INTERNATIONAL

Designation: E 477 – 99

Standard Test Method for Measuring Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers[1]

This standard is issued under the fixed designation E 477; 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.

1. Scope

1.1 This test method covers the laboratory testing of duct liner materials, integral ducts, and in-duct absorptive straight and elbow silencers used in the ventilation systems of buildings. Procedures are described for the measurement of acoustical insertion loss, airflow generated noise, and pressure drop as a function of airflow.

1.2 Excluded from the scope are reactive mufflers and those designed for uses other than in ventilation systems, such as automobile mufflers.

1.3 This test method includes a provision for a simulated semi-reflective plenum to fit around thin-walled duct and silencer test specimens, since the acoustical environments around such thin-walled specimens can affect the measured insertion loss.

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:*

C 423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method[2]

C 634 Terminology Relating to Environmental Acoustics[2]

E 90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions[2]

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

E 717 Guide for Preparation of the Accreditation Annex of Acoustical Test Standards[2]

E 795 Practices for Mounting Test Specimens During Sound Absorption Tests[2]

2.2 *ANSI Standards:*

S1.1 Acoustical Terminology[4]

S1.11 Octave, Half-Octave and Third-Octave Band Filter Sets[4]

S1.13 Measurement of Sound Pressure Levels[4]

S12.31-1990, Precision Methods for the Determination of Sound Power Levels of Broad-Band Noise Sources in Reverberation Rooms

2.3 *ASME Test Codes:*[5]

ANSI/ASME PTC 11-1984 (R 1990) Fans

ASME MFC-3M (1989)

ASME 19.5-72

2.4 *AMCA Standards:*[6]

ANSI/AMCA 210-85

AMCA 300

2.5 *ASHRAE Documents and Standards:*[7]

ASHRAE Handbook, Fundamentals Volume (current edition), Chapter on Measurement and Instruments

ANSI/ASHRAE 41.2-1987 (RA92) Standard Methods for Laboratory Airflow Measurement

2.6 *ISO Standards:*[8]

ISO 3741

ISO 7235

3. Terminology

3.1 *Definitions*—The acoustical terms used in this method are consistent with Terminology C 634, ANSI S1.1, and ANSI S1.13.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acoustical duct liner material*—a material that has sound absorptive properties and is attached to the inside wall of a duct to attenuate the sound that propagates down that section of duct.

[1] This test method is under the jurisdiction of ASTM Committee E-33 on Environmental Acoustics and is the direct responsibility of Subcommittee E33.08 on Mechanical and Electrical System Noise.

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[2] *Annual Book of ASTM Standards,* Vol 04.06.

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

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[5] Available from American Society of Mechanical Engineers, 345 East 47th St., New York, NY 10017.

[6] Available from Air Movement and Control Association, 30 W. University Dr., Arlington Heights, IL 60004.

[7] Available from ASHRAE, 1791 Tullie Circle, NE, Atlanta, GA 30329.

[8] Available from ISO, Case Postale 56, CH-1211, Genève 20, Switzerland.

3.2.2 *airflow generated noise*—the noise generated by air flowing through a device.

3.2.3 *background noise*—the total of all noise sources of interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal.

3.2.4 *empty duct measurements*—the sound pressure levels measured in the reverberation room as a result of the noise generated by the sound sources in the source chamber and transmitted through the empty duct system without the test specimen inserted.

3.2.5 *equivalent diameter of rectangular ducts*—$\{4(W \times H)/\Pi\}^{1/2}$, where W and H are the width and height of the duct, respectively.

3.2.6 *forward flow (+)*—noise that propagates in the same direction as airflow.

3.2.7 *in-duct sound-attenuating devices*—units specifically designed to be installed in a ventilating duct system for the purpose of attenuating the sound that transmits through the in-duct sound-attenuating device.

3.2.8 *insertion loss (IL)*—the reduction in sound power level, in decibels, at a given location due solely to the placement of a sound-attenuating device in the path of transmission between the sound source and the given location. The path of transmission in this case is within the test duct system.

3.2.9 *integral duct*—a duct formed from an integral composite of materials, typically having a porous inner layer to provide sound absorption, with an impervious outer surface.

3.2.10 *reverse flow (−)*—noise that propagates in the opposite direction to airflow.

3.2.11 *signal source chamber*—an enclosure at the upstream end of the duct system in which one or more sound sources are located for the purpose of generating sound to be transmitted through the duct system and discharged into the receiving reverberation room.

3.2.12 *standard air density* (d_s)—1.202 kg/m^3(0.075 lb/ft^3). This corresponds approximately to dry air at 21°C (70°F) and 101.3 kPa (29.92 in. Hg).

3.2.13 *static pressure at a plane of traverse,* P_s, Pa (in. water)—the arithmetic average of the static pressure at points in the plane of traverse.

3.2.14 *static pressure at a point,* P'_s, Pa (in. water)—the pressure measured by the static connection of a pitot tube pointed upstream at that point.

3.2.15 *test run*—pertains to all readings and calculations at any one setting of the throttling device.

3.2.16 *thin-walled duct*—a duct or silencer whose wall mass or stiffness are low enough to allow significant energy to escape into the environment about it (low STC). This term applies to ducts whose walls are thinner than 24 gage, or are flexible, or are of rigid fiberglass construction.

3.2.17 *total pressure at a plane of traverse,* P_t, Pa (in. water)—the algebraic sum of the velocity pressure at the plane of traverse and the static pressure at the plane of traverse.

3.2.18 *traverse*—a series of readings made with a pitot tube inside a duct in accordance with *ASHRAE Fundamentals Handbook*, Measurement and Instruments chapter.

3.2.19 *velocity pressure at a plane of traverse,* P_v, Pa (in. water)—the square of the average of the square roots of the velocity pressures at that point.

3.2.20 *velocity pressure at a point,* P'_v, Pa (in. water)—the pressure measured by the differential reading of a pitot tube pointed upstream at that point.

3.3 *Symbols:Symbols*—see *ASHRAE Fundamentals Handbook*, Measurement and Instruments chapter:[7]

3.3.1 D = air density in reverberation room, kg/m^3(lb/ft^3).

3.3.2 BP = barometric pressure, kPa (in. Hg).

3.3.3 t_d = dry bulb temperature, °C (°F).

3.3.4 T = absolute temperature of air in reverberation room, K (°C + 273) or [°R = (°F + 460)].

3.3.5 P_v = velocity pressure at a plane of transverse, Pa (in. water).

3.3.6 P_s = static pressure at a plane of transverse, Pa (in. water).

3.3.7 V = average velocity in the duct across the plane of traverse, m/min (ft/min).

3.3.8 ΔP = pressure differential or pressure drop across the in-duct sound attenuating device, Pa (in. water).

3.3.9 Q = discharge rate, L/s (ft^3/s).

3.3.10 K = values of constant K.

3.3.11 A_2 = orifice area, m^2(ft^2).

G_c = gravitational conversion factor, 9.806 m/s^2(32.174 ft/s^2).

3.3.12 hf = pressure drop obtained by the pressure taps, Pa (lbf/ft^2).

4. Summary of Test Method

4.1 To measure the insertion loss of a test specimen, two separate measurements must be made. The sound pressure level in the reverberation room is measured while sound is entering the room through a length of straight or elbow empty duct with a sound source at the far end. The sound pressure level in the reverberation room is measured again after a section of the empty duct has been replaced with the test specimen. The insertion loss is equal to the difference between the two measured sound pressure levels. The section of straight empty duct is designed to have negligible attenuation at all measurement frequencies. The construction of the test facility duct system and the shape of the test elbow silencer determine the geometry of the elbow empty duct. The elbow duct must be fully described in all test reports to include information on the shape, angle, radius, centerline, and so on, due to different elbow constructions having various attenuation properties.

4.2 The airflow generated noise is measured in terms of frequency band sound power levels while air, originally quiet, is passing through the system with the test specimen installed.

4.3 Pressure drop performance is obtained by measuring the static pressure at designated locations upstream and downstream of the test specimen at various airflow settings. The pressure drop and airflow may be measured with a variety of standard acceptable instrumentation such as piezometer rings, flow nozzles, orifices, etc. However, the method described herein is the pitot tube and manometer method.

5. Significance and Use

5.1 The procedures described are for measurement of the properties of silencing elements as installed in a laboratory facility of the type described herein. The insertion loss, airflow generated noise, and pressure drop of a silencer in an actual installation may differ from the values obtained from this test method due to interaction with other elements of the ventilation system. Provisions have been included for surrounding a thin-walled test specimen with a simulated semi-reflective plenum.

5.2 Silencers are often designed to be used under conditions which do not duplicate the duct-to-duct test set-up covered in this test standard. Mock-up or specialized test set-ups for such silencers (such as those to be used at the end of a duct) are not considered to be in full conformance with this standard. See Annex A2 for information regarding such tests.

6. Test Facilities

6.1 The test facility shall consist of a signal source chamber and a reverberation room coupled together by means of a length of straight or elbow duct. Provisions shall be made in the duct system for inserting either a test specimen, or a section of empty duct having the same interior cross-sectional dimensions at the duct connection points, length, and shape (for elbow testing) as the test specimen. An example of a facility set-up to accomodate straight silencer testing is shown in Fig. 1. An example of a facility set–up to accommodate elbow silencer testing (at various angles) is shown in Fig. 2. Airflow and noise source plenum(s) may be at a fixed or a mobile location within the test facility to accommodate straight and/or elbow silencer testing.

6.2 *Signal Source Chamber*—The signal source chamber shall be an enclosure large enough to accommodate one or more sound sources. The sound source system shall be structurally isolated from the chamber and duct system. This enclosure should be joined to the duct system through an opening in the chamber having dimensions the same as or greater than the duct. In the latter case, a tapered transition piece is placed between the duct and the opening in the chamber.

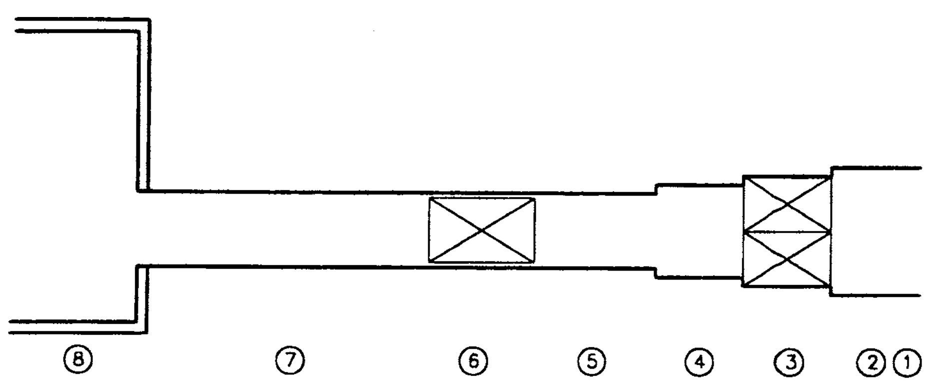
6.2.1 The signal source chamber should be constructed of material having sufficient sound transmission loss and be adequately isolated to reduce the possibility of sound entering the reverberation room by paths other than through the duct connecting the signal source chamber and reverberation room.

6.2.2 In order to ensure that the reaction on the sound source remains essentially constant with or without the test specimen in place, the interior wall surfaces of the signal source chamber must be lined with sound-absorbing material. The material shall have a minimum NRC = 0.25, as determined by Test Method C 423 and Type A mounting per Practices E 795 for all the test frequencies but should be kept low enough so that the sound pressure level in the reverberation room is 10 dB above ambient when the test specimen is in place and the sound source is on.

6.2.3 The physical size of the signal source chamber shall be such that no inside dimension is less than the largest dimension of the duct system and that the sound source is totally enclosed and does not obstruct the opening into the duct.

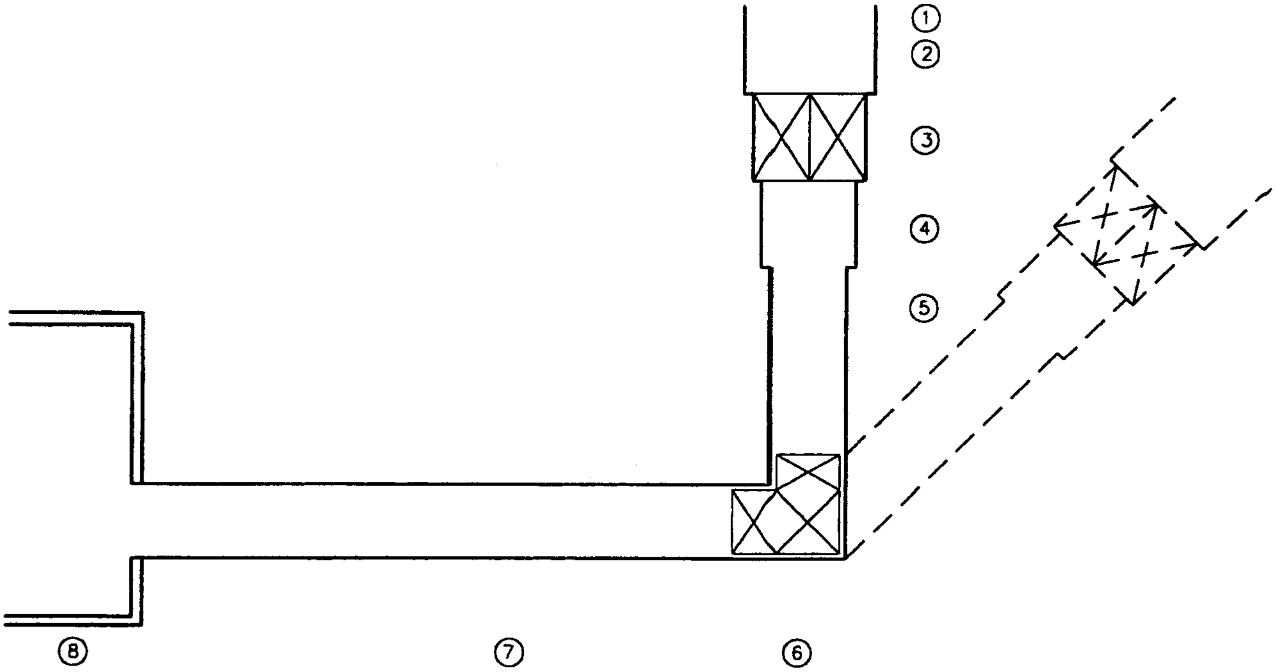
6.2.4 A second duct may be attached to the signal source chamber through which quiet airflow can be supplied to the system.

6.3 *Duct System (Between Source Chamber and Reverberation Room)*—The construction of the duct system shall be of adequate mass (14 gage or heavier steel) so that any environmental or flanking noises entering the duct system have a negligible effect on the measurements. When testing high insertion loss silencers, it may be necessary to apply a damping



1 – Airflow measurement station
2 – System fan
3 – System silencer
4 – Signal source chamber
5 – Upstream pressure test station for forward (+ve) airflow and downstream pressure test station for reverse (−ve) airflow
6 – Straight silencer under test
7 – Downstream pressure test station for forward (+ve) airflow and upstream pressure test station for reverse (−ve) airflow
8 – Reverberation room

FIG. 1 Typical Facility for Rating Straight Duct Silencers With or Without Airflow



1 – Airflow measurement station
2 – System fan
3 – System silencer
4 – Signal source chamber
5 – Upstream pressure test station for forward (+ve) airflow and downstream pressure test station for reverse (−ve) airflow
6 – Elbow silencer under test
7 – Downstream pressure test station for forward (+ve) airflow and upstream pressure test station for reverse (−ve) airflow
8 – Reverberation room

FIG. 2 Typical Facility for Rating Elbow Duct Silencers With or Without Airflow

material to the outside of the duct walls or increase the transmission loss, or both, by adding one or more layers of gypsum board to the exterior. The interior surface of the duct system shall be smooth and have a low sound absorption coefficient in the frequency range of interest.

6.3.1 The length of the duct system is primarily determined by the requirements of air-flow measurements. The duct length upstream, regardless of the shape of the test specimen and layout of test facility, shall be not less than 5 equivalent diameters from the entrance to the test specimen. Similarly downstream, it shall be not less than 10 duct diameters from the exit of the specimen to the reverberant room, not including the length of any transitions, if airflow is being measured. If airflow is not measured, the downstream length shall be not less than 5 equivalent duct diameters. The test specimen is to remain in the same position for both the insertion loss and airflow measurements.

6.3.2 The upstream and downstream sections shall have the same cross-sectional dimensions as the entrance and discharge of the test specimen. Any transitions to adapt the test specimen to the facility duct dimensions shall be made upstream and downstream of the required duct length. Any transitions to adapt the test specimen to the facility duct dimensions shall have an included angle of not greater than 15° (slope no greater than 7.5°). The duct shall terminate at the reverberation room wall abruptly with the same cross-sectional dimensions as the system duct.

6.3.3 There are occasions when a silence, designed to be used at the termination of a duct system, must be tested. Testing of such silencers, mounted at the termination of the facility duct or in the reverberation room, shall be considered a special circumstance, and shall be noted as an exception to this test standard in the test report. Full details concerning the mounting and testing must also be included.

6.4 *Reverberation Room*—The requirements regarding the reverberation room are based on those given in Method E 90. If flow-generated noise is to be measured, the room shall be qualified in accordance with ANSI S12.31 or ISO 3741.

6.5 *Test Signal*—The sound signals delivered to the loudspeaker system for these tests shall form a series of bands of pink noise.

6.5.1 The bandwidth of each test signal shall be one-third octave. Specifically, the overall frequency response of the electrical system, including the filter or filters in the source and microphone circuits, shall conform to the specifications in ANSI S1.11 for a one-third octave band filter set, Order 3 or higher, Type 1 or better. Filtering may be done in the source or microphone system or partially in both, provided that the