Designation: C423 – 22

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

This standard is issued under the fixed designation C423; 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 U.S. 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 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 method to measure the absorption of rooms in the field is described in Test Method E2235.

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

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C634 Terminology Relating to Building and Environmental Acoustics

E795 Practices for Mounting Test Specimens During Sound Absorption Tests

E2235 Test Method for Determination of Decay Rates for Use in Sound Insulation Test Methods

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]

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

2.3 *IEC Standards*

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

3. Terminology

3.1 Except as noted in 3.3, the terms and symbols used in this test method are defined in Terminology C634. The following definition is not currently included in Terminology C634:

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.

[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.

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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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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.

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, Δt, [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:

$$A = 0.9210 \frac{Vd}{c} \quad (1)$$

where:

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

NOTE 1—Previous editions of this test method, which included mixed units, included the in./lbs unit of sound absorption, the sabin (Sab). The number of sabins is the value of A that would be derived from Eq 1 with the volume in ft^3 and the speed of sound in ft/s. This unit finds frequent use in older literature. One Sab of sound absorption is approximately equal to 0.0929 m^2 of sound absorption.

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.

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.

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[4] 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 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 Test Method E2235 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

[4] 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.

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 2—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 (± 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.