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.

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[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.

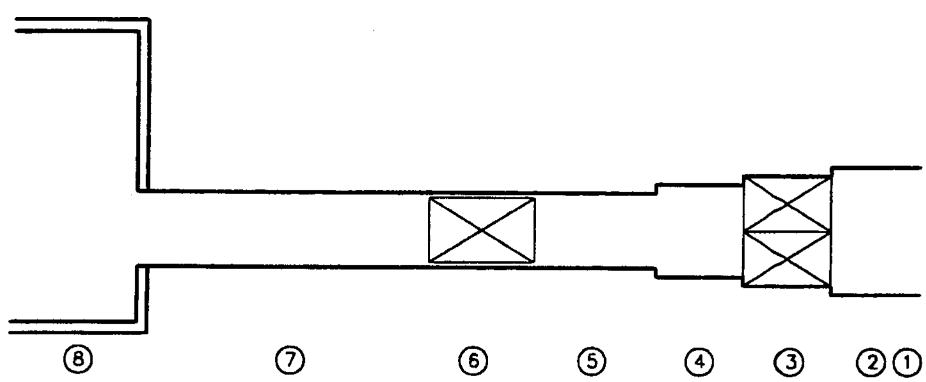
6.2.1 The signal source chamber should be constructed of material having sufficient sound transmission loss and be adequately isolated to reduce the possibility of sound entering the reverberation room by paths other than through the duct connecting the signal source chamber and reverberation room.

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.

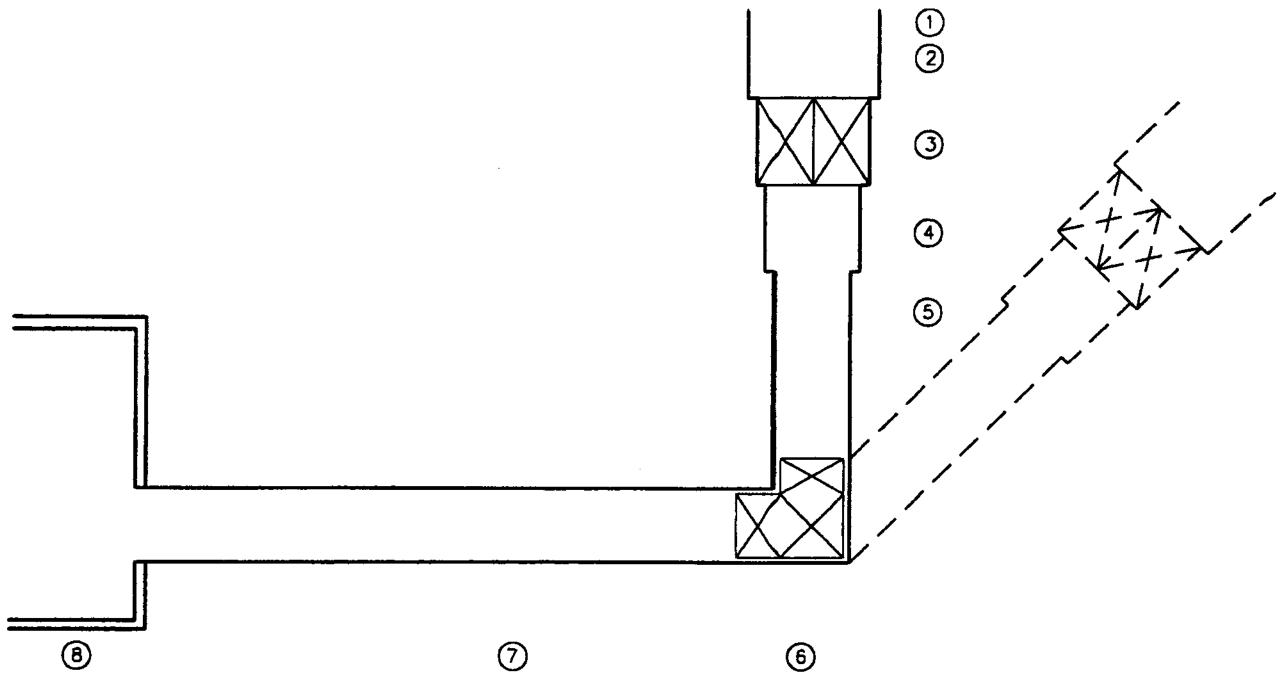
6.2.4 A second duct may be attached to the signal source chamber through which quiet airflow can be supplied to the system.

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 required overall characteristic and bandwidth is achieved. Apart from defining the one-third octave bands of test signals, a filter in the microphone system serves to filter out extraneous noise lying outside the test band including possible distortion products in the source system; a filter in the source system serves to concentrate the available power in the test band.

6.5.2 The minimum range of measurements shall be a series of contiguous one-third octave bands with center frequencies from 50 to 5000 Hz (optional to 10 000 Hz). If desired, the range may be extended in further one-third octave band downward or upward. Note that at this time there is no standard method of qualifying a reverberation room below 100 Hz. However, recent research shows that reproducible data are obtainable for both insertion loss and airflow generated noise at these lower frequencies. Based on this research, the standard deviation for ⅓ octave band measurements increases to about 6 dB at the lowest frequencies.

6.5.3 The sound source in the source chamber should be a loudspeaker system mounted in a baffle capable of reproducing the lowest test frequency with adequate power. When more than one loudspeaker is used they should be electrically coupled so that they act in phase or in unison, in response to a given signal. The loudspeaker should be placed on one side of the source chamber such that it does not beam directly into the duct system.

6.5.4 The signal shall be monitored electrically by measuring the loudspeaker voice coil voltage. The test signal at a given band shall be maintained to ±½ dB throughout the test. Power shall be applied to the speaker voice coil for a minimum time of ½ h prior to conducting tests in order to stabilize speaker output due to voice coil heating.

6.5.4.1 As an alternate check, a microphone may be used to measure the sound pressure level at a specific position in the empty duct before and after placing the test specimen in the duct. Said position is to be on the signal source side of the test specimen. This applies only to 0 flow conditions.

7. Apparatus and Methods of Measurement for Airflow and Pressure Drop

7.1 The measurement of airflow may be accomplished by employing venturi, nozzle or orifice flowmeter instruments. A pitot traverse may also be used (see 2.5).

7.1.1 The following information is required prior to each test and once every two hours during the test to ensure accurate airflow setting and measurements: barometric pressure at the measurement laboratory, and wet and dry bulb temperatures. The airflow is to be recalculated each time new data are taken. Wet and dry bulb temperatures are to be taken in the reverberation room.

7.2 Pressure drop measurements of the test specimen shall be made for at least three airflow settings in accordance with ANSI/ASHRAE Standard 41.3-89. These airflow settings shall be broad enough to cover the full design operating range of the specimen.

7.2.1 The static pressure readings shall be made at planes 2½ duct diameters (or equivalent diameters for rectangular ducts) upstream from the inlet to the test specimen and 5 duct diameters downstream from the outlet of the test specimen. A piezometer ring or pitot traverse shall be used to ensure accurate pressure readings.

7.3 Pitot tubes and other flow measuring devices mounted between the test specimen and the reverberation room shall be removed from the duct system during airflow generated noise measurements if their empty duct noise levels are within 10 dB of the airflow noise level of the test specimen.

7.4 The total pressure drop across the silencing element shall be calculated from the upstream and downstream total pressures measured directly or calculated from static and velocity pressures measured at the plane of the transverse. This calculation shall be made and reported without correcting for the pressure drop of the substitution duct.

8. Test Specimen

8.1 *Installation*:

8.1.1 The test specimen shall be installed in the duct system in a manner normally specified for use with the element. The geometry of the duct shall conform to the geometry of the inlet and outlet of the element. The substitution elbow duct shall have the same bend angle as the test specimen. In order to minimize attenuation effects, the substitution elbow duct shall be a radius geometry (*inside radius* = 1 × duct width; *outside radius* = 2 × duct width).

8.1.1.1 To reduce the effects of structural flanking, the test specimen shall be de-coupled from the inlet and outlet duct

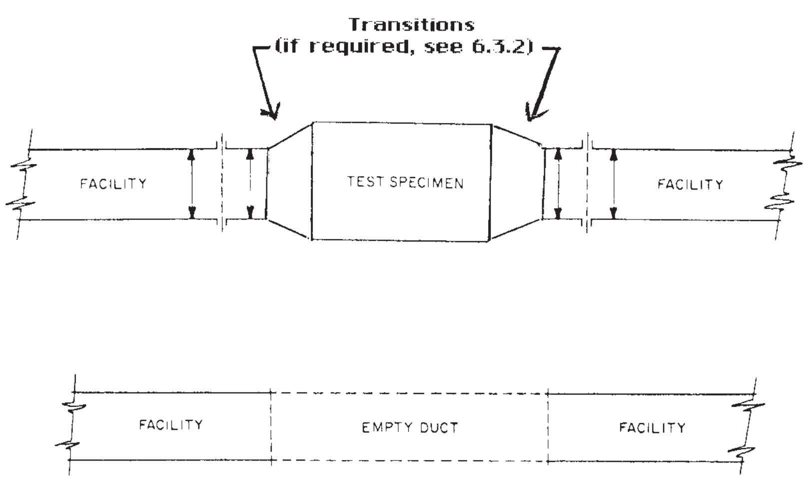


FIG. 3 Test Specimen with Inlet and Outlet Dimensions the Same as the Facility Duct, also Showing Nature of any Required Transitions

sections. This can be accomplished by applying a 12-mm (½-in.) bead of mastic material (Dux Seal or similar material) between the flanges that connect the test specimen to the inlet and outlet duct sections. At least a 6-mm (¼-in.) gap shall remain between the flanges after they have been bolted or clamped together.

8.1.2 The removable portion of the duct system shall be the same gage as the test system duct except where a lined and unlined duct are being compared. In this case, while the unlined and lined duct sections shall be of the same gage, they may be different than the remainder of the test duct.

8.1.3 Duct liner materials should be applied to another duct as a separate assembly which then becomes a test specimen. Application should conform to the generally accepted trade methods used and shall be specified in the report.

8.1.3.1 The free (inside) area of the lined duct section shall be the same as the free area of the removable duct section; that is, the outside dimensions of the lined duct will be larger than the unlined.

8.1.4 For a thin-walled duct, it is likely that the amount of absorption surrounding the test specimen will significantly affect the measured insertion loss. If the specimen wall material is thinner than 24 gage, or is flexible, or is of rigid fiberglass construction, then a simulated plenum shall be fitted around it to provide a semi-reflective environment (see Fig. 4). This can be accomplished by mounting a 19-mm (¾-in.) thick plywood reflector 50 mm (2 in.) above and below the test specimen. Both reflectors shall be 1.2 m (4 ft) wide and long enough to project not less than 0.6 m (2 ft) beyond the ends of the specimen. The test specimen shall be centered in the plywood reflectors. The sides of the plenum as indicated in Fig. 5, shall be 19-mm (0.75-in.) thick plywood, lined with 2 to 3-lb density absorptive (glass fiber) lining 0.15 m (6 in.) thick.

NOTE 1—The 50-mm (2-in.) distance has been chosen to simulate a reasonable plenum clearance. Other distances may affect the test results, however, the magnitude of these differences has not been determined.

8.2 *Size*:

8.2.1 The smallest dimension should be not less than 0.610 m (2 ft), and may not be less than 0.305 m (1 ft) except for prefabricated duct, where the smallest dimension may be that which is normally supplied by the manufacturer. The largest dimensions of the test specimen shall not exceed the limits of the test facility. Transition ducts for the purpose of mating the test specimen geometry to the laboratory duct system geometry may be used, provided that the requirements of 6.3 are met. If inlet and outlet transition elements form a part of the test specimen, then this should be fully described in the report.

8.2.2 There is no restriction on the length of prefabricated silencers except that the entrance and terminating duct lengths meet the conditions of 6.3. Duct liner materials and flexible duct shall be 3 m (10 ft) long.

NOTE 2—The length of duct liner materials and flexible duct controls attenuation. 3-m (10-ft) length has been chosen as representative of the length used in actual installations.

9. Measurement of Insertion Loss (With or Without Airflow)

9.1 The purpose of the measurement is to find the change in sound power delivered to the reverberation room before and after the test specimen is inserted into the duct under conditions of forward and reverse flow or without flow. Since the absorption of the receiving room is the same during the two measurements, the change in sound power level is equal to the change in sound pressure level and, by definition, to the insertion loss.

9.1.1 For each condition of test (that is, with and without the test specimen in the duct system) the averaging time for each one-third octave band shall be sufficient to permit a recording of the time-average level as observed on instrumentation meeting the requirements of ANSI S1.11.

9.1.2 Sound field sampling techniques and microphone requirements shall be in accordance with ANSI S12.31 or ISO 3741.

9.1.3 Use the same microphone positions for the entire test, that is, for sound pressure level measurements with and without the test specimen installed in the duct.

9.1.4 Check the background noise levels regularly. Flanking transmission, which is part of the background noise, can be checked by inserting a massive obstruction with a high transmission loss in the duct system at the upstream end of the test specimen location, then observing the levels in the receiving room with the sound source generating the same power levels to be used for the test. The background noise must be at least 5 dB below the total level due to signal plus background

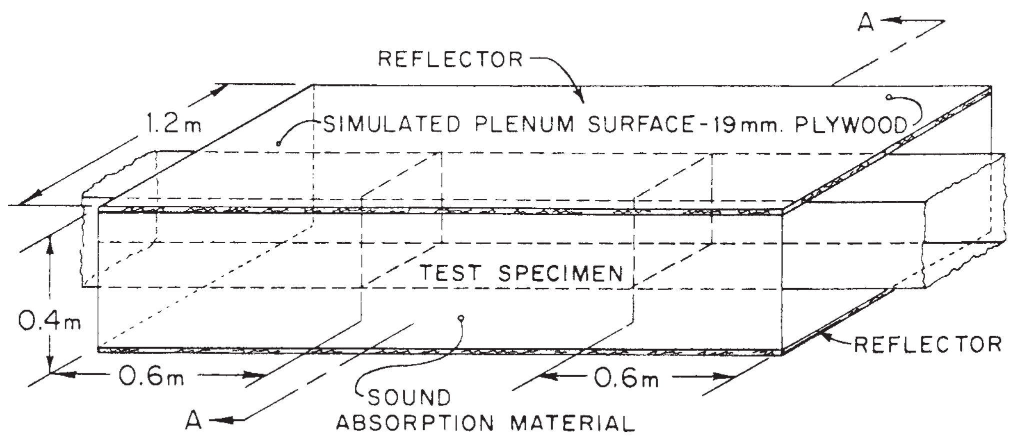


FIG. 4 Simulated Semi-Reflective Plenum Configuration

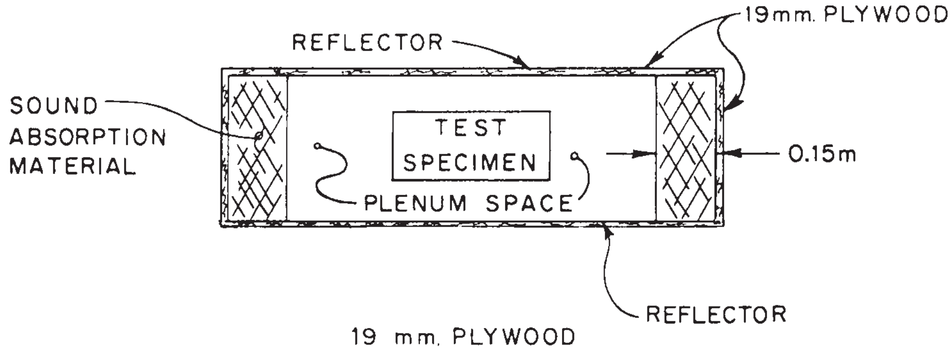


FIG. 5 Section A-A

with the silencer in place and corrections should be made unless the background level is at least 10 dB below the total level. (See 10.4.1.)

9.1.5 To obtain the insertion loss in octave bands, the following equation shall be used:

$$IL_{oct,cf} = -10 \log(1/3 \sum_{B = B_{c-1}}^{Bc + 1} 10^{-IL_B/10}) \quad (1)$$

where:

$IL_{oct,cf}$ = IL in preferred octave band center frequency, and

IL_B = IL in three adjacent ⅓ octave bands designated $B_{c}-1$, B_c, and $B_c + 1$.

The octave band insertion loss is the difference between the octave band sound pressure levels with and without the test specimen in place.

9.2 A sufficient number of measurements shall be taken so that the uncertainty of the mean value of the insertion loss *IL* is no more than ±1 dB with 90 % confidence except for the lowest band for which the uncertainty shall be no more than ± 2 dB (**1**).[9]

NOTE 3—The insertion loss of thin-walled test specimens may be influenced by the amount of absorption surrounding the test specimen. Tests should be performed in accordance with 9.1.5.

10. Power Level Measurements for Airflow Generated Noise

10.1 The purpose is to measure the sound power generated by air flowing through the test specimen under operating conditions (**2**).

10.1.1 For forward airflow (+) air is injected into the system at a measured rate through the source chamber. The air then passes through the duct system, in-duct sound attenuating device, and into the receiving room. Conversely, for reverse airflow (−), air is injected into the system from the receiving room at a measured rate through the connecting straight duct. The air then passes through the duct system, in-duct sound-attenuating device, and source chamber to the fan. The one-third octave band or octave band sound power level is obtained by sound pressure level measurements made in the receiving room in accordance with ANSI S1.13.

10.1.2 Time-space-average sound pressure levels are measured in the reverberation receiving room for each rate of volume flow in cubic feet per minute in the manner described in Section 8 with the sound source turned off. Empty duct sound pressure levels are measured to establish the noise levels of the system, including fan, and whether they may interfere with the sound level measurements of the specimen. The empty duct airflow sound pressure levels should always be at least 10 dB below the sound pressure levels obtained when the test specimen is in place.

10.1.3 A silencing element placed between the fan and the source chamber usually will be required to reduce the noise levels of the fan to meet this criterion (see Fig. 1 and Fig. 2).

10.2 With the above requirements met, the sound power levels produced by the specimen shall be arrived at by the comparison method specified in ANSI S12.31 or ISO 3741.

10.2.1 In obtaining airflow generated sound power levels of the test specimen, corrections must be added for end reflection in accordance with the size and geometry of the duct downstream of the test specimen and its discharge into the reverberation room (**3**) per AMCA 300. Alternatively, an exponential horn properly shaped to transmit 50 Hz sound may be used. (See Annex B, ISO 7235 for design information.) The method used shall be incorporated in the report.

10.3 A sufficient number of measurements shall be taken so that the uncertainty of the mean value of the sound power level L_w is no more than ±1 dB with 90 % confidence except for the lowest band for which the uncertainty shall be no more than ±2 dB.

10.4 When high insertion loss specimens are being tested with airflow, the airflow generated signal may approach the attenuated signal from the sound source. This can be determined by turning the sound source on and off.

10.4.1 If the attenuated sound signal is less than 2 dB greater than the level of the airflow generated sound at any measurement frequency, means shall be taken to increase the sound source signal. If the difference is 2 dB, the true insertion loss can be obtained by adding 4 dB to the indicated insertion loss; at 3 dB difference, add 3 dB; 5–9 dB difference, add 1 dB; and at 10 dB or greater, 0 dB.

10.5 To obtain the airflow generated sound power levels in octave bands combine the three one-third octave band levels in each octave band as follows:

[9] The boldface numbers in parentheses refer to the references listed at the end of this test method.

$$L_{w,oct\,cf} = 10\log\left(\sum_{i=1}^{3} 10^{L_i/10}\right) \quad (2)$$

where:

$L_{w,oct\,cf}$ = the combined octave band sound power level, and

L_i = the individual one-third octave band sound power level.

11. Report

11.1 The report shall include the following:

11.1.1 A statement, if true in every respect, that the test was conducted in accordance with the provisions of this method,

11.1.2 *A Description of the Substitution Duct Used in the Test*:

11.1.2.1 A description of the test specimen sufficiently detailed to identify the device at least in terms of the elements that may affect its acoustic and aerodynamic performance. The specimen size, manufacturer's model designation, and total weight shall always be reported. Wherever possible the testing laboratory should observe and report the composition, dimensions, and other relevant physical properties of the major components and the manner in which they are combined, including net open area. A designation and description furnished by the sponsor of the test may be included in the report provided that they are attributed to the sponsor.

11.1.3 Insertion loss to the nearest 1 dB for the individual one-third octave bands for each rate and direction of airflow (**4-6**). Octave-band insertion loss and airflow generated sound levels, rounded to the nearest 1 dB, shall be included; calculated by Eq 1 and 2 for the several operating conditions of the test specimen.

11.1.4 Temperature in test room at the time of test,

11.1.5 For both straight and elbow silencers, the actual total pressure drop across the silencing element shall be reported for each airflow rate used in the test, without subtracting the pressure drop of the substitution duct. If the testing laboratory does not conduct airflow tests, then a statement to this effect should be included in the report unless the laboratory assumes the responsibility of arranging with an accredited laboratory to conduct these tests using the same specimen. In this case, the name of the laboratory and the results of the tests shall be included as part of the report,

11.1.6 One-third octave band or octave band sound power levels of the airflow generated noise of the test specimen at the airflow rates and direction at which the test specimen is most likely to be operated or is designed for, and

11.1.7 A statement by the testing laboratory of the precision of the Insertion Loss and Power Level data.

12. Precision and Bias

12.1 *Precision*—For tests made in the same laboratory using the same apparatus and the same specimen without reinstallation, the repeatability standard deviation is 1 dB or less at all frequencies from 63 to 4000 Hz. The corresponding 95 % confidence limit is 3 dB or less. There are no data available to determine the repeatability standard deviation where the specimen is removed and reinstalled. From round robin testing on a pair of 3-ft silencers, the interlaboratory reproducibility of octave band insertion loss data is 2 dB or less at all frequencies between 125 and 8000 Hz. The corresponding 95 % confidence limit is 6 dB or less. (It may be greater below this frequency limit.) For airflow generated noise, based on limited data, the octave band sound power variability is somewhat greater than this at all frequencies.

12.2 *Bias*—There is no known bias in this test method.

13. Keywords

13.1 airflow generated noise; airflow performance; duct liner materials; insertion loss; prefabricated elbow silencers; prefabricated straight silencers

ANNEXES

(Mandatory Information)

A1. LABORATORY ACCREDITATION

A1.1 Scope

A1.1.1 This annex describes information that must be supplied by a laboratory to an accrediting agency to demonstrate compliance with all the provisions of this test method.

A1.2 Referenced Documents

A1.2.1 *ASTM Standards*:

C 634 Terminology Relating to Environmental Acoustics[2]

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

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

A1.3 Laboratory Information and Procedures

A1.3.1 The laboratory must show compliance with the following sections of this test method:

A1.3.1.1 Signal source chamber (6.2), duct system (6.3), reverberation room (6.4), construction, and size.

A1.3.1.2 Test signal (6.5).

A1.3.1.3 Test specimen installation (8.1 and 8.2).

A1.3.1.4 Measurement and calculation of insertion loss (9.1).

A1.3.1.5 Number of measurements taken (9.2).

A1.3.1.6 Method of determining the sound power level for airflow generated noise (10.1 and 10.2).

A1.3.1.7 Method of measuring the airflow and pressure drop and instrument calibration (7.1, 7.2, 7.3, and 10.4).

A1.3.1.8 Method of reporting test data (11.1).

A1.4 Reference Tests

A1.4.1 The laboratory shall maintain a reference silencer to be used during periodic tests for quality assurance. The silencer shall be suitable for both insertion loss and self-generated noise tests. It should be so constructed that it will not deteriorate with use and should maintain its properties for at least ten years.

A1.4.2 The laboratory shall measure the insertion loss at 0 flow and the self-generated noise and pressure drop at least one flow velocity, in either direction, at least every six months. Said measurements are to occur at all the ⅓ octave band frequencies cited in 6.5.2.

A1.4.3 The data and the standard deviations generated by this procedure shall be analyzed by the control chart method described in Chapter 3 of ASTM MNL 7.[10] The analysis shall be according to the subsection entitled "Control—No standard given."

[10] *Manual on Presentation of Data and Control Chart Analysis*, 6th ed., ASTM MNL 7, ASTM.

A2. MOCK-UP TEST PROCEDURES

A2.1 Silencers are occasionally designed to be used under conditions which do not duplicate the duct-to-duct test set-up covered in this standard. Such mock-up or specialized test set-ups require some testing set-up precautions and reporting requirements covered in this Annex.

A2.2 If the test specimen is designed to be used at the termination of the duct system, it shall be placed at the termination of the facility duct, which is the wall of the reverberation room. It shall be mounted in a manner typical of the way it is to be used.

A2.2.1 When the test specimen is mounted for the test at the termination of the duct system, the static pressure for either forward or reverse flow condiitons shall be measured in the reverberation room. A static pressure tube tap (mounted flush with the reverberation room wall) or a pilot tube shall be used.

A2.3 The actual test set-up for this and other mock-up or specialized tests shall be fully reported in the test report.

A2.3.1 Said report shall also state that the described test is non-standard and the data applicable only to described test item and set-up.

REFERENCES

(**1**) *Manual on Presentation of Data and Control Chart Analysis, ASTM STP 15D,* ASTM, 1976, p. 56 (Table 2).

(**2**) Ingard, U., Oppenheim, A., and Hirschorn, M.," Noise Generation in Ducts," ASHRAE *Transactions*.

(**3**) AMCA 300, "Reverberant Room Method for Sound Testing of Fans," AMCA, 30 W. University Dr., Arlington Heights, IL 60004.

(**4**) Callaway, D. B., and Hirschorn, M., "New Rating Method for Duct Silencers," *Heating, Piping and Air Conditioning*, December 1966.

(**5**) Schultz, T. J., "The Effects of Flow on the Attenuation of Sound in an Absorbent Lined Duct" (Summarized from progress reports through August 1959, submitted to WADD, Dayton, Ohio, by Professor Dr. E. Meyer and his group at III Physikalisches Institute, Universitat Gottingen).

(**6**) Kerka, W. F., "The Attenuation of Sound in Lined Ducts With and Without Air Flow," *Final Report for Completion of Contract 72291*, Bureau of Ships, Department of the Navy.