Designation: E 2235 – 04

Standard Test Method for Determination of Decay Rates for Use in Sound Insulation Test Methods[1]

This standard is issued under the fixed designation E 2235; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This test method is part of a set of methods used to evaluate the sound-insulating properties of building elements. It is intended for use in conjunction with methods for measuring the transmission of sound through a partition or partition element in a laboratory or in a building. These methods include the laboratory measurement of airborne sound transmission loss of building partitions and elements (Test Method E 90), the measurement of sound isolation in buildings (Test Method E 336), the laboratory measurement of impact sound transmission through floors (Test Method E 492), the measurement of impact sound transmission in buildings (Test Method E 1007), the measurement of sound transmission through building facades and facade elements (Guide E 966), and the measurement of sound transmission through a common plenum between two rooms (Test Method E 1414).

1. Scope

1.1 This test method covers the measurement of sound decay rate in rooms and the calculation of the sound absorption of the room and its contents. The sound absorption so calculated may be used in calculations in sound insulation test methods.

1.2 The method shall be used only in conjunction with other test methods where the logarithm of the sound absorption is used in formulas. It is not sufficiently precise for use in situations where room sound absorption is to be used without taking logarithms.

1.3 For laboratory measurements of the sound absorption of materials and objects, Test Method C 423 should be used.

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

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 336 Test Method for Measurement of Airborne Sound Insulation in Buildings

E 492 Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine

E 966 Guide for Field Measurements of Airborne Sound Insulation of Building Facades and Facade Elements

E 1007 Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures

E 1414 Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum

2.2 *ANSI Standards:*

S1.4 Specification for Sound-Level Meters[3]

S1.6 Standard 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]

3. Terminology

3.1 Definitions of the acoustical terms used in this test method are given in Terminology C 634.

3.2 *Definitions of Terms Specific to This Standard:*

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

Current edition approved April 1, 2004. Published April 2004. Originally approved in 2003. Last previous edition approved in 2003 as E 2235 – 03.

[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.

3.2.1 *output interval,* Δ*t;* [T]; s—*of a real-time analyzer*, the time between successive outputs of sound pressure levels during a single decay measurement.

4. Summary of Test Method

4.1 Sound decay rate in rooms is a function of frequency so measurements are made in a series of frequency bands. Bands of random electrical noise are used as signals to drive loudspeakers in the room until the sound pressure level reaches a steady state. When the sound is then turned off, the sound pressure level decays at a rate determined by the sound absorption in the room. The decay rate is measured in each frequency band by measuring the slope of a straight line fitted to the average decay curve. The absorption of the room and its contents is calculated from the Sabine formula:

$$A = 0.921\frac{Vd}{c} \tag{1}$$

where:
A = sound absorption, m^2,
V = volume of reverberation room, m^3,
c = speed of sound, m/s, and
d = decay rate, dB/s.

4.1.1 The speed of sound changes with temperature and it shall be calculated for the conditions existing at the time of test from the equation:

$$c = 20.047\sqrt{273.15 + t}\ \text{m/s} \tag{2}$$

where:
t = room temperature, °C.

5. Significance and Use

5.1 Several ASTM test methods to evaluate the sound-insulating properties of building elements require the measurement of room sound absorption as part of the procedure. The room sound absorption in these standards appears in an equation in the form 10 log (x/A), where x is a quantity with the same units as A, m^2. Room sound absorption is calculated from the decay rate using Eq 1.

5.2 The requirements of this standard have been chosen so the uncertainty associated with the measurement of room sound absorption will be acceptably small so long as the logarithm of the absorption is being used in calculations.

5.3 Other test methods should specify explicitly that they make use of this test method.

5.4 Where measurement requirements in the parent standard differ from those given here, the requirements in the parent standard shall be satisfied.

5.5 This test method shall not be used when room sound absorption or decay rate is to be used directly to satisfy some criterion, for example in a room that must not be overly reverberant so speech will be intelligible.

NOTE 1—The uncertainty of the room sound absorption obtained will usually be too high and additional measurements are necessary.

5.6 Any companion standard may specify the use of the procedures in this method for determining whether the decay rates in a room are slow enough to satisfy the requirements of the companion standard. The measured decay rates shall still be used only to calculate the logarithm of the room absorption.

6. Sound Source Requirements

6.1 Sound sources shall be loudspeaker systems driven by power amplifiers.

NOTE 2—Loudspeaker systems should be omnidirectional. In practice, using multiple driver elements to cover different frequency ranges and placing sources in trihedral corners of the room will be adequate.

7. Sound Source Positions

7.1 At least one source position shall be used in the room.

NOTE 3—Where more than one source position is used, decay rate data may be collected for each source position in sequence and then the decay rates averaged. Alternatively, multiple loudspeakers may be activated simultaneously. If this is done, the sound power emitted by the loudspeaker sources should be approximately equal. Separate electronic noise generators and amplifiers for each system are not necessary.

8. Electrical Signal

8.1 The electrical signal fed to each power amplifier shall be a band of random noise with a continuous spectrum covering the frequency range over which measurements are made.

9. Frequency Range

9.1 The frequency range of the measurements shall be that specified in the companion standard for which the measurements are being made.

9.2 *Bandwidth*—For each test band, the overall frequency response of the electrical system, including the filter or filters in the source or microphone systems, shall satisfy the specifications given in ANSI Specification S1.11 for a one-third octave band filter set, Order 3 or higher, Type 1.

NOTE 4—The shape of the filter response curve can influence the minimum decay rate that can be measured. This problem is dealt with by the requirement in 13.5.

10. Microphone Requirements

10.1 A microphone used to measure decay rate shall be omnidirectional with a ±1 dB random-incidence amplitude response within any one-third octave band for all frequencies and sound pressure levels used for decay rate measurements.

11. Microphone Positions

11.1 *Stationary Microphones*:

11.1.1 In the absence of an over-riding requirement in the companion standard, the number of stationary microphone positions shall be at least three.

11.1.2 In the absence of an over-riding requirement in the companion standard, stationary microphone positions shall be at least 1.5 m apart, and at least 0.75 m from any surface of the room.

11.2 *Moving Microphones*:

11.2.1 Only one location of a moving microphone assembly is required in the room.

11.2.2 The length of the path for a moving microphone shall be that specified in the companion standard for which measurements are being made.

NOTE 5—Longer paths are preferred since they improve the precision of the measurements at low frequencies.

11.2.3 All points on the path shall be at least 0.75 m from any surface of the room.

11.2.4 The moving microphone shall be at a different point on its path at the start of each decay measurement.

12. Number of Sound Decays to be Collected

12.1 *Stationary Microphones*—The product of the number of microphone positions, the number of decays collected at each microphone position and the number of speakers shall be at least 15.

12.2 *Moving Microphones*—Collect a total of at least 10 decays with a moving microphone.

13. Instrument of Analysis

13.1 The instruments used for analysis shall be digital. Analog devices such as level recorders shall not be used.

13.2 Instruments used for measurements according to this standard shall meet the provisions of either 13.3 or 13.4.

13.3 A sound level meter or other instrument that calculates reverberation time or decay rate values using internal algorithms and presents the calculated values but not individual decay curves.

13.3.1 The algorithm used by the instrument shall satisfy the procedures of Method 2 (see 15.2) for calculation of decay rate.

13.4 An instrument that provides decay curves for each one-third-octave band with or without calculated reverberation time or decay rates.

13.5 Instrument decay rates in each frequency band shall be at least 3 times the room decay rates.

NOTE 6—The instrument decay rate can be measured by attaching an electronic noise source directly to the input, switching off the generator and then measuring the decay.

14. Measurement Procedures

14.1 *Measurement of Decays*:

14.1.1 Turn on the test signal until the sound pressure level in each measurement band is steady.

14.1.2 Turn off the test signal and measure sound pressure levels in each measurement band during the decay. Start and stop times are determined as necessary to suit measurement conditions.

14.1.3 Where a real-time analyzer is used to collect decay curves, the output interval, Δt, shall be small enough that at least five samples are used in the calculations described in 15.2. In furnished rooms, this may require a Δt of 20 ms or less.

14.2 *Measurement of Background Sound Pressure Level*:

14.2.1 Measure the background sound pressure levels in the room using the same microphone and analyzer gain settings used to measure decays.

NOTE 7—This accounts properly for residual noise in the instrumentation.

15. Calculation of Decay Rates

15.1 *Method 1*:

15.1.1 Where the sound level meter or analyzer calculates reverberation times or decay rates, no additional calculations are necessary.

15.1.2 When different decay ranges for calculating reverberation time are available, the range closest to 25 dB shall be selected.

15.2 *Method 2*:

15.2.1 The procedures in 15.2.2 and 15.2.3 shall be used when the instrument used to measure decay rates provides the user with individual or averaged decay curves.

15.2.2 Where the instrument provides curves for single decays, transfer each decay at each frequency from the instrument to a computer and form an average decay curve using Eq 3 or Eq 4.

$$\overline{L_i}(f) = \frac{1}{N}\sum_{j=1}^{N} L_{ij}(f) \quad (3)$$

$$\overline{L_i}(f) = 10\log\left[\frac{1}{N}\sum_{j=1}^{N} 10^{L_{ij}(f)/10}\right] \quad (4)$$

where:

i and j = integers,
$\overline{L}_i(f)$ = average of the sound pressure levels measured at time $i\Delta t$ in frequency band f,
N = the number of decays, and
$L_{ij}(f)$ = the sound pressure level measured at the time $i\Delta t$ during the jth decay in frequency band f.

NOTE 8—It is assumed that the i-th time point is always at the same time after the cessation of the sound.

NOTE 9—Although Eq 4 is technically more correct, for the purposes of this standard either Eq 3 or Eq 4 is satisfactory.

15.2.3 Where the instrument provides average decay curves, they shall be used in the determination of decay rate provided the average decay curves are obtained using Eq 3 or Eq 4.

16. Determination of Decay Rate

NOTE 10—Fig. 1 gives an example of an averaged decay curve and may clarify the following paragraphs.

16.1 All points used in the determination of decay rate must be 10 dB or more above the background noise level.

16.2 The first point to be included in the analysis shall be as soon as practical after the sound has been switched off. The sound pressure level for the first point shall be no more than 5 dB below the level when the sound was on. (See Fig. 1)

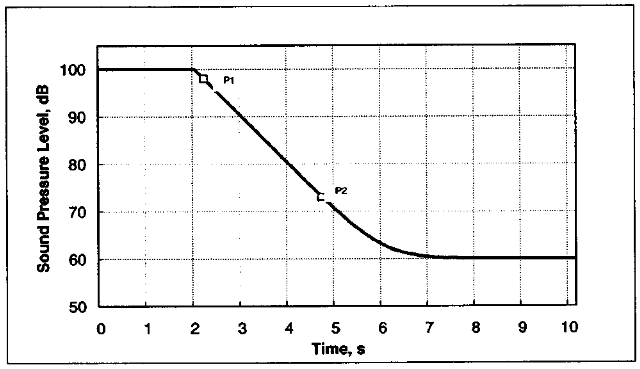
16.3 For laboratory measurements, the last point to be included in the determination of decay rate shall be the first point that is at least 25 dB below the sound pressure level of the first analysis point provided that the level of the last point satisfies 16.1. (See Fig. 1)

16.3.1 For field measurements, the last point to be included in the determination of decay rate shall be more than 15 dB but less than 25 dB below the sound pressure level of the first analysis point provided that the level of the last point satisfies 16.1.

NOTE 11—Background noise levels in field situations are often much higher than those encountered in laboratories. The required decay range is therefore relaxed so measurements can be made in such situations.

NOTE 12—It may be necessary, especially in field measurements, to increase the level of sound from the loudspeaker to increase the signal to background noise ratio so an adequate decay range is obtained.

16.3.2 When the signal level can not be increased sufficiently to comply with 16.3.1, a smaller amount of the decay may be used for the calculation. The last point shall be in compliance with 16.1 and shall be at least 15 dB below the first point.



P1 is the first point used in the fitting process. P2 is 25 dB below P1 and more than 10 dB (actually 12 dB) above the background noise and is the last point used in the fitting process.

FIG. 1 Idealized Decay Curve and the Fitting Process

16.4 For each frequency band, calculate the mean slope of the average decay curve between the first and last points using linear regression analysis.

$$d(f) = \frac{6}{M(M^2 - 1)\,\Delta t}\left[(M+1)\sum_{i=1}^{M}\overline{L}_i(f) - 2\sum_{i=1}^{M} i\overline{L}_i(f)\right] \qquad (5)$$

where:

M = number of points used in the fitting procedure,

Δt = output interval, s, and

$\overline{L}_i(f)$ = average of the sound pressure levels measured at time $i\Delta t$.

16.5 At each frequency, calculate the room sound absorption using Eq 1.

17. Report

17.1 The room sound absorption values calculated in this test method shall not be reported as independent results. They shall only be used in conjunction with other ASTM standards that require the measurement in a room of average sound pressure levels that are then normalized to remove the effect of room sound absorption.

18. Precision and Bias

18.1 The method has no bias.

18.2 Procedures for calculating uncertainties are given in the standards that specify the use of this one.

19. Keywords

19.1 decay rate; normalization of sound pressure level; reverberation time; room sound absorption