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Standard Test Method for Laboratory Measurement of Noise Reduction of Sound-Isolating Enclosures[1]

This standard is issued under the fixed designation E596; 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 reverberation room measurement of the noise reduction of sound-isolating enclosures.

1.2 The noise isolation class may be determined from the noise reduction measured in accordance with this test method.

1.3 *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.*

1.4 *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]

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

C634 Terminology Relating to Building and Environmental Acoustics

E413 Classification for Rating Sound Insulation

2.2 *ANSI Standards:*

S1.4 Specification for Sound Level Meters[3]

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

3. Terminology

3.1 Terms used in this standard are defined either in Terminology C634 or within this standard. The definitions of terms explicitly given within this standard take precedence over definitions given in Terminology C634. The definitions within Terminology C634 and this standard take precedence over any other definitions of defined terms found in any other documents, including other documents referenced in this standard.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *sound-isolating enclosure, n*—any enclosure that completely encloses a space, is intended to provide sound isolation for the enclosed space, and can be tested in a reverberation room.

3.2.2 *useful volume of a sound isolating enclosure, UV*$[L^3](m^3)$, *n*—the part of the space inside the enclosure in which the noise reduction is of interest. For example, in an audiometric booth, the useful volume is the part of the space inside the booth where a test subject's head is likely to be during audiometric tests.

4. Summary of Test Method

4.1 The enclosure to be tested is placed in a reverberation room and prepared for testing. The background noise levels inside the enclosure and in the reverberation room are measured in one-third octave bands. After bands of random noise are produced in the reverberation room, one-third octave band sound pressure levels are measured at several points in the reverberation room and at appropriate points inside the enclosure. The noise reduction in each one-third octave band is the difference between the space-averaged sound pressure level in the reverberation room and the space-averaged sound pressure level inside the enclosure. The noise isolation class (NIC) may be determined from the noise reduction data.

5. Significance and Use

5.1 The noise reduction of an enclosure is a property of the enclosure, the location of the sound source used to measure noise reduction, and the space in which the enclosure is placed. It is not a property of the enclosure alone, and its measurement

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[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.

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

under different conditions can be expected to give different results. When the noise reduction is measured in accordance with this test method, the sound source is outside the enclosure and the sound field outside the enclosure approximates a diffuse sound field. Measurements made in accordance with this test method can be expected to be reproducible from one laboratory to another.

5.2 The noise reduction measured in accordance with this test method may be used for the following purposes:

5.2.1 To rank the order of sound-isolating enclosures according to noise isolation class, NIC.

5.2.2 To estimate the highest one-third octave band sound pressure levels that can occur outside the enclosure without exceeding specified sound pressure levels inside the enclosure.

5.2.3 To estimate the one-third octave band sound pressure levels that will occur inside the enclosure with specified sound pressure levels outside.

5.3 The noise reduction measured in accordance with this test method may not estimate accurately the isolation that the enclosure will provide when it is used to isolate a noise source inside it from the space outside. The user should be cautious when using noise reductions measured by this test method to evaluate enclosures used to enclose noise sources.

5.4 Sound-isolating enclosures are frequently made from prefabricated modular panels. The noise reduction measured by this test method applies to the complete enclosure and not to individual panels from which it is made and cannot be used to infer the sound transmission loss of the individual panels.

5.5 Specifications for sound-isolating enclosures may include reference to noise reduction and noise isolation class measured in accordance with this test method.

6. Reverberation Room

6.1 *Sound Diffusion*—The sound field in the reverberation room shall closely approximate a diffuse field when the enclosure to be tested is in place for testing. In general, the requirements for the reverberation room are those listed in the section dealing with *Reverberation Room* of Test Method C423. These requirements include:

6.1.1 The effective room volume (actual room volume minus the volume occupied by the enclosure) should not be less than 200 m^3.

NOTE 1—Experience and experimental data have shown that as long as the requirements of 9.1.2 and 9.5 are satisfied, the room volume is not critical.

6.1.2 The sound absorption in the reverberation room shall be made as low as possible in order to achieve the best possible simulation to an ideal diffuse field and in order to keep the region dominated by the direct field of the source as small as possible. Within the frequency range described below the sound absorption of the reverberation room should be no greater than the following:

$$A = V^{2/3}/3 \quad (1)$$

where:

V = room volume, m^3, and

A = room sound absorption in metric sabins.

For frequencies below $f = 2000/V^{1/3}$ (where the number 2000 is an empirical constant with the units seconds per metre), 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. For frequencies above 2000 Hz, atmospheric absorption may make it impossible to avoid a slightly higher value of sound absorption.

6.1.3 Diffusing devices such as rotating and stationary diffusing surfaces are useful for creating an adequate approximation to a diffuse sound field.

6.2 *Background Noise:*

6.2.1 The sound pressure level of the background noise inside the enclosure should be at least 10 dB below the level of the test signal. If the difference between the level of the test signal and the background noise level is less than 10 dB and greater than 5 dB, the adjusted value of the signal level is calculated by:

$$L_a = 10\log\left(10^{.1L_c} - 10^{.1L_b}\right) \quad (2)$$

where:

L_a = adjusted signal level, dB,

L_c = level of combined signal and background noise, dB, and

L_b = level of background noise, dB.

If the difference between the level of the test signal and the background noise level is not at least 5 dB, then subtract 2 dB from the level of the combined signal and background noise and use this adjusted level. When the difference between the signal level and the background noise level is less than 5 dB, the measurements provide only an estimate of the lower limit of the noise reduction of the enclosure. Identify such limited measurements in the test report.

6.2.2 Structure-borne noise within the reverberation room structure can excite the enclosure to be tested and cause the sound pressure level within the enclosure to be higher than would be measured due to the test signal alone. Therefore, the reverberation room floor should be adequately isolated against structure-borne vibrations which are propagated into the reverberation room from the outside.

NOTE 2—When the background noise inside the enclosure is the same as the background noise in the reverberation room, it is likely that either the vibration isolation (if any) between the enclosure and the reverberation room floor is ineffective or the measured background noise is the internal noise of the measuring instruments.

6.3 *Construction*—In accordance with 6.1.2, the reverberation room should be constructed of materials that have low sound absorption coefficients. Normally, when a reverberation room is to be used to measure sound absorption, sound power level, or sound transmission loss, it must be constructed using materials and design details that will provide needed sound insulation against outside noise sources. If a reverberation room is to be constructed solely for testing sound-isolating enclosures in accordance with this test method, the sound isolation requirements are not so critical, and lighter materials may be used as long as the requirements of 6.1 and 6.2 are met.

7. Measuring Instrumentation

7.1 The minimum instrumentation required for this test method is:

7.1.1 A microphone and amplifier that satisfy the requirements of ANSI S1.4 for Type 1 or better sound level meters with the exception that A and B-weighting networks are not required.

NOTE 3—A flat characteristic is desirable and, when available, should be used in place of the C-weighting network.

7.1.2 A one-third octave filter set satisfying the requirements of ANSI S1.11 for a one-third octave band filter set, Order 3 or higher, Type 1 or better. The nominal center frequencies of the filters shall be those frequencies that are within the frequency range where the noise reduction is to be measured. This frequency range shall include all of the preferred one-third octave bands from 125 to 4000 Hz and may be extended, if desired.

7.1.3 A level meter, graphic level recorder, or other device from which the sound pressure level can be read. The averaging time of the instrumentation shall be sufficient to permit reading the average sound pressure level with adequate precision (see Section 11).

7.2 Additional microphone systems may be used. If additional microphones are used, differences in their responses should be accounted for either by careful calibration or by an appropriate measurement procedure (see 9.6).

8. Test Signal

8.1 The test signals shall be bands of random noise at least one-third octave wide and including every one-third octave band within the test range. The test range shall include all of the preferred one-third octave bands from 125 to 4000 Hz and may be extended, if desired.

8.2 The signal source shall be placed so that the enclosure to be tested is not in its direct field; the minimum distance from the source to any part of the enclosure shall be:

$$r \geq 0.63\,A^{1/2} \tag{3}$$

where A is the sound absorption in the reverberation chamber with the enclosure present. Normally, the best practice is to direct the source into a trihedral corner of the reverberation room. If more than one loudspeaker is used, it is advisable that each loudspeaker be driven by an independent noise source.

8.3 The signal level shall be at least 10 dB above the measured background noise inside the enclosure at each test frequency.

9. Procedure

9.1 *Enclosure Placement*—Place the enclosure in the reverberation room so that:

9.1.1 No enclosure wall is parallel to a reverberation room wall.

9.1.2 The enclosure is at least one-half wavelength away from the reverberation room walls and ceiling and any diffusing surfaces at the center frequency of the lowest one-third octave band in which the noise reduction is to be measured.

9.1.3 The enclosure is mounted on the floor in the same way as when it is in normal use. Do not mount the enclosure on beams, rails, or vibration isolators unless they are normally used with the enclosure.

9.2 *Enclosure Preparation:*

9.2.1 If the enclosure is equipped with a self-contained air conditioning or ventilating system, operate the system for at least 10 min, turn the system off, and test without further adjustment.

9.2.2 After the procedure of 9.2.1 has been completed, open and close each enclosure door and access opening at least ten times and test without further adjustment.

9.2.3 If the enclosure is equipped with a connector for external air conditioning and ventilation, connect the enclosure to an external duct system that satisfies the manufacturer's specifications or recommendations for the enclosure.

9.3 *Inside Measuring Positions*—Select at least four microphone positions inside the enclosure as follows:

9.3.1 Determine the useful volume of the enclosure.

9.3.2 Distribute microphone positions evenly throughout the useful volume.

9.3.2.1 Microphone positions or traverses should not be located or pass within 0.30 m of the enclosure interior walls unless the useful volume necessarily includes these regions.

9.3.2.2 Microphone positions should not approach one another to within a distance of one-half-wavelength at the lowest frequency of interest.

9.3.2.3 For low frequencies it is almost never possible to select four microphone positions that satisfy the requirement of 9.3.2.2. Whenever this is the case, microphone positions inside the enclosure should be selected to get the best estimate of the space-time average sound pressure level within the useful volume, disregarding spatial correlation among positions.

9.3.3 The potential number of statistically independent microphone positions N within a space is calculated as

$$N = UV/\left(\frac{\lambda}{2}\right)^3 \tag{4}$$

where UV is the useful volume.

9.3.3.1 The effective number of independent measurement locations n shall be calculated as follows:

$$n = N \text{ if } N \text{ independent stationary microphone locations are used,} \tag{5}$$

$$= 2\pi r/(\lambda/2) \text{ if rotating microphone traverse of radius } r \text{ is used,}$$

$$= L/(\lambda/2) \text{ if linear microphone traverse of length } L \text{ is used.}$$

NOTE 4—A half-wavelength correlation distance is assumed, and the number of independent data samples is calculated on this basis. A minimum of four independent data points is required for calculation of the 95 % confidence limits from the table. This is not often possible in small enclosures at low frequencies. When this is the case, the data should be so identified in the report.

9.4 *Background Noise*—With the sound sources not operating, measure the background noise levels in the receiving room at each microphone position or traverse. Corrections shall be made unless the background level is more than 10 dB below the combination of signal and background. (The signal is the sound pressure level due to transmission through the test enclosure.) If the background level is between 5 and 10 dB below the combined level, correct the signal level using:

$$L_s = 10\log\left[10^{L_{sb}/10} - 10^{L_b/10}\right] \quad (6)$$

where:

L_b = the background noise level, dB,
L_{sb} = the level of signal and background combined, dB, and
L_s = the adjusted signal level, dB.

9.5 *Outside Measuring Positions*—Select at least six independent microphone positions in the reverberation room. Microphone positions shall be no less than one-half wavelength or 1 m, whichever is less, away from any solid surface at the lowest test frequency. In addition, outside measuring positions should not lie within the direct field of the signal source as defined in 8.2.

9.6 *Measurements*—The purpose of these measurements is to obtain the difference between the space-averaged, one-third octave band sound pressure level outside the enclosure and the space-averaged, one-third octave band sound pressure level inside the enclosure. This may be done by one of the following three methods:

9.6.1 Use one microphone to measure sound pressure level both inside and outside the enclosure. If this test method is used, the sound power level of the test signal shall be constant throughout the measurement.

9.6.2 Use two microphones to measure the required sound pressure levels, one inside the enclosure and one outside. Interchange the microphones and make the same measurement again. Average the two sets of measurements. The averaging eliminates errors caused by the difference between the sensitivities of the two microphones.

9.6.3 Use two or more calibrated microphones and adjust the measured sound pressure levels for microphone sensitivity.

9.7 *Noise Reduction*—Calculate the noise reduction in each one-third octave band as follows:

$$NR = \bar{L}_1 - \bar{L}_2 \quad (7)$$

where:

NR = noise reduction,
$\bar{L}_1$ = space averaged sound pressure level measured outside the enclosure (in the reverberation room), and
$\bar{L}_2$ = space averaged sound pressure level measured inside the enclosure.

9.7.1 *Determination of Space-Average Levels*—The space-average level corresponding to each set of sound pressure level data is given by:

$$\bar{L} = 10\log\left(\frac{1}{n}\sum_{i=1}^{n} 10^{\frac{L_i}{10}}\right) \quad (8)$$

9.7.2 *Octave Band Noise Reduction*—Calculate ⅓-octave band noise reduction data as follows:

$$NR_{octi} = -10\log\sum_{j=i-1}^{i+1}\frac{10^{-\frac{NR_j}{10}}}{3} \quad (9)$$

It is not permissible to calculate the noise reduction using octave band sound pressure levels.

9.7.3 *Measurement Uncertainty:*

TABLE 1 Factors for 95 % Confidence Limits for Averages

Number of Measurements	Confidence Limits[A], $\bar{X} + as$
n	*a*
4	1.591
5	1.241
6	1.050
7	0.925
8	0.836
9	0.769
10	0.715
11	0.672
12	0.635
13	0.604
14	0.577
15	0.554
16	0.533
17	0.514
18	0.497
19	0.482
20	0.468
21	0.455
22	0.443
23	0.432
24	0.422
25	0.413

[A] Limits that may be expected to include the "true" average. $\bar{X}$, 95 times in 100 in a series of problems, each involving a single sample of observations.

9.7.3.1 It is strongly recommended that the uncertainty of the noise reduction measurement (NR) be monitored to determine if more microphone positions would be beneficial. The overall uncertainty is derived from the uncertainty of the outside and inside sound pressure level measurements. The procedure is to calculate the 95 % confidence interval for both sound fields and then combine them to calculate the uncertainty for NR. The method, described in ASTM STP 15D,[4] is summarized in 9.7.3.2 and following.

9.7.3.2 The standard deviation of the sound field is calculated as:

$$s = \left(\frac{\sum_{i=1}^{n}\left(L_i - \bar{L}\right)^2}{n-1}\right)^{1/2} \quad (10)$$

where:

s = standard deviation,
L_i = an individual sound pressure level reading, and
$\bar{L}$ = the average sound pressure level.

9.7.3.3 The 95 % confidence interval in each sound field is:

$$\Delta_L = a\, s \quad (11)$$

where the factor a is determined by the number of independent microphone positions n and is drawn from Table 1.

9.7.3.4 The uncertainty of the noise reduction is the combined uncertainty of the sound pressure levels inside and outside the enclosure:

$$\Delta_{NR} = \left(\Delta_{L1}^{\ 2} + \Delta_{L2}^{\ 2}\right)^{1/2} \quad (12)$$

9.7.3.5 *Precision Requirements*—It is recommended that the noise reduction uncertainty be no greater than 3 dB for the one-third octave bands centered on 125 and 160 Hz, 2 dB for

[4] *Manual on Presentation of Data and Control Chart Analysis*, ASTM STP 15D, ASTM, 1976.