Standard Test Method for Airflow Calibration of Fan Pressurization Devices[1]

This standard is issued under the fixed designation E1258; 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 airflow measurement calibration techniques for fan pressurization systems used for measuring air leakage rates through building envelopes.

1.2 This test method is applicable to systems used for air leakage measurement as described in Practice E779.

1.3 This test method involves the installation of the fan pressurization system in a calibration chamber. Use of the fan pressurization system in an actual building may introduce additional errors in the airflow measurement due to operator influence, interference of internal partitions and furnishings, weather effects, and other factors.

1.4 The proper use of this test method requires a knowledge of the principles of airflow and pressure measurement.

1.5 This standard includes two basic procedures, a preferred procedure, based on ASHRAE 51/AMCA 210, and an optional procedure based on a nonstandard airflow measurement technique, commonly used by manufacturers of fan pressurization devices, but which has not been compared with standard airflow measurement techniques.

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

1.7 *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]

E631 Terminology of Building Constructions

E779 Test Method for Determining Air Leakage Rate by Fan Pressurization

2.2 *American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard:*[3]

ASHRAE 51/AMCA 210 Laboratory Methods for Testing Fans for Rating

2.3 *American Society of Mechanical Engineers Standard:*[4]

ASME MFC-3M Standard Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi

3. Terminology

3.1 *Definitions*—For definitions used in this test method, see Terminology E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ambient conditions, n*—conditions in the space from which air is drawn into the calibration chamber and into which the chamber air is expelled.

3.2.2 *chamber, n*—an enclosure of rectangular or circular cross section to simulate the entrance and exit conditions that the fan is expected to encounter in service.

3.2.3 *fan air density, n*—density of air at the fan inlet expressed in kilograms per cubic metre.

3.2.4 *fan airflow rate, n*—volumetric airflow rate at the fan air density expressed in cubic metres per second.

3.2.5 *fan outlet area, n*—gross inside area measured in the plane of the fan outlet opening expressed in square metres.

3.2.6 *fan pressure difference, n*—the static pressure difference between two stations expressed in pascals, measured using the static pressure taps described in Fig. 1. One station is located within the chamber between the fan and the nearest flow conditioners. The other station is outside the chamber.

3.2.7 *fan pressurization system, n*—a device for measuring the air leakage rate of a building envelope under controlled pressurization or depressurization of the building interior. The system includes controllable air-moving equipment, an airflow rate measuring system, and a device for measuring the pressure

[1] This test method is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.41 on Air Leakage and Ventilation Performance.

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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 Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

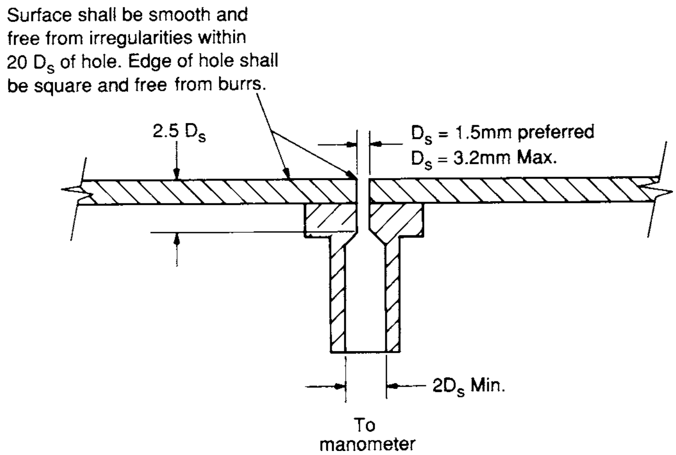


FIG. 1 Static Pressure Tap Specifications

difference across the building envelope. Such a system is often referred to as a blower door.

3.2.8 *fan signal, n*—an output from a fan pressurization system (other than fan speed) that is related to fan airflow rate by the system calibration, such as the static pressure difference across a constriction that is integral to the system.

3.2.9 *fan speed, n*—speed of rotation of the fan impeller expressed in inverse seconds.

3.2.10 *flow conditioners, n*—a combination of screens or perforated plates located within the calibration chamber to reduce pressure disturbances within the chamber.

3.2.11 *nozzle, n*—a gradually tapered constriction, of very precise elliptical shape, used in airflow rate measurement (see Fig. 2).

3.2.12 *nozzle chamber pressure difference, n*—static pressure difference measured across a nozzle or bank of nozzles when nozzles are installed in a chamber expressed in pascals.

3.2.13 *nozzle throat diameter, n*—diameter of nozzle discharge end expressed in square metres.

3.2.14 *nozzle throat pressure difference, n*—static pressure difference across the nozzle in a duct measured with throat taps expressed in pascals (see Fig. 2).

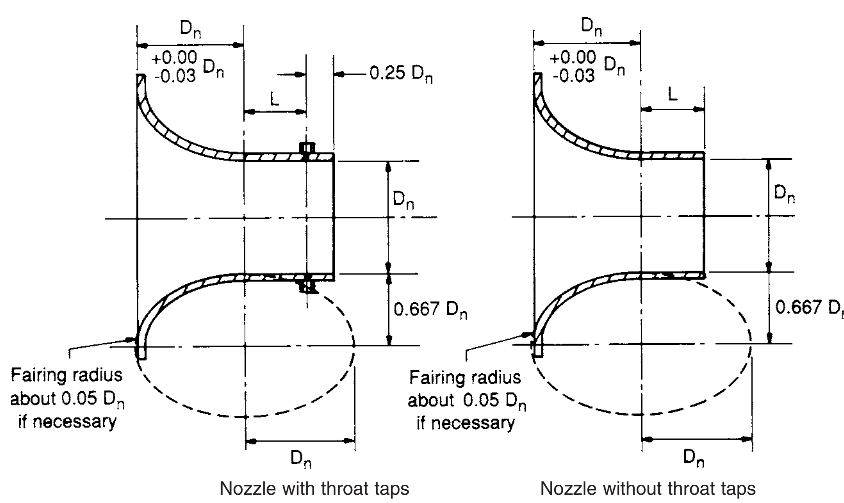
3.2.15 *orifice, n*—a sharp-edged circular constriction used in airflow measurement (see Fig. 3).

3.2.16 *orifice pressure difference, n*—static pressure difference measured across an orifice when the orifice is installed in a chamber expressed in pascals.

3.2.17 *revolution-per-minute (r/min) door, n*—a fan pressurization system with a calibration that relates the fan airflow rate to the fan speed.

3.2.18 *signal door, n*—a fan pressurization system with a calibration that relates the fan airflow rate to an output signal other than fan speed.

3.2.19 *transformation piece, n*—an element to connect a duct with a measuring station to a fan when the fan connection is a different size than the duct (see Fig. 4).



NOTE 1—Nozzle throat dimension L shall be either 0.6 D_n ± 0.005 D_n (recommended) or 0.5 D_n ± 0.005 D_n.

NOTE 2—Nozzle shall have elliptical section as shown. Two and three radii approximations to the elliptical form that do not differ at any point in the normal direction more than 1.5 % D_n from the elliptical form may be used. The outlet edge of the nozzle shall be square, sharp, and free from burrs, nicks, or roundings.

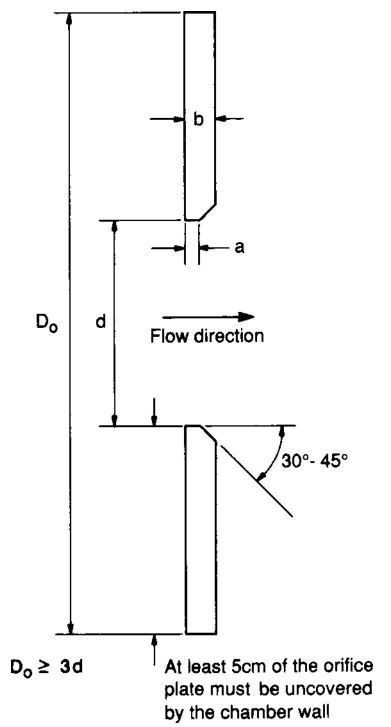
NOTE 3—The nozzle throat shall be measured (to an accuracy of 0.001 D_n) at the minor axis of the ellipse and the nozzle exit. At each place, four diameters, approximately 45° apart must be within ±0.002 D_n of the mean. At the entrance to the throat the mean may be 0.002 D_n greater, but no less than the mean at the nozzle exit.

NOTE 4—The nozzle surface shall fair smoothly so that a straightedge may be rocked over the surface without clicking and the surface waves shall not be greater than 0.001 D_n peak to peak.

NOTE 5—When nozzles are used in a chamber, either of the types shown above may be used. Where a nozzle discharges directly to a duct, nozzles with throat taps shall be used, and the nozzle outlet should be flanged.

NOTE 6—Throat tap nozzles shall have four static pressure taps 90° apart connected to a piezometer ring.

FIG. 2 Nozzle Specifications



Recommended Plate Thickness, *b*
1.5 mm for *d* up to 150 mm
2.5 mm for *d* up to 300 mm
3.2 mm for *d* up to 600 mm
4.5 mm for *d* up to 1200 mm
Recommended Edge Thickness, *a*
Less than 0.02 *d*

NOTE 1—For thin plates ($b < 0.02\ d$), there is no need for beveling the edge of the orifice.

FIG. 3 Sharp-Edged Orifice Design

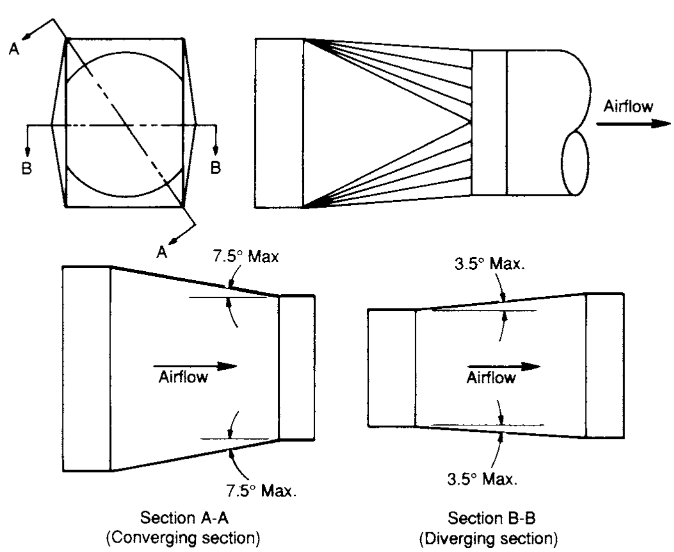


FIG. 4 Transformation Piece

4. Summary of Test Method

4.1 This test method contains two procedures for calibrating fan pressurization devices, a preferred procedure based on ASHRAE 51/AMCA 210, and an optional procedure employing an orifice in a chamber.

4.2 Both procedures involve the installation of the fan pressurization system in a chamber.

4.3 The calibration consists of a comparison of the airflow rate through the fan pressurization system measured by the system itself, and the airflow rate measured in the calibration facility. In the preferred procedure, three modes of airflow measurement are acceptable: (*1*) a nozzle or bank of nozzles in the chamber, (*2*) a traverse in a duct using a pitot tube (see Fig. 5), and (*3*) a nozzle in a duct. Other airflow rate measurement techniques in a duct can be used such as orifice plates (ASME MFC-3M) or constant injection tracer gas methods.[5] In order for an alternative airflow rate measurement technique to be included as a preferred procedure, the errors introduced by the procedure must be demonstrated not to exceed those introduced by a nozzle or pitot traverse. In the optional procedure, the airflow is measured with a series of sharp-edged orifices installed in the wall of the chamber.

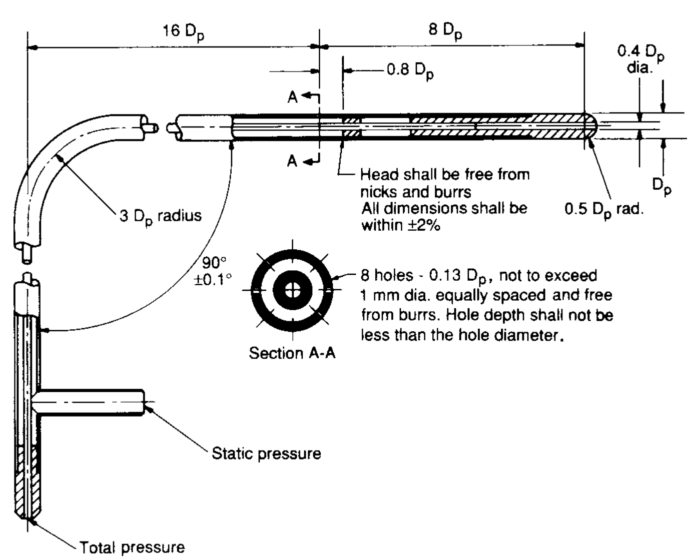
4.4 The calibration must include measurement points that cover a specific range in both fan pressure difference and fan airflow rate.

5. Significance and Use

5.1 The fan pressurization procedure provides a relatively fast evaluation of the airtightness of building envelopes. In order for the accuracy of the test results to be known, the airflow rate measurement technique of the fan pressurization system must be calibrated.

5.2 This test method is applicable to fan pressurization systems that are installed in an opening in the building envelope, as opposed to pressurization techniques involving the mechanical ventilation system of the building.

[5] Persily, A. K., "Air Flow Calibration of Building Pressurization Devices," *NBSIR 84-2849,* National Bureau of Standards, 1984.



NOTE 1—Surface finish shall be 1 µm or better. The static orifices may not exceed 1 mm in diameter. The minimum pitot tube stem diameter recognized under this standard shall be 2.5 mm. In no case shall the stem diameter exceed 1⁄30 of the test duct diameter.

FIG. 5 Pitot Tube Specifications

5.3 The technique of pressurization testing of buildings puts specific requirements on the calibration of fan pressurization systems. The calibration must cover the range of fan pressure differences (approximately 12.5 to 75 Pa) that is induced during pressurization tests. The calibration must also cover a range in fan airflow rates corresponding to the range in building size and airtightness that the fan pressurization system will encounter in the field.

5.4 The fan pressurization system must be calibrated in both directions of airflow used to pressurize and depressurize a building if the system airflow direction is reversible. These two calibrations can be conducted using the various setups described in this test method; however some of the setups can be combined such that a single calibration facility can be used to calibrate the fan in both directions. Such a single setup may involve moving the fan pressurization system from one end of the chamber to the other, reversing the orientation of the system at the same end of the chamber, or it may not require moving the system at all.

5.5 The calibration technique is applicable to the two basic types of fan pressurization systems in use, r/min doors and signal doors.

5.6 For fan pressurization systems that operate in multiple ranges of airflow rate, the system must be calibrated in each range.

5.7 The calibration technique is intended to provide a complete calibration of a fan pressurization system. After calibrating several systems of an identical or similar design, the fan airflow rate may be found to be independent of certain parameters such as fan pressure difference. Other simplifying relations between fan airflow rate and fan speed or fan signal may be observed. If these relations are observed, a manufacturer or other calibrator may choose to simplify the calibration procedure by reducing the number of calibration points.

5.8 The use of fan pressurization systems in actual buildings introduces additional factors that may cause errors in the airflow rate measurement that are not accounted for by the calibration. These factors include operator and weather effects and interference from internal partitions and other obstructions.

6. Hazards

6.1 Provide secure guards and cages for fans and motors to prevent accidental contact with any moving parts of the equipment.

6.2 When the calibration is being conducted, a large volume of air is being drawn into and forced out of the apparatus. Exercise care to prevent any objects from being knocked down or blown around the test area.

6.3 Noise may be generated by the moving air. Make hearing protection equipment available for personnel involved in the testing.

6.4 Design the ducts, chamber, and other equipment utilized to withstand the pressure and other forces to be encountered.

7. Apparatus

7.1 The calibration facility must include the following components:

7.1.1 *Preferred Procedure:*

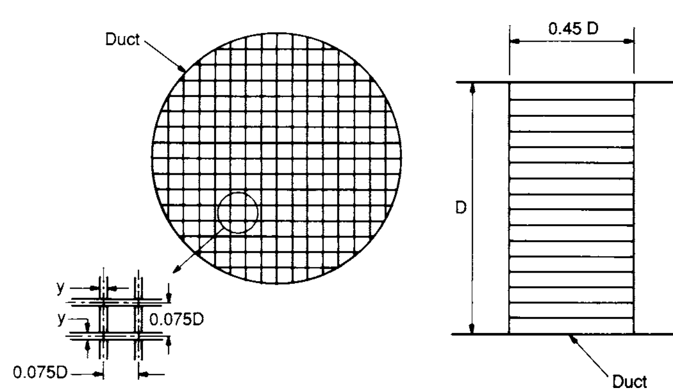
7.1.1.1 *Chamber*—An enclosure of rectangular or circular cross section with characteristic dimension, *M*. In the case of a rectangular cross section, the height *H* shall be at least 2.1 m, the width *W* shall be at least 2.4 m, and *M* is given by $\sqrt{4HW/\pi}$. In the case of a circular cross section, the chamber diameter shall be at least 2.5 m and *M* is equal to the chamber diameter. When multiple nozzles are used in a chamber, the chamber must be large enough to accommodate all the nozzles as described in 7.1.2.1 and 7.1.2.2.

7.1.1.2 *Flow Conditioners*—A combination of screens or perforated plates located in the chamber to reduce pressure disturbances within the enclosure. These air to be located within the chamber in accordance with 7.1.2. Where a measuring plane is located downstream of the flow conditioners, the flow conditioners are provided to ensure a substantially uniform flow ahead of the measuring plane. Where a measuring plane is located upstream of the flow conditioners, the purpose of these screens is to absorb some of the kinetic energy of the upstream jet, and allow its normal expansion as if in an unconfined space. Screens of square-mesh round wire with open areas of 50 to 60 % are suggested and several will usually be needed. Any combination of screens or perforated plates that provide this flow conditioning may be used.

7.1.1.3 *Airflow Rate Measurement System,* for measuring the fan airflow rate. Acceptable systems include a nozzle or bank of nozzles within the chamber, a nozzle in a duct, or a pitot traverse in a duct in accordance with 7.1.2.

7.1.1.4 *Flow Straighteners,* for straightening the flow upstream of the measuring stations when the airflow rate measurement system uses a nozzle in a duct or a pitot traverse in a duct. The downstream plane of the straightener shall be located between 5 and 5.25 duct diameters upstream of the plane of the pitot traverse or nozzle. A recommended form for the straightener is shown in Fig. 6. The dimension *D* is the inside diameter of the duct. The dimension *y*, which is the thickness of the straightener elements, shall not exceed 0.005 *D*.

7.1.1.5 *Variable Supply/Exhaust System*—A controllable fan or throttling device to enable variation in the fan pressure difference at a particular airflow rate.



NOTE 1—All Dimensions shall be within ±0.005 *D* except *y* which shall not exceed 0.005 *D*.

FIG. 6 Flow Straightener Specifications

7.1.1.6 *Pressure Difference Measuring Device,* for measuring the fan pressure difference, and if applicable the nozzle chamber or nozzle throat pressure difference, with a maximum error of 1 % of the maximum observed reading or 1.25 Pa, whichever is greater.

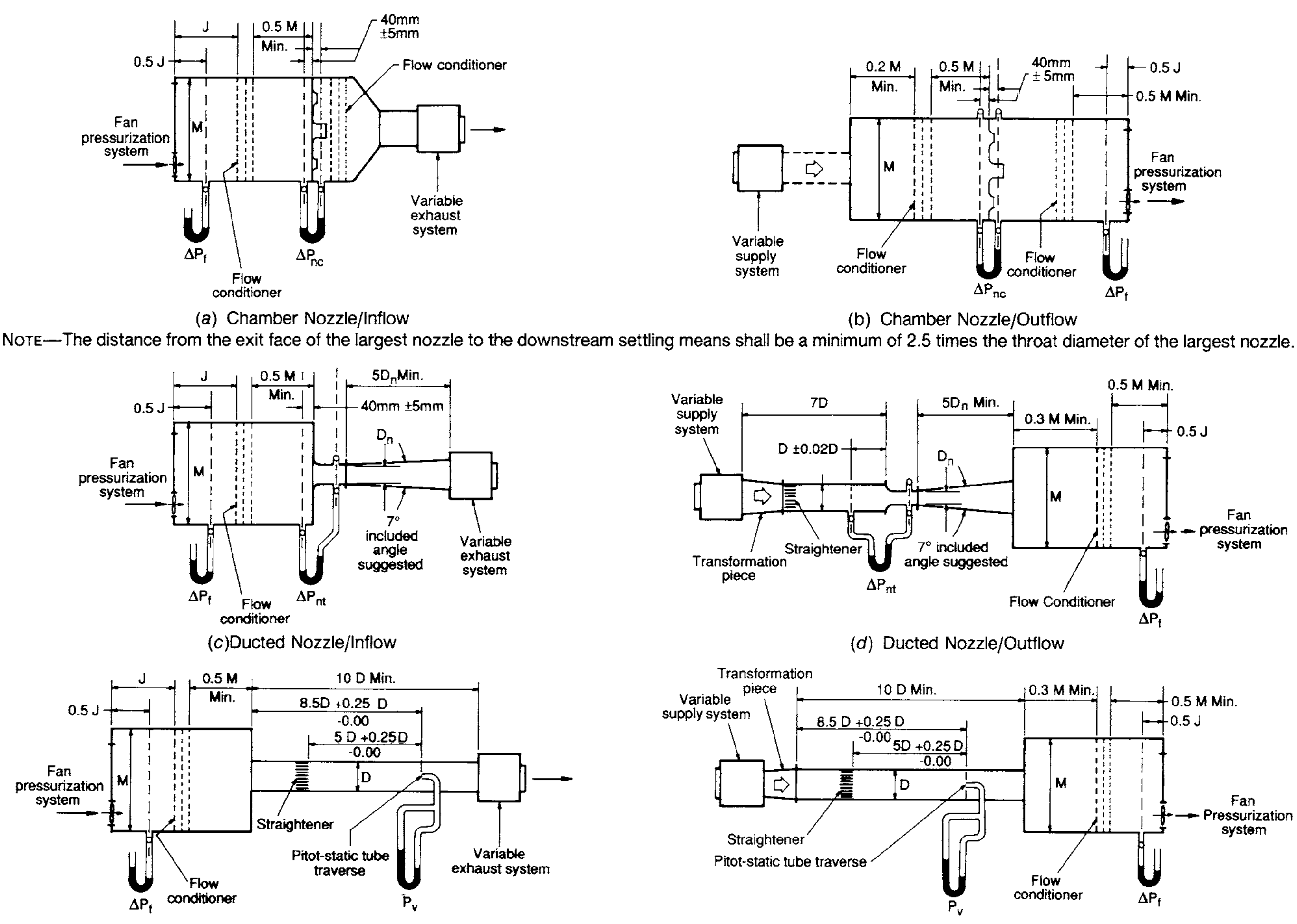
7.1.1.7 *Temperature Measuring Devices,* to measure dry-bulb temperatures within an accuracy of ±1°C.

7.1.1.8 *Barometric Pressure Measuring Device,* for measuring the barometric pressure within an accuracy of ±200 Pa.

7.1.2 *Calibration Setups*—The six basic calibration setups are described in 7.1.2.1-7.1.2.6 and shown in Fig. 7 *(a)* through Fig. 7 *(f)* (adapted from ASHRAE 51/AMCA 210). These setups are of two basic types: inflow and outflow. In the inflow setups, the fan pressurization system forces air into the chamber. In the outflow setups, the system pulls air out of the chamber. In all cases there must be a minimum distance of 2*M* between the fan pressurization system inlet and outlet and the nearest wall or other vertical obstruction.

7.1.2.1 *Chamber Nozzle/Inflow*—The airflow rate measurement station consists of a nozzle or bank of nozzles within the chamber with flow conditioners on either side. Multiple nozzles shall be located as symmetrically in the measurement plane as possible. The centerline of each nozzle shall be at least 1.5 times the nozzle throat diameter from the chamber wall. The minimum distance between centers of any two nozzles in simultaneous use shall be three times the throat diameter of the larger nozzle. The fan pressurization system is in the inlet wall and a variable exhaust system is located in the outlet (see Fig. 7 (*a*)).

7.1.2.2 *Chamber Nozzle/Outflow*—The setup is basically the same as that in 7.1.3 with the locations of the fan pressurization system and the variable exhaust (now supply) system reversed. Multiple nozzles shall be located as symmetrically as possible. The centerline of each nozzle shall be at least 1.5 times the nozzle throat diameter from the chamber wall. The minimum distance between centers of any two nozzles in simultaneous



J ≥ 2 × fan outlet diameter
ΔP_{nt} = nozzle throat pressure difference
ΔP_f = fan pressure difference
ΔP_{nc} = nozzle chamber pressure difference
D = duct diameter
D_n = nozzle throat diameter
M = $\sqrt{4 \times \text{chamber height} \times \text{chamber width}/\pi}$ (rectangular cross section)
M = chamber diameter (circular cross section)

FIG. 7 Calibration Setups for the Fan Pressurization System—Preferred Procedure

use shall be three times the throat diameter of the larger nozzle, with flow conditioners on either side (see Fig. 7 (*b*)).

7.1.2.3 *Ducted Nozzle/Inflow*—The airflow rate measurement station is a ducted nozzle at the end of the chamber. One set of flow conditioners is required in the chamber. The variable exhaust system is located downstream of the measurement station (see Fig. 7 (*c*)).

7.1.2.4 *Ducted Nozzle/Outflow*—The airflow rate measurement station is a ducted nozzle in the inlet to the chamber. One set of flow conditioners is required in the chamber, along with flow straighteners upstream of the nozzle. The variable supply system is located upstream of the measurement duct. A transformation piece may be required between the supply system and the duct. The ratio of the nozzle throat diameter to the diameter of the inlet duct shall not exceed 0.5 (see Fig. 7 (*d*)).

7.1.2.5 *Pitot Traverse/Inflow*—The airflow rate measurement station is a pitot traverse in an outlet duct. One set of flow conditioners is required in the chamber. A set of flow straighteners is required between the chamber outlet and the measurement station. The variable exhaust system is located downstream of the measurement station (see Fig. 7 (*e*)).

7.1.2.6 *Pitot Traverse/Outflow*—The airflow rate measurement station is a pitot traverse in an inlet duct. One set of flow conditioners is required in the chamber. The variable supply system is located upstream of the measurement station. A set of flow straighteners is required between the variable supply system and the measurement station. A transformation piece may be required between the supply system and the duct. The axes of the fan opening and the duct shall coincide (see Fig. 7 (*f*)).

7.1.3 *Optional Procedure:*

7.1.3.1 *Chamber*—An enclosure of rectangular cross section with characteristic dimension *M*. The height *H* shall be at least 2.1 m, the width *W* shall be at least 2.4 m, and *M* is given by $\sqrt{4HW/\pi}$.

7.1.3.2 *Flow Conditioners,* in accordance with 7.1.1.2 except that the perforated plates are located in the chamber to provide proper flow patterns within the enclosure. These are to be located within the chamber in accordance with 7.1.4.

7.1.3.3 *Orifice Plates*—A series of sharp-edged orifices for installation in the calibration chamber as described in 4.3. Recommended specifications for the orifice plates are given in Fig. 3. The primary considerations in designing the orifice plate is that the edge is smooth and circular, and that the plate is thick enough not to deform.

7.1.3.4 *Pressure Difference Measuring Device,* for measuring the fan pressure difference and the orifice pressure difference, with a maximum error of 1 % of the maximum observed reading or 1.25 Pa whichever is greater.

7.1.3.5 *Temperature Measuring Devices,* in accordance with 7.1.1.7.

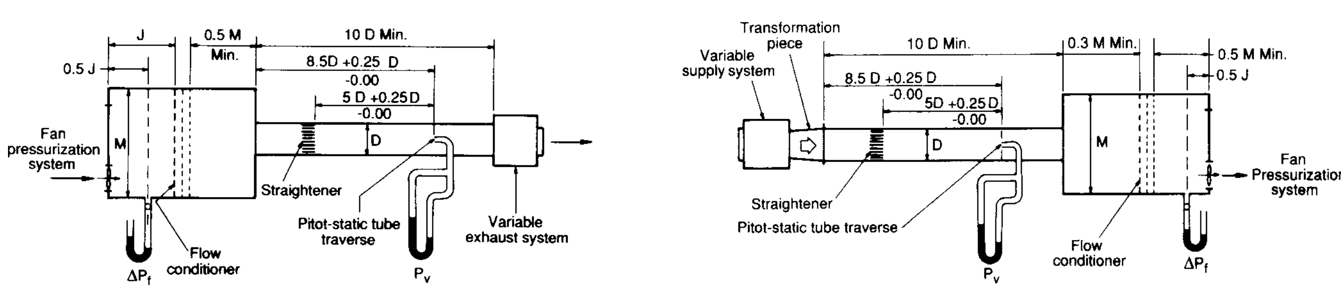
7.1.3.6 *Barometric Pressure Measuring Device,* in accordance with 7.1.1.8.

7.1.4 *Calibration Setups*—The calibration setups are shown in Fig. 8 *(a)* and Fig. 8 *(b).* In all cases there must be a minimum distance of 2*M* from the nearest wall or fixed obstruction to the fan pressurization system inlet or outlet, as well as to the orifice. In addition, there must be a minimum clearance of *M*/4 on the top and sides of the chamber to allow airflow from the orifice back to the fan inlet. In the inflow setup, the fan pressurization system is located at the chamber inlet and the orifice is at the outlet. In the outflow setup, the locations of the fan pressurization system and the orifice are reversed. In both setups there are flow conditioners located within the chamber. A single facility may be used to conduct both inflow and outflow calibrations as long as all other requirements are met. When installing the orifice, the airflow must impinge on the leading edge of the orifice. The upstream face of the orifice plate must be flush with the inside wall of the chamber. The downstream face of the orifice plate must be uncovered except for no more than 5 cm of the outer perimeter (see Fig. 3).

8. Preparation of Apparatus

8.1 Install the fan pressurization system in the chamber as it would be during an air leakage measurement in a building. Any appurtenance that is considered a part of the fan pressurization system shall be in place during the calibration.

8.2 Sufficiently tighten all joints in the chamber and associated ductwork such that the leakage rate at 50 Pa is less than 3 % of the minimum airflow rate induced at 50 Pa during the calibration. Conduct the leakage measurement as follows:



(*a*) Chamber Orifice/Inflow (*b*) Chamber Orifice/Outflow

J = 2 × fan outlet diameter
ΔP_f = fan pressure difference
ΔP_o = orifice pressure difference
$M = \sqrt{4 \times \text{chamber height} \times \text{chamber width}/_{\pi}}$ (rectangular cross section)
M = chamber diameter (circular cross section)

FIG. 8 Calibration Setups for the Fan Pressurization System—Optional Method

8.2.1 Install the fan pressurization system in the chamber in the manner in which it will be calibrated.

8.2.2 In the inflow modes seal the fan inlet. In the outflow modes seal the fan outlet.

8.2.3 Using an auxiliary fan located at the opposite end of the chamber as the fan pressurization system (such as the variable supply/exhaust system), pressurize the chamber to 50 Pa. Because of the low airflow rates associated with this chamber leakage test, the airflow rate measurement device used in the calibration will generally not be appropriate for use in the leakage test and some other device must be used. The airflow rate required to induce this pressure difference must be measured with an accuracy of ±10 %.

9. Procedure

9.1 Calibrate the fan pressurization system in both directions of airflow used to pressurize or depressurize a building, unless the system is constructed such that operation is possible in only one direction (see 5.4). Calibrate the system in each airflow rate range if it has multiple ranges.

9.2 *Calibration Points*—The number of calibration points in each airflow direction, corresponding to building pressurization and depressurization, must satisfy the following requirements:

9.2.1 Obtain calibration points at fan pressure differences of 12.5, 25, 37.5, 50, 62.5, and 75 Pa.

9.2.2 The fan airflow rates at each fan pressure difference need cover only a recommended range, dependent on the fan pressure difference. If the recommended minimum cannot be reached by the fan pressurization system, the minimum airflow rate shall be the lowest rate that the system can induce in a stable manner. Similarly, if the recommended maximum rate cannot be reached, the maximum airflow rate shall be the largest rate that the system can induce in a stable manner. Of course, the calibration can cover wider ranges of airflow rate.

9.2.2.1 For each fan pressure difference the recommended fan airflow rates are as follows:

Minimum		Maximum	
Pa	*m^3/s*	*Pa*	*m^3/s*
12.5	(0.070)	12.5	(0.760)
25.0	(0.095)	25.0	(1.200)
37.5	(0.120)	37.5	(1.555)
50.0	(0.140)	50.0	(1.875)
62.5	(0.165)	62.5	(2.020)
75.0	(0.190)	75.0	(2.440)

9.2.3 At each fan pressure difference the number of airflow measurement points required to establish the fan performance will depend on the shape of the curve relating fan airflow rate to fan speed (r/min doors) or fan signal (signal doors). For smooth characteristic curves, obtain at least eight calibration points at the six fan pressure differences specified in 9.2.1. Additional calibration points may be required to define curves that are not smooth.

9.2.4 The various combinations of fan pressure difference and fan airflow rate are obtained as follows:

9.2.4.1 *Preferred Procedure*—By varying the fan airflow rate induced by the fan pressurization system and modulating the variable exhaust/supply system.

9.2.4.2 *Optional Procedure*—By varying the fan airflow rate induced by the fan pressurization system and changing the size of the orifice plate in the chamber.

9.2.5 As the airflow rates are varied the following adjustments must be made:

9.2.5.1 In the preferred procedure the airflow measurement system must be adjusted. In the case of a single nozzle in a duct or chamber, this requires changing the nozzle size. In the case of a bank of nozzles, this requires covering and uncovering individual nozzles. The suitability of a given nozzle is a function of the Reynolds number based on the nozzle exit diameter. For any nozzle to be used, this Reynolds number must be 12 000 or greater. In the case of airflow rate measurement with a pitot tube, select the duct diameter to maintain the average duct velocity within a range from 3 to 50 m/s.

9.2.5.2 In the optional procedure it will become necessary to change the size of the orifice plates in the chamber wall. The appropriateness of a given orifice plate is a function of the Reynolds number based on the orifice diameter. For any orifice plate to be used, this Reynolds number must be 2×10^4 or greater. To obtain eight calibration points at each fan pressure difference, eight different orifice plates are required. Based on the minimum and maximum recommended airflow rates in 15.2.2.1, the minimum orifice diameter would be about 0.18 m and the maximum about 0.65 m. Multiple orifices may be used simultaneously, located as symmetrically as possible in the measurement plane. The centerline of each orifice shall be at least 1.5 times the orifice diameter from the chamber wall. The minimum distance between the centers of any two orifices in simultaneous use should be three times the diameter of the larger orifice.

9.2.6 Establish equilibrium conditions at each calibration point. To test for equilibrium, make trial observations until steady readings are obtained. Consider steady conditions to exist when successive readings yield a value of the 95 % confidence interval (2 % or less) of the mean.

9.3 Record the following information:

9.3.1 Record test data for each calibration point and make the readings simultaneously if possible. In all cases the test data must include ambient barometric pressure, dry-bulb temperature, and fan pressure difference at the fan inlet.

9.3.2 For r/min doors record the fan speed at each calibration point. For signal doors record the fan signal.

9.3.3 *Preferred Procedure:*

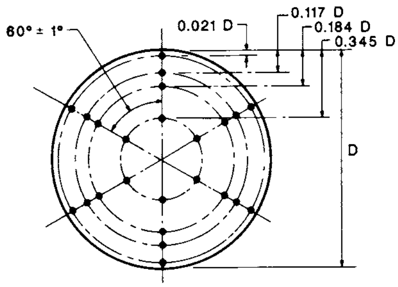
9.3.3.1 *Airflow Rate Measurement Using Nozzles in a Chamber or Duct*—Record the nozzle throat or nozzle chamber pressure difference. Also record the throat diameter of the nozzles in use, and the duct diameter, if applicable.

9.3.3.2 *Airflow Rate Measurement Using a Pitot Traverse in a Duct*—Record the velocity pressure at each of the 24 points in the traverse shown in Fig. 9. Also record the duct diameter.

9.3.4 *Optional Procedure*—Record the diameter of the orifice in use and the orifice pressure difference.

10. Calculation

10.1 *Preferred Procedure*—Convert all test data to airflow rates in units of cubic metres per second at the fan inlet conditions as follows:



NOTE 1—All pitot positions are ±0.0025 *D* relative to inside duct walls.

NOTE 2—*D* is the average of four measurements at traverse plane at 45° angles measured to accuracy of 0.2 % *D*. Traverse duct shall be round within 0.5 % *D* at traverse plane and for a distance of 0.5 *D* on either side of traverse plane.

FIG. 9 Pitot Traverse Points

10.1.1 *For a Nozzle or Bank of Nozzles*—Calculate the airflow rate as follows from the nozzle throat pressure difference ΔP_{nt} or the nozzle chamber pressure difference ΔP_{nc}, respectively.

10.1.1.1 Calculate the Reynolds number *Re* based on the nozzle throat diameter D_n as follows:

$$Re = 70\,900\,D_n\sqrt{\Delta P\rho/(1-\beta^4)}$$

where ρ = fan air density, kg/m^3.

In the case of a nozzle in a duct, ΔP is the nozzle throat pressure difference in pascals and β is the ratio of the nozzle exit diameter to the approach duct diameter. In the case of a nozzle in a chamber, ΔP is the nozzle chamber pressure difference and β is zero.

10.1.1.2 Calculate the nozzle discharge coefficient *C* as follows:

Nozzles with $L/D_n = 0.6$:

$$C = 0.9986 - 7.006/\sqrt{Re} + 134.6/Re$$

Nozzles with $L/D_n = 0.5$:

$$C = 0.9986 - 6.688/\sqrt{Re} + 131.5/Re$$

where *L* = nozzle throat dimension as shown in Fig. 2.

10.1.1.3 Calculate the airflow rate at the entrance to the nozzle Q_n as follows:

$$Q_n = \left[C\pi D_n^2/\sqrt{1-1.043\beta^4}\right]\sqrt{2\Delta P/\rho}$$

For a bank of nozzles, calculate Q_n for each nozzle and add the airflow rates together.

10.1.2 *For a Pitot Traverse*—Calculate the airflow rate from the individual velocity pressure measurements P_{vi} taken during the pitot traverse at the 24 traverse points.

10.1.2.1 Calculate the velocity pressure P_v corresponding to the average velocity from the individual measurements P_{vi} as follows:

$$P_v = \left[\Sigma\sqrt{P_{vi}}/24\right]^2$$

10.1.2.2 Calculate the average velocity at the plane of traverse V_t from the fan air density and the corresponding velocity pressure P_v as follows:

$$V_t = \sqrt{2P_v/\rho}$$

10.1.2.3 Calculate the airflow rate *Q* from the velocity V_t and the traverse duct diameter D_t as follows:

$$Q = V_t\pi D_t^2/4$$

10.1.3 Continue in accordance with 10.3 through 10.6.

10.2 *Optional Procedure:*

10.2.1 Calculate the airflow rate at the entrance to the orifice Q_o as follows:

$$Q_o = (0.61\,D_o^2/4)\sqrt{2\Delta P_o/\rho}$$

where:

D_o = orifice diameter,
P_o = orifice pressure difference, and
ρ = fan air density.

10.2.2 Continue in accordance with 10.3 through 10.6.

10.3 Plot the fan airflow rate against the fan speed (r/min doors) or the fan signal (signal doors), distinguishing between the different values of fan pressure differences ΔP_f.

10.4 Nondimensionalize the calibration data for r/min doors as follows:

$$Q' = Q/NA^{1.5}$$

$$P' = \Delta P_f/\rho N^2 A$$

where:

Q = airflow rate at the fan inlet, m^3/s,
N = fan speed, s^{-1},
A = fan outlet area, m^2,
ΔP_f = fan pressure difference, Pa, and
ρ = air density at the fan inlet.

When this nondimensionalization is used, plot *Q*' against *P*'.

10.5 Fit curves of appropriate form to the plotted data where the dependent variable is *Q* and the independent variable is fan speed or fan signal, as appropriate, for each value of the fan pressure difference. If the data are nondimensionalized, fit curves where *Q'* is the dependent variable and *P'* is the independent variable. If the plots exhibit significant changes in shape, it may be necessary to fit separate curves for specific ranges of the calibration data.

10.6 For each curve, determine the 95 % confidence interval estimates for the line as a whole.

11. Report

11.1 Report the following general information:

11.1.1 Date of calibration;

11.1.2 Name and location of laboratory conducting the calibration;

11.1.3 Fan pressurization system model number;

11.1.4 Complete description of the calibration setup;

11.1.5 Names, model numbers, serial numbers, and calibration information of all instruments used; and

11.1.6 Manufacturer's calibration, if available.

11.2 *Calibration Points*—For each calibration point report the following information:

11.2.1 Ambient barometric pressure,

11.2.2 Dry-bulb temperature at fan inlet,

11.2.3 Airflow rate range (if system has multiple ranges),

11.2.4 Fan pressure difference,

11.2.5 Fan speed (r/min doors only),

11.2.6 Fan signal (signal doors only), and

11.2.7 *Preferred Procedure—Airflow Rate Measurement:*

11.2.7.1 For pitot tube airflow rate measurement:

(1) Velocity pressure at each pitot traverse point, and

(2) Duct diameter.

11.2.7.2 For ducted nozzle airflow rate measurement:

(1) Nozzle pressure difference,

(2) Duct diameter, and

(3) Nozzle throat diameter.

11.2.7.3 For chamber nozzle airflow rate measurement:

(1) Throat diameters of open nozzles, and

(2) Nozzle pressure difference.

11.2.7.4 Calculated fan airflow rate.

11.2.8 *Optional Procedure—Airflow Rate Measurement:*

11.2.8.1 Orifice pressure difference,

11.2.8.2 Orifice diameter, and

11.2.8.3 Calculated fan airflow rate.

11.2.9 Nondimensionalized fan airflow rate Q' and nondimensionalized pressure difference P' (r/min doors only),

11.2.10 Plot of fan airflow rate against fan speed for each fan pressure difference (r/min doors only),

11.2.11 Plot of nondimensionalized airflow rate Q' against nondimensionalized pressure difference P' (r/min doors only),

11.2.12 Plot of fan airflow rate against fan signal for each fan pressure difference (signal doors only),

11.2.13 Equations of curve fits to calibration data along with ranges of airflow rates included in each curve fit, and

11.2.14 Estimates of 95 % confidence interval for each curve fit as a whole.

12. Precision and Bias

12.1 *Precision*—It is not practicable to specify the precision of the preferred procedure or the optional procedure in this test method for calibrating fan pressurization systems because neither the within-laboratory repeatability nor the between-laboratory reproducibility of the test method have been determined. However, the pitot tubes and nozzles used in the preferred procedure are considered primary instruments and need not be calibrated provided that they are maintained and employed in the specified conditions.

12.2 *Bias*—No justifiable statement can be made on the bias of the preferred procedure or the optional procedure in this test method for calibrating fan pressurization systems because no experiments have been conducted to determine this bias.

12.3 The preferred procedure in this test method is based in large part on ASHRAE 51/AMCA 210 which is the product of many years of research, experimentation, and committee effort, and therefore it is presented as the preferred procedure for calibrating fan pressurization devices.

12.4 Airflow rate measurement employing orifices in a chamber wall is not a standard airflow rate measurement technique and there have been no empirical studies of its precision or bias, therefore it is presented as an optional procedure for calibrating fan pressurization devices.

13. Keywords

13.1 air-leakage measurement; airflow calibration; airflow measurement; building envelopes; fan depressurization devices