd}{c} \tag{1}$$

where:

A = sound absorption, m^2 or Sab,
V = volume of reverberation room, m^3 or ft^3,
c = speed of sound (calculated according to 11.13), m/s or ft/s, and
d = decay rate, dB/s,

These conditions must be fulfilled if the measurement is to have meaning. The sound absorption calculated according to Eq 1 is sometimes called the Sabine absorption.

4.1.2 In general, sound absorption is a function of frequency and measurements are made in a series of frequency bands.

4.2 *Measurement of a Sound Absorption Coefficient* —The absorption of the reverberation room is measured as outlined in 4.1 both before and after placing a specimen of material to be tested in the room. The increase in absorption divided by the area of the test specimen is the dimensionless sound absorption coefficient. In inch-pound units it is reported with the dimensionless "unit" sabin per square foot, Sab/ft^2.

4.3 *Measurement of the Sound Absorption of an Object Such as an Office Screen, a Theater Chair, or a Space Absorber*— The absorption of the reverberation room is measured as outlined in 4.1 both before and after placing one or several identical objects in the room. The increase in absorption divided by the number of objects is the absorption in square meters per object or sabins per object.

5. Significance and Use

5.1 Measurement of the sound absorption of a room is part of the procedure for other acoustical measurements, such as determining the sound power level of a noise source or the sound transmission loss of a partition. It is also used in certain calculations such as predicting the sound pressure level in a room when the sound power level of a noise source in the room is known.

5.2 The sound absorption coefficient of a surface is a property of the material composing the surface. It is ideally defined as the fraction of the randomly incident sound power absorbed by the surface, but in this test method it is operationally defined in 4.2. The relationship between the theoretically defined and the operationally measured coefficients is under continuing study.

5.3 Diffraction effects[5] usually cause the apparent area of a specimen to be greater than its geometrical area, thereby increasing the coefficients measured according to this test method. When the test specimen is highly absorptive, these values may exceed unity.

5.4 The coefficients measured by this test method should be used with caution because not only are the areas encountered in practical usage usually larger than the test specimen, but also the sound field is rarely diffuse. In the laboratory, measurements must be made under reproducible conditions, but in practical usage the conditions that determine the effective absorption are often

[5] Chrisler, V., "Dependence of Sound Absorption Upon the Area and Distribution of the Absorbent Material," *Journal of Research,* National Bureau of Standards, Vol 13, 1934, p. 169: Northwood, T. D., Grisaru, M. T., and Medcof, M. A., "Absorption of Sound by a Strip of Absorptive Material in a Diffuse Sound Field," *Journal of the Acoustical Society of America,* Vol 31, 1959, p. 595: and Northwood, T. D., "Absorption of Diffuse Sound by a Strip or Rectangular Patch of Absorptive Material," *Journal of the Acoustical Society of America,* Vol 35, 1963, p. 1173.

unpredictable. Regardless of the differences and the necessity for judgment, coefficients measured by this test method have been used successfully by architects and consultants in the acoustical design of architectural spaces.

5.5 *Field Measurements*—When sound absorption measurements are made in a building in which the size and shape of the room are not under the operator's control, the approximation to a diffuse sound field is not likely to be very close. This matter should be considered when assessing the accuracy of measurements made under field conditions. (See Appendix X2 for a procedure that can be used in the field with less sophisticated instrumentation.)

6. Interferences

6.1 Changes in temperature and relative humidity during the course of a measurement may have a large effect on the decay rate, especially at high frequencies and at low relative humidities. The effects are described quantitatively in ANSI S1.26. These effects of temperature and relative humidity changes shall be minimized as follows:

6.1.1 During all measurements of decay rate The average temperature shall be no less than 10 °C; Deviations from the average temperature shall not exceed 5 °C. The average relative humidity in the room shall be no less than 40%. Deviations from the average relative humidity shall not exceed ± 5% in the measured relative humidity value.

6.1.2 All decay rates in the 1000 Hz one-third octave band and above shall be adjusted by subtracting the decay rate due to air absorption from the decay rate calculated according to 11.4. For these calculations, assume the values calculated for the mid-band frequency apply to the complete one-third-octave band. The air absorption shall be calculated according to ANSI S1.26 using its standard air absorption values at the center frequency of each one third octave band, respectively. Use Eq 2 below:

$$d_{air} = m'c \tag{2}$$

where:

d_{air} = decay rate due to sound absorption by the air, dB/s,
m' = attenuation coefficient, dB/m, taken from ANSI S1.26, as described in 6.1.2.1, and
c = speed of sound, m/s, calculated according to 11.13.

6.1.2.1 The attenuation coefficients *m'* shall be derived from the equations and calculation procedures of 5.1-5.3 and Annex B of ANSI S1.26. Table 1 of ANSI S1.26 shall not be used.

7. Reverberation Room

7.1 *Description*—A reverberation room is a room designed so that the reverberant sound field closely approximates a diffuse sound field both in the steady state, when the sound source is on, and during decay, after the sound source has stopped.

7.2 *Construction*:

7.2.1 The room is best constructed of massive masonry or concrete materials, but other materials, such as well-damped steel, may be used. Lighter construction may be excessively absorptive, especially at frequencies below 200 Hz.

7.2.2 The average absorption coefficient of the room surfaces at each frequency, determined by dividing the absorption of the empty room (measured according to Sections 10 and 11) by the area of the room surfaces, including both sides of the diffusers (see 7.4), shall be less than or equal to 0.05 for the one-third octave bands centered at 250 through 2500 Hz, after allowance has been made for atmospheric absorption according to ANSI S1.26. For the bands centered below 250 Hz, and above 2500 Hz, the similarly determined coefficient shall be less than or equal to 0.10.

7.2.3 The room shall be isolated sufficiently to keep outside noises and structural vibrations from interfering with the measurements.

7.3 *Size and Shape*—The volume of the room shall be no less than 125 m^3. It is recommended that the volume be 200 m^3 or greater. No two room dimensions shall be equal nor shall the ratio of the largest to the smallest dimension be greater than 2:1. (See 11.12 on calculating room volume.)

7.4 *Sound Diffusion*:

7.4.1 Means shall be taken to ensure an approximation to a diffuse sound field both before and during decay. Experience has shown that a satisfactory approximation can be achieved with a number of sound-reflective panels hung or distributed with random orientations about the volume of the room. It is strongly recommended that some of these panels be mounted on a rotating shaft or otherwise kept moving, presenting, in effect, a room that continually changes its shape.

7.4.2 The goal is to achieve a rapid and continuous interchange of energy between the directions of sound propagation, thereby increasing the probability that each surface area of the room is exposed to sound of the same intensity.

7.4.3 Laboratories are strongly encouraged to follow the procedures in Appendix X1 to determine the necessary area of diffusing panels to maximize the measured absorption coefficients. If these procedures are followed, the data collected shall be preserved and made available on request. If the procedures in Appendix X1 are not followed, the surface area of the diffusing elements in the room (both faces) shall be at least 25 % of the surface area of the reverberation room. (See Note X1.1.)

7.4.4 The reverberation room shall be qualified according to Annex A3.

7.5 *Background Noise*—The level of the background noise in each measurement band, which includes both the ambient acoustical noise in the reverberation room and the electrical noise in the measuring instruments, shall be at least 15 dB below the lowest level used to calculate decay rate (see 11.3).

8. Instrumentation

8.1 *Sound Source*— The sound source shall be one or more loudspeaker systems in a configuration such that the test facility satisfies the qualifications of Annex A3. With adequate diffusion, loudspeakers facing into the trihedral corners of the room will satisfy these requirements. The sound pressure level produced when the source is on and the sound in the reverberation room is in the steady state shall be at least 45 dB above the background noise in each measurement band.

NOTE 1—The value of 45 dB is the minimum value required by this method. In fact, the steady state may need more than 45 dB above the background noise to satisfy the requirements of 7.5 and 11.3.

8.2 *Test Signal*— The test signal shall be a band of random noise with a continuous spectrum covering the range over which measurements are made. The frequency range of the measurements shall include the one-third octave bands with midband frequencies, as defined in ANSI S1.6, from 100 Hz to 5000 Hz.

8.3 *Microphones*— The microphone or microphones used to measure decay rate shall be omnidirectional with a flat (± ~~1~~2 dB within any one-third octave band) random-incidence amplitude response over the range of frequencies and sound pressure levels used for decay rate measurements.

8.4 *Electronic Instrumentation* —The electronic instruments used to measure sound pressure levels shall be functionally equivalent to the instruments specified in 8.4.1 and 8.4.2.

8.4.1 *Real-time Analyzer*—Sound pressure level measurements shall be made with a one-third octave band real-time analyzer or functional equivalent. The analyzer shall conform to or exceed the requirements of ANSI S1.43 or IEC 61672. The analyzer shall be capable of measuring with an integration time of 50 ms or less and an output interval of 50 ms or less using either linear or exponential averaging. Linear averaging is preferred. The filter response of the analyzer shall be ~~Order 3~~class 1 or better according to ANSI S1.11.

NOTE 2—The response of the real-time analyzer should be checked to determine the minimum decay rate that can be measured at a given integration time setting by feeding a signal directly into the analyzer input and measuring the decay rate when the signal is turned off. The decay rate measured by this check should be at least three times the decay rate measured during a sound absorption measurement.

8.4.2 *Control and Storage Circuitry* —Control and storage circuitry shall be provided to:

8.4.2.1 Turn the source on and off and start and stop the real-time analyzer as specified in Section 10, and

8.4.2.2 Store the levels measured during decays as required by Section 10.

9. Test Specimen

9.1 *Floor, Wall, or Ceiling Specimens for Absorption Coefficient*:

9.1.1 The specimen shall be a rectangular patch assembled from one or more pieces. An area of 6.69 m^2 (72 ft^2) is customary and recommended, in a shape 2.44 by 2.74 m (8 by 9 ft). An area less than 5.57 m^2(60 ft^2) shall not be used, and extreme aspect ratios, such as long narrow strips, shall be avoided.

9.1.2 *Mounting*—Insofar as its acoustical properties are concerned, the specimen shall be mounted in a way that simulates actual installation. The types of mountings most commonly used are specified in Practices E 795. If a mounting fixture is used, it shall be removed from the reverberation room during the empty room tests unless it can be shown that the mounting fixture does not contribute to the empty room sound absorption.

9.1.3 *Placement*—The specimen may be placed on the floor of the reverberation room for convenience of measurement. It is best to avoid symmetry: do not place the specimen in the exact center of the floor or with its sides parallel to the walls. When the orientation of the specimen may affect its acoustical properties (if, for instance, the specimen is a curtain), provision shall be made for mounting in the usual position. No part of the specimen shall be closer than 0.75 m to a reflective surface other than the one backing it.

9.1.4 *Precautions*—When testing ceiling materials it is important that sound be prevented from entering the specimen by any path other than through the front surface. For this reason, the sides of the specimen should be covered tightly with non-absorptive material and any paths to the back of the specimen should be sealed. See Practices E 795 for methods to seal the edges of test specimens.

9.2 *Specimens that are Office Screens* :

9.2.1 *Size*—For test purposes, an office screen shall have an overall area, measured on one side and including the frame, of not less than 2.32 m^2 (25 ft^2). For the purpose of determining the sound absorption coefficient, α, the total area of the screen is the area of the two sides. It does not include the area of the edges, that is, the product of the perimeter of the screen and its thickness. Should the screens submitted for test be too small, two or more should be fitted together to make, in effect, a single screen. To prevent extreme aspect ratios, the ratio of the screen or combined-screen height (including frame) to width (including frame) used to calculate the total area shall be no greater than 2:1 and no less than 1:2.

9.2.2 *Number of Screens*—For a standard test the absorption of an office screen shall be measured with just one screen or a combination of screens that are fitted together to make, in effect, a single screen (see 9.2.1) in the reverberation room. It is the result of this measurement that is to be used when screens of different kinds are compared. However, if desired, two or more screens may be tested at the same time provided all details of the arrangement are described in the report. The details shall include distances from each other and the room boundaries, and the angles they make with each other.

9.2.3 *Placement*—The office screen shall be free-standing, at least 0.75 m away from the room boundaries and other reflective surfaces except the floor, and not parallel to the walls.

9.2.4 For office screens that have different sound-absorptive constructions on either side of the central plane of the screen, see Annex A2.

9.3 *Specimens that are Detached Objects*—The absorption of objects, such as space absorbers, theater chairs, or ceiling baffles, is dependent on the number tested together and their distance from each other and from the room boundaries. Complete information shall be given in the report.

9.4 *Preconditioning*— The test specimen shall be allowed to adjust to the temperature and humidity in the reverberation room before tests are performed.

10. Procedure for Measuring Decay Rate

10.1 *Microphone Positions*:

10.1.1 If a fixed microphone or microphones are used, make measurements at five or more positions which are at least 1.5 m apart, and at least 0.75 m from any surface of the test specimen.

10.1.2 If a moving microphone is used, the microphone path shall be at least 0.75 m from any surface of the room or test specimen. The same limit shall apply to the distance from any fixed diffusing element (excluding edges). The length of the microphone path shall be at least 7.5 m. Longer paths are preferred since they improve the precision of the measurements at low frequencies.

10.1.3 If moving or rotating diffusers are used, the period of the diffusers, the time between the beginning of successive decays and the period of the motion of the microphone should be adjusted to spread out the points at which decays start, as much as feasible, over the positions of the diffusers and the positions of the microphone.

10.2 *Number of Decays*:

10.2.1 Measure at least 50 decays in each room condition (that is, in the empty room and in the room with the test specimen).

10.2.2 If stationary microphone positions are used, measure the same number of decays, at least 10 decays, at each microphone position.

NOTE 3—It is no longer required (as it was in previous versions of this test method) not to use decays that deviate substantially from a straight line over the measuring range when graphed on a logarithmic scale. Reverberation rooms that satisfy the requirements of Section 7 provide the best diffusion that is practically achievable and, hence, are as likely as possible to be free from nonlinear decays.

10.3 *Analyzer Settings*:

10.3.1 If the real time analyzer has settings for both integration time and output interval, the integration time of the analyzer shall be between 90 and 100 % of the output interval time.

10.3.2 The output interval shall be short enough to provide at least five measurement points that satisfy 11.3 in every measurement band. Whenever conditions permit, the output interval shall be adjusted to provide at least ten measurement points that satisfy 11.3 in every measurement band.

10.3.3 The output shall include all of the one-third octave bands in the frequency range from 100 to 5000 Hz, inclusive, specified by ANSI S1.6.

10.4 *Measurement of Decay Rate*:

10.4.1 Turn on the test signal until the sound pressure level in each measurement band is steady (see 4.1).

10.4.2 Turn off the test signal and start measuring sound pressure level in each measurement band either immediately or after a delay in range of 100 to 300 ms (see Fig. 1). (Data collected before the first 100 to 300 ms have elapsed may be viewed or retained for informational purposes, but these data are not used in the calculation of decay curves.)

NOTE 4—The delay time period in the range of 100 to 300 ms ensures that data collected for decay rate calculation include no distortions or tansients caused by turning off the test signal. Viewing the decays on an oscilloscope, computer screen or paper chart can help avoid a number of problems, such as those related to transients.

10.4.3 Measure and store the sound pressure level in each measurement band every Δt seconds (see 3.3.1) until the level is about 32 dB below the steady state level (see 7.5).

10.4.4 Store the measured levels and repeat this procedure the number of times required by 10.2.

11. Calculations

11.1 In each measurement band, calculate the points in the average decay curve, defined as follows:

$$(L_i) = \frac{1}{N}\sum_{j=0}^{N} L_{ij} \tag{3}$$

where:

i and j = integers,
(L_i) = average of the sound pressure levels measured at the ith data point in each of N decays,
N = the number of decays, at least 50, and
L_{ij} = the sound pressure level measured at the ith data point during the jth decay.

11.2 In each measurement band, the first data point to be used to calculate the decay rate shall be the first data point for which integration begins at least 100 to 300 ms after the test signal was turned off.

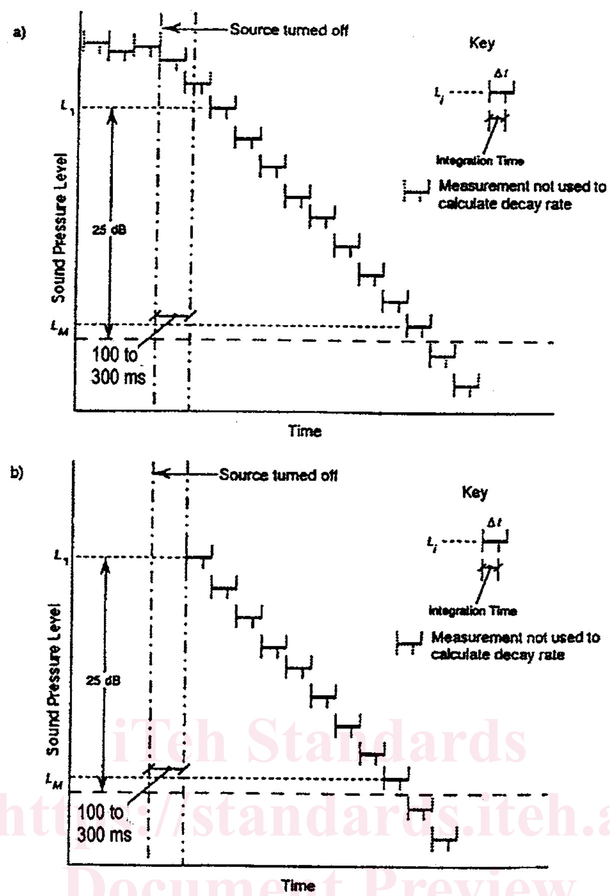

FIG. 1 Schematic Example of a Decay Measurement—a) Starting the Real-Time Analyzer When the Source Stops: b) Starting the Real-Time Analyzer 100 to 300 ms After the Source Stops

11.3 In each measurement band the number of data points in the average decay, M, shall be the maximum value of the index, i, for which:

$$(L_1) - (L_i) \leq 25dB \tag{4}$$

where (L_1) is the average of the first data points satisfying 11.2 (see Fig. 1).

11.4 Calculate the decay rate in every measurement band. In this test method, the operational definition for the decay rate is the negative of the slope of the linear, first-order regression on the average decay curve of Eq 3. The expression for the decay rate is shown below:

$$d' = \frac{6}{M(M^2 - 1)\Delta t}[(M + 1)\sum_{i=1}^{M}(L_i) - 2\sum_{i=1}^{M} i\,(L_i)] \tag{5}$$

where d' is the decay rate, dB/s, and M is defined in 11.3.

11.4.1 Adjust the decay rate by subtracting the decay rate due to air absorption as noted in 6.1, thus:

$$d = d' - d_{air} \tag{6}$$

11.5 The procedures of 11.1, 11.2, 11.3, and 11.4 may be used to calculate decay rates for each microphone position. In this case the average of the decay rates in each measurement band over all microphone positions shall be used to calculate sound absorption.

11.6 The calculation of sound absorption of the reverberation room using the Sabine formula (Eq 1) is described in 4.1.1.

11.7 In every measurement band calculate the absorption added to the room by the test specimen as follows:

$$A = A_2 - A_1 \tag{7}$$

where:

A = absorption of the specimen, m^2 or Sab,
A_1 = absorption of the empty reverberation room, m^2 or Sab, and