Designation: E 1554 – 9403

An American National Standard

Standard Test Methods for Determining External Air Leakage of Air Distribution Systems by Fan Pressurization[1]

This standard is issued under the fixed designation E 1554; 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 These test methods cover two techniques for measuring the air leakage of the sections of air distribution systems that pass outside the conditioned space in low-rise residential and small low-rise commercial buildings. Both techniques use air flow and pressure measurements to determine the leakage characteristics, and include separate measurements of the supply-side and the return-side distribution system leakage.

1.2 These test methods also specify the auxiliary measurements needed to characterize the magnitude of the distribution system air leakage during normal operation (a measurement of pressure differentials across duct leaks during normal distribution-system operation), and to normalize the distribution system's air leakage by the total recirculating air flow induced by the distribution-system air handler fan.

1.3 The air-leakage measurement portion of these test methods is applicable to small temperature differentials and low wind pressures; the uncertainty in the measured results increase with increasing wind speeds and temperature differentials.

1.4 The proper use of these test methods requires a knowledge of the principles of air flow and pressure measurements.

1.54 These test methods are intended to produce a measure of the air tightness leakage between an air distribution system and its surroundings exterior to the conditioned space of a building.

1.65 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.76 *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.* For specific hazard statements, see Section 7.

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[1] These test methods are under the jurisdiction of ASTM Committee E-6 E06 on Performance of Buildings and are the direct responsibility of Subcommittee E06.41 on Air Leakage and Ventilation.

Current edition approved Jan. 15, 1994. Dec. 1, 2003. Published April 1994. January 2004. Originally published as E 1554 – 93. approved in 1993. Last previous edition approved in 1994 as E 1554 – 934.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 631 Terminology of Building Constructions

E 741 Test Method~~s~~ for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution

E 779 Test Method for Determining Air Leakage Rate by Fan Pressurization

E 1258 Test Method for Airflow Calibration of Fan Pressurization Devices

2.2 *ASME Standard:*

MFC-3M Measurement of Fluid Flow in Pipes Using Orifice Nozzle and Venturi[3]

3. Terminology

3.1 *Definitions*—Refer to Terminology E 631 for definitions of other terms used in these test methods.

3.1.1 *air handler fan*—the air moving fan for the distribution system located in the air-handling unit.

3.1.2 *air-handling unit*—the distribution-system fan and portion of the distribution system that is integral to the furnace, air-conditioner, or heat-pump.

~~3.3 *air-leakage rate*—the volume of air movement per unit time across the building envelope or the exterior envelope of the air distribution system.~~

~~3.3.1 *Discussion*—This movement includes flow through joints, cracks, and porous surfaces, or combinations thereof. The driving forces for such air leakage in service can be mechanical pressurization and depressurization, natural wind pressures, and air temperature differentials between the building interior and the outdoors.~~

~~3.4~~

3.1.3 *building envelope*—the boundary or barrier separating the interior volume of a building from the outside environment.

~~3.5 *building pressure difference*~~

3.1.4 *conditioned space*—the ~~pressure difference across the building envelope, expressed in pascals (inches~~ portion of ~~water, pounds-force per square foot, or inches of mercury).~~

~~3.6 *distribution-system pressure difference*—the pressure difference across the exterior air-distribution envelope, expressed in pascals (inches of water, pounds-force per square foot, or inches of mercury).~~

~~3.7 *exterior air-distribution envelope*— the boundary or barrier separating the interior volume of the~~ a building whose air ~~distribution system from the outside environment~~ temperature or ~~unconditioned spaces.~~

~~3.7.1 *Discussion*—For the purpose of these test methods, the interior volume~~ humidity is ~~the deliberately conditioned space within a building, generally not including the attic space, basement space, and attached structures, unless such spaces are part of the heating and air conditioning system, such as a crawl space that acts as a plenum.~~

~~3.8 *unconditioned space*—any space that is not~~ intentionally ~~heated or cooled~~ controlled for human ~~occupancy, including attics, crawlspaces, unfinished basements, attached structures (such as a garage), or any space completely outside the building envelope (for example, rooftop ductwork on small commercial buildings).~~ occupancy.

4. Summary of Test Methods

~~4.1 These test methods consist of mechanical pressurization and depressurization of an air distribution system and the conditioned space of the building through which it passes, during which measurements of air flow rates are made over a range of pressure differentials between the distribution system and its surroundings outside the conditioned portion of the building. From the relationship between the measured air flow rates and pressure differences, the external air leakage characteristics of the supply and return sides of the air distribution system are separately evaluated.~~

~~4.2 Two~~

4.1 Two alternative measurement and analysis procedures are specified. The first of these techniques, Test Method A, is based upon ~~comparisons of the air leakage rates from three fan pressurization tests: with the entire distribution system~~ changes in ~~good communication with the building, with the return side of the~~ flow through distribution system leaks at fixed envelope pressure differences due to air handler operation. The envelope pressure differences are generated by a separate air moving fan, both pressurization and ~~the supply side, and with the entire distribution system sealed from the building.~~ depressurization measurements are performed. The second technique, Test Method B, is based upon ~~two fan pressurization tests utilizing direct measurement of distribution-system leakage flows: with all but one supply register sealed, and with all but one return register sealed. Both tests in Test Method B are conducted with~~ pressurizing the ~~supply side sealed from the return side~~ distribution system at the same time as the house in order to isolate the leaks that are outside the building envelope. Measured system operating pressures are then used to estimate leakage under operating conditions. Test ~~Methods A and~~ Method B ~~are~~ is shown schematically in Fig~~s~~. 1 ~~and 2, respectively.~~

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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*~~, Vol 04.11.~~ volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Mechanical ~~Engineers, 345 E. 47th St.,~~ Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 1001~~7~~6-5990.

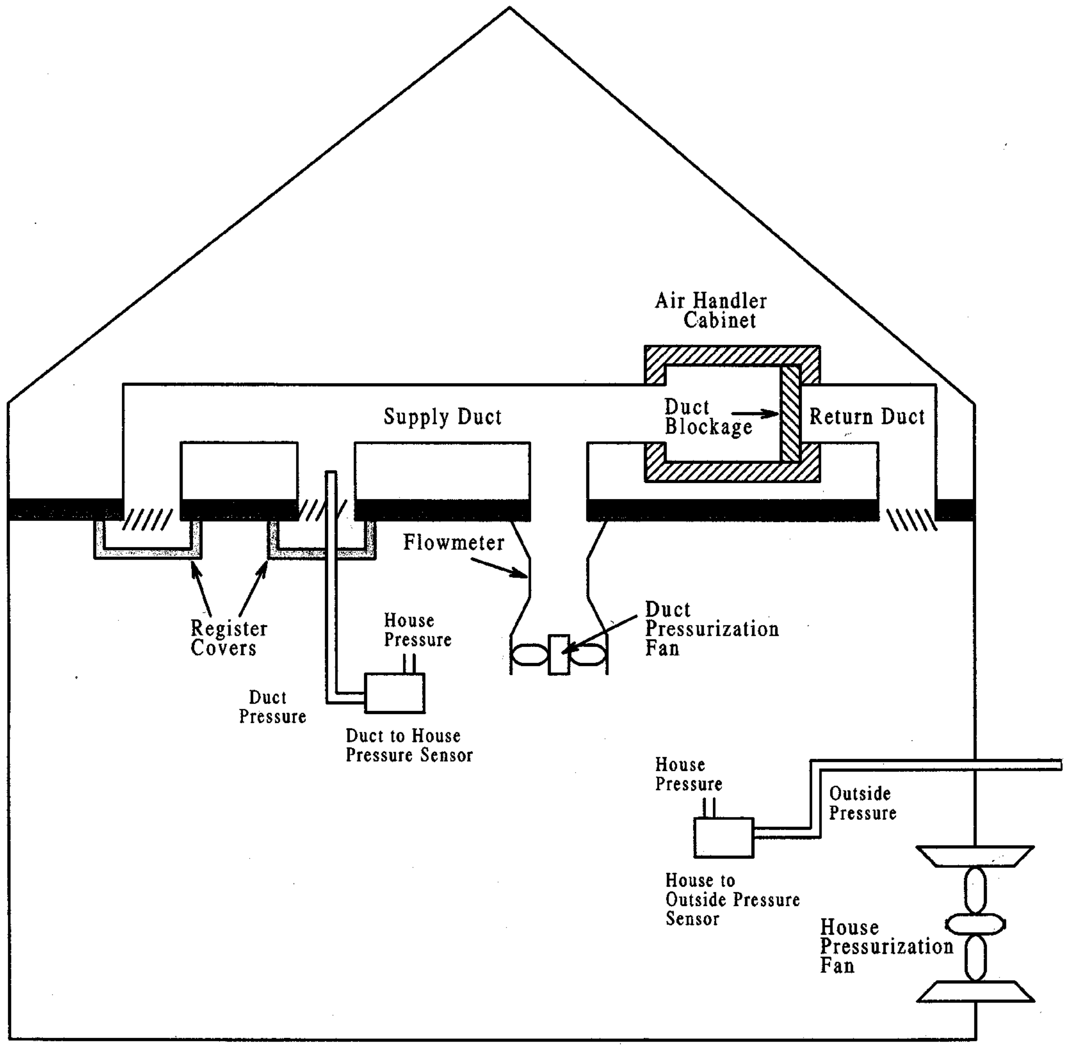

FIG. 1 Schematic of Method B—Duct Pressurization Test (for Supply Leakage)

4.3 These.

4.2 These test methods also include specifications for the auxiliary measurements to interpret the air leakage measurements. These include measurement of the pressures that drive distribution-system air leakage during normal system operation and measurement of the recirculating flow through the distribution system. The former involves measurement of the characteristic pressures across the distribution-system surface, and the latter involves measurement of the airflow into the return grill(es) with only the distribution-system air handler fan in operation. flow.

5. Significance and Use

5.1 Air leakage between an air distribution system and unconditioned spaces affects the energy losses from the distribution system, the ventilation rate of the building, and potentially the entry rate of various air pollutants.

5.2 The determination of infiltration energy loads and ventilation rates of residences and small commercial buildings are typically based on the assumption that the principal driving forces for infiltration and ventilation are the wind and indoor/outdoor temperature differences. This can be an inappropriate assumption for buildings that have distribution systems that pass through unconditioned spaces, because the existence of relatively modest leakage from that system has a relatively large impact on overall ventilation rates. The air leakage characteristics of these exterior distribution systems are needed to determine their ventilation, energy, and pollutant-entry implications.

5.3 Air leakage through the exterior air distribution systems envelope may be treated in the same manner as air leakage in the building envelope as long as the system is not operating (see Test Method E 779). However, when the distribution-system air handler fan is turned on, the pressures across the air distribution-system leaks are significantly larger than those driving natural infiltration, thereby inducing much larger flows. Thus, it is important to be able to isolate these leaks from building envelope leaks. Also, due Due to the different impacts of supply-side and return-side distribution-system leaks, these two air leakage pathways

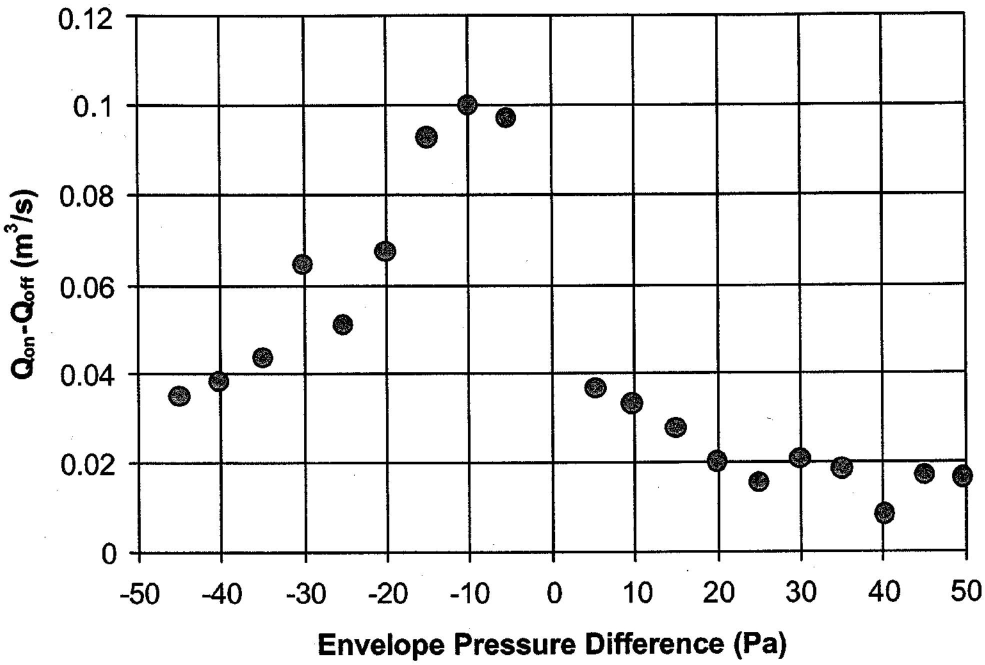

FIG. 2 Example of Air-Flow Difference and Envelope Pressure Plot for Test Method A

shall be measured separately. The leakage of air distribution systems must be measured in the field, because it has been shown that workmanship is often more important than design in determining the leakage of these systems. ~~Also,~~ In addition, it is important to distinguish leaks to the conditioned parts of a building from leaks to the outside.

5.4 As an alternative to the ~~fan pressurization method,~~ test methods in this standard, air infiltration with and without an air distribution system operating may be measured directly using the tracer dilution method (see Test Method E 741). The ~~fan pressurization method provides~~ test methods described in this standard provide an indirect way to relate the infiltration rate to the leakage of the building and the air distribution system.

5.5 ~~T~~Combined with the fan pressurization method for measuring envelope leakage (Test Method E 779) ~~and the fan pressurization method for measuring the external leakage of air distribution systems have~~ there are several advantages over the tracer dilution method. The ~~fan pressurization method produces~~ methods described in this standard produce results that characterize the air tightness of the building envelope and the air distribution systems. The ~~fan pressurization method for measuring the external leakage of air distribution systems is used:~~ methods described in this standard are used to compare the relative air ~~tightness~~ leakage of several similar air distribution systems, to identify the leakage sources and rates of leakage from different components of an air distribution system, and to determine the air leakage reduction for individual retrofit measures applied incrementally ~~on~~ to an existing air distribution system.

6. Apparatus

6.1 The following description of apparatus is general in nature. Any arrangement of equipment using the same principles and capable of performing the test procedure within the allowable tolerances is permitted. Those items required for Test Method A are labeled (A only), those for Test Method B are labeled (B only), and those for both test methods are labeled (A and B). Most of the components are illustrated in ~~Figs. 1 and 2.~~ Fig. 1.

6.2 *Major Components*:

6.2.1 *Air-Moving Equipment* (A and B)—A fan, blower, or blower door assembly that is capable of moving air into and out of the conditioned space at the flow rates required to create the full range of test pressure differences ~~(10~~ (up to ~~60~~ 25 Pa). The system shall provide constant air flow at each incremental pressure difference at fixed pressure for the period required to obtain readings of air flow rate. The air moving equipment shall be able to accomplish both pressurization and depressurization of the conditioned space and distribution system.

6.2.2 *Air Flow-Regulating System* (A and B)—A device, such as a damper~~,~~ or variable speed motor control, that will regulate and maintain air flow through the air moving equipment (6.2.1) and pressure difference across the leaks within specific limits.

6.2.3 ~~*Duct Flow Measurement Apparatus* (A and B)—A device to measure air flow into or out of an air distribution register within ±6 % of the true value. The calibration of this air flow measuring device shall be performed using a standardized flow measurement technique (for example, ASME MFC-3M) in an installation that is similar in both flow range and entering flow profile to those in which it will be applied in the field. The temperature dependence and range of the calibration shall be explicitly reported.~~

~~6.2.4~~ *Air Flow Measuring Device* (A only)—A device to measure ~~air flow through the air moving equipment (6.2.1) within ±3 %~~ airflow with an accuracy of ±5 % of the ~~true value.~~ measured flow. The ~~calibration of this air-flow measurement~~ airflow measuring system shall ~~follow~~ be calibrated in accordance with Test Method E 1258 or ASME MFC-3M, whichever is applicable. The ~~size~~ temperature dependence and range of the ~~air moving equipment~~ calibration shall be ~~matched~~ explicitly reported.

6.2.4 *Duct Flow Measurement Device* (B only)—A device to measure airflow with an accuracy of ±5 % of the measured flow. The airflow measuring system ~~so that the linear flow velocity falls within the~~ shall be calibrated in accordance with Test Method E 1258 or ASME MFC-3M, whichever is applicable. The temperature dependence and range of ~~measurement of~~ the ~~air flow meter.~~ calibration shall be explicitly reported.

6.2.5 *Pressure-Measuring Device* (A and B)—A manometer or pressure indicator to measure pressure differences with an accuracy of ±0.25 Pa (±0.00~~2~~1 in. H_2O) or ±1 % of measured pressure, whichever is greater.

6.2.6 *Duct Pressure Measuring Probe* ~~(A and B)~~ (B only)—A probe to measure the static pressure within a duct under flow ~~conditions (that is, a pressure probe with a small velocity-pressure coefficient).~~ conditions.

6.2.7 *Air Temperature Measuring Device* (A and B)—To give an accuracy of ±0.5°C (1°F).

6.2.8 ~~*Wind Speed Measuring Device* (A only)—To give an accuracy within ±0.25 m/s (0.5 mph) at 2.5 m/s (5 mph).~~

~~6.2.9~~ *Simultaneous Pressure and Flow Measurement System* (A ~~only, suggested for~~ and B)—A system that provides for essentially simultaneous measurement of building envelope and distribution-system pressures, as well as building envelope and distribution-system flows. Three alternative systems are~~:~~ a computerized data acquisition system, a multi-channel sample and hold system, and an interleaved multi-point sampling technique (that is, sequential recording of the pressures and flow signals averaged over at least three sets of signal-series samples).

~~6.3 *Blower Door Assembly*—An accepted variation of air-moving, flow-regulating, and flow-measuring equipment. Issues particular to this assembly are:~~

~~6.3.1 The door mount for the fan or blower must be adjustable to fit common door openings.~~

~~6.3.2 The fan or blower shall possess a variable-speed motor to accommodate the wide range of required flow rates up to 1.4 m^3/s (3000 ft^3/min).~~

7. Hazards

7.1 Glass should not break at the pressure differences normally applied to the building, however, protective eye wear shall be provided to personnel.

7.2 When conducted in the field, safety equipment required for general field work shall be supplied, such as safety shoes, hard hats~~, etc.~~

~~7.3 As~~ and so forth.

7.3 Because air-moving equipment is involved in this test, a proper guard or cage to house the fan or blower and to prevent accidental access to any moving parts of the equipment must be provided.

7.4 Hearing protection shall be provided for personnel who work close to noises such as those generated by moving air.

7.5 When the blower or fan is operating, a large volume of air is being forced into or out of ~~a~~ the building, the air-distribution system, or both. Plants, pets, occupants, or internal furnishings shall not be damaged due to the influx of cold or warm air. Similar precautions shall be exercised with respect to sucking debris or exhaust gases from fireplaces and flues into the interior of the building.

8. Procedure

8.1 *General*—The basic procedure involves pressurization and depressurization of air distribution systems and buildings with concurrent flow and pressure measurements to determine the air leakage of the distribution system. It also includes measurement of distribution-system pressures and ~~recirculating~~ fan flows during normal ~~distribution-fan operation.~~ system operation. The air handler fan speed and heating or cooling function must be the same for all steps of the test procedure.

8.1.1 *Test Method A (Flow Difference) for Air Leakage Determination*—This technique is based upon ~~comparisons of~~ changing the ~~air leakage rates from three fan pressurization tests: with the entire~~ flow through distribution system ~~in good communication with~~ leaks by operating the ~~building, with~~ air handler fan and simultaneously pressurizing (and depressurizing) the ~~return side of the distribution system sealed from the~~ building envelope and ~~the supply side (at the fan), and with the entire~~ distribution ~~system sealed from the building (see Fig. 1).~~ system.

8.1.2 *Test Method B (Fan Pressurization) for Air Leakage Determination*—This technique is based upon ~~two fan pressurization tests utilizing direct measurement~~ sealing the registers of ~~distribution-system leakage flows: with all but one supply register sealed~~ the distribution system and ~~all return registers unsealed, and with all but one return register sealed and all supply registers unsealed. Both tests are conducted with~~ pressurizing the ~~supply side sealed from~~ system to measure the ~~return side~~ flow out through the leaks at the ~~fan (see Fig. 2).~~ imposed pressure difference. With the house pressurized to the same pressure, this test isolates the leaks that are to outside only. Measurements of system operating pressures allow the leakage flow at the fixed test pressure to be converted to the leakage flow at operating conditions (pressures).

8.1.3 *Choice of Test Method*—In general, Test Method A ~~is subject to higher flow-measurement uncertainties, and Test Method B is subject to higher pressure-measurement uncertainties. The larger~~ will have lower operating condition air leakage flow uncertainties for leaky systems than Test Method ~~A result from the subtraction of total blower-door flows, as compared~~ B, due to the direct measurement of flow through distribution-system leaks with Test Method B. As the entire leakage flow of the distribution uncertainties in Test Method B when converting to operating system passes through a single register in pressures. Test Method B, the larger pressure uncertainties associated with this test method stem from the pressure non-uniformities created by pressure drops across internal distribution-system resistances. Test Method A shall B will be used preferred for leakier distribution systems (that is, houses that have very leaky envelopes, where the flow through the external distribution-system leakage is greater than 15 to 20 % of the building changes in envelope flow), pressures and distribution systems that have significant internal resistance (that is, systems with supply-duct dampers near the supply plenum), whereas Test Method B shall be flows used for more airtight distribution systems without supply-plenum dampers.

8.1.3.1 Test Method A includes a direct determination of envelope leakage characteristics, whereas in Test Method B does not. The user of Test Method B shall include an envelope leakage measurement such as that specified A will result in 8.2.4.1-8.2.4.9, greater uncertainties, or that specified in Test Method E 779.

8.1.4 *Auxiliary Measurements*—Auxiliary measurements are also required if testing to interpret the air leakage measurements. These include: measurement of the pressures that drive air leakage during normal system operation, and measurement of the recirculating flow through the distribution system. The former involves measurement of characteristic pressure differentials across the distribution-system envelope, and the latter involves measurement of the airflow into the return grill(es) determine compliance with only the distribution-system fan in operation. a specified low leakage value.

8.2 *Procedure for Test Method A* :

8.2.1 *Environmental Measurements*—At the beginning and the end of each fan pressurization test, measure the wind speed, outdoor temperature, indoor temperature, as well as temperatures in all unconditioned spaces. Preferred test conditions are wind speeds of 0 to 2 m/s (0 to 4 mph) and an outside temperature between 5 and 35°C (41 to 95°F). indoor temperature.

8.2.2 *Auxiliary MeasurementsBuilding Preparation*:

8.2.2.1 *Distribution-System Operating Pressures*—Install duct pressure measuring probes in the supply plenum, the supply duct closest to the supply plenum, the supply duct furthest from the supply plenum, the return plenum, the return duct closest to the return plenum, and the return duct furthest from the return plenum. Reference the duct-pressure probes to the unconditioned zone in which that duct section is located. OpenEnvelope—Open all interconnecting doors in the conditioned space (except for closet doors, which shall be closed) so that a uniform pressure will be maintained within the conditioned space to within 10 % of the measured inside/outside pressure difference. Verify this condition by performing differential pressure measurements between several rooms at the highest test pressure. Fireplace and other operable dampers shall be closed. If the air handling unit is located in a closet, the closet door shall be closed during testing. Turn on the distribution-system fan, measure each of the specified pressure differentials, and then turn off the distribution-system fan. testing.

8.2.2.2 *Recirculating Flow*—Install a duct air flow measuring device onDistribution System—HVAC-balancing dampers and registers, in general, shall not be adjusted. However, for multiple zoned systems, the return-air register (in the case position of multiple return registers, repeat this zonal dampers should be fixed for each register). Turn on the distribution-system fan and measure the flow rate in cubic metres per second (cubic feet per second) at the local air density into the return register. In the case duration of multiple return registers, the volumetric flows into each register and their individual indoor air temperatures shall test. Several tests may be measured, and any change in velocity performed with zone dampers fixed at the other return registers due to the installation different settings, but at least one of the duct air flow measuring device shall be recorded. tests should have all zone control dampers in the fully open position.

8.2.3 *Building PreparationTest Method A: Flow Difference Measurements*:

8.2.3.1 *Envelope*—Open all interconnecting doors in

8.2.3.1 Connect the conditioned space (except for closet doors, which shall be closed) so that a uniform pressure will be maintained within the conditioned space air moving/flow-regulating/flow measurement assembly to within 10 % of the measured inside/outside pressure difference. Verify this condition by selected differential pressure measurements throughout the building at the highest test pressure. Fireplace and other operable dampers shall be closed. If envelope using a significant fraction of the distribution system being measured passes through an unconditioned basement, open the windows window or outside door of that basement so as to provide at least 0.3 m^2 (3.3 ft^2) of open area, opening. Seal or so as tape openings to assure that avoid leakage at these points.

8.2.3.2 Install the envelope pressure difference between the basement and sensor. The outside is less than 5 % of the pressure difference between the conditioned space measurement location should be sheltered from wind and outside. Follow sunshine. The inside pressure measurement location should be as far away as possible from the same procedure if localized air flows induced by the air-handling unit or significant lengths of duct, or both, are located in a relatively airtight garage. If the air handling unit is located in a closet, moving apparatus. All the closet door shall be closed during testing.

8.2.3.2 *Distribution System*—HVAC-balancing dampers and registers, in general, shall not be adjusted. However, ensure that envelope pressures use the return registers are not outside pressure as the reference.

8.2.3.3 With air moving fan opening blocked, air moving fan off and that at least 75 % of air handler fan off measure pressure difference across envelope: ΔP_{zero}.

8.2.3.4 With the supply registers are not blocked or dampered shut. Remove the return-air filter for the air handler fan pressurization tests.

8.2.4 *Fan Pressurization Measurements* :

8.2.4.1 Connect off, turn on the air-moving/flow-regulating/flow measurement assembly to air moving device and adjust the building flow until there is 5 Pa (0.02 in. of water) envelope using a window, door, or vent opening. Seal or tape openings to avoid leakage pressure difference, with the house at these points.

8.2.4.2 If a damper is used to control higher pressure than outside (for pressurization testing). Record the envelope pressure difference (ΔP_{env}) and flow (Q_{off}) through the air-moving equipment it shall be in a fully closed position device at this pressure station. Only record pressure and flow readings when the beginning pressure reading is within 1.0 Pa (0.004 in. of a test. Turn on water) of the fan or blower, adjust the damper or air flow regulator to increase the air flow, and take readings 5 Pa (0.02 in. of water) operating point. It is recommended that multiple pressure and flow readings are recorded at esach operating point and averaged for use ind the calculation procedure. The ΔP_{zero} offset pressure differences.

8.2.4.3 When a blower door assembly shall be added to all target pressures. For example, if ΔP_{zero} is used, record 2 Pa, then the raw data outputs from first target pressure for pressurization is 7 Pa and -3 Pa for depressurization. All the air-flow measuring air-moving device and use curve fits obtained with Test Method E 1258 to determine flows from that raw data (for example, revolutions per minute or pressure differentials, or both).

8.2.4.4 The range are positive out of the induced pressure differences across house and negative if into the building house.

8.2.3.5 Repeat step 8.2.3.4, but with the envelope shall be from 10 to 60 pressure difference, ΔP_{env}, incremented by 5 Pa (0.04 to 0.24 in. H_2 O) in increments of 10 Pa (0.04 in. H_2O).

8.2.4.5 At each building-envelope pressure differential, measure time until the air flow rate in cubic metres per second (cubic feet per second) simultaneously with the building-envelope envelope pressure readings and difference is 50 Pa. At each ΔP_{env} pressure station the duct pressure measuring probe readings using one difference must be within 1 Pa (0.004 in. of water) of the measurement techniques described in 6.2.9.

8.2.4.6 Since required operating point. Record the capacity of envelope pressure difference with the air handling equipment, handler fan off, ΔP_{off}, for each pressure station. Because the tightness of the building, and the weather conditions affect leakage measurements, the full range of the higher values may not be achievable. In such cases, substitute a partial range encompassing at least five data points, with the size of pressure increments suitably adjusted.

8.2.4.7 The maximum variation between adjusted. At each pressure station, the *measured* pressure differential across air handler fan on and off conditions must both have the building envelope same target pressure.

8.2.3.6 Turn on the air handler fan and repeat the *average* measurements in 8.2.3.4 and 8.2.3.5, recording Q_{on} and ΔP_{on} at each pressure differential across station.

8.2.3.7 Repeat 8.2.3.6, but with the building envelope (due to external influences such as wind, thermal stack effect, or both) shall be no more than 1 Pa. This corresponds to a wind speed of approximately 2 m/s house depressurized, that is, for a single-point outdoor-pressure reference, and a wind speed of approximately 5 m/s for a 4-wall-average outside-pressure reference.

8.2.4.8 When the unconditioned space first point, adjust the flow through which the distribution system (or a part thereof) passes air-moving device until there is at a -5 Pa envelope pressure differential relative to outside that is not at least 80 % of difference, with the indoor-outdoor house at a lower pressure differential, than outside.

8.2.3.8 Repeat 8.2.3.7, but with the unconditioned zone pressure shall be made to meet this requirement, or that pressure differential shall be separately monitored and reported.

8.2.4.9 For each fan-pressurization test, collect data for both pressurization and depressurization.

8.2.4.10 *Second Fan-Pressurization Test*— Seal all return registers and seal the return side from the supply side at the distribution-system fan.

8.2.4.11 Repeat 8.2.1, 8.2.4.4, 8.2.4.5, and 8.2.4.9.

8.2.4.12 *Third Fan-Pressurization Test*— Unseal the distribution-system fan and seal all return and supply registers.

8.2.4.13 Repeat 8.2.1, 8.2.4.4, 8.2.4.5, and 8.2.4.9.

8.2.4.14 Unseal all return and supply registers, and replace the return air filter. handler fan off.

8.3 *Procedure for Test Method B* :

8.3.1 *Environmental Measurements*—At the beginning and the end of each fan pressurization test, measure the wind speed, outdoor temperature, indoor temperature, as well as temperatures in all unconditioned spaces. Preferred test conditions are wind speeds of 0 to 2 m/s (0 to 4 mph) and an outside temperature between 5 and 35°C (41 to 95°F). indoor temperature.

8.3.2 *Auxiliary MeasurementsBuilding Preparation*:

8.3.2.1 *Distribution-System Operating Pressures*—Install duct pressure measuring probes in the supply plenum, the supply duct closest to the supply plenum, the supply duct furthest from the supply plenum, the return plenum, the return duct closest to the return plenum, and the return duct furthest from the return plenum. Reference the duct-pressure probes to the unconditioned zone in which that duct section is located. OpenEnvelope—Open all interconnecting doors in the conditioned space (except for closet doors, which shall be closed) so that a uniform pressure will be maintained within the conditioned space within a range of less than 10 % of the measured inside/outside pressure difference. Verify this condition by performing differential pressure measurements between several rooms at the highest pressure differential contemplated. Fireplace and other operable dampers shall be closed. If the air handling unit is located in a closet, the closet door shall be closed during testing. Turn on the distribution-system fan, measure each of the specified pressure differentials, and then turn off the distribution-system fan. testing.

8.3.2.2 *Recirculating Flow*—Install a duct air flow measuring device onDistribution System—HVAC-balancing dampers shall be in their fully open position during the return-air register (in the case of multiple return registers, repeat this for each register). Turn on the distribution-system fan pressurization tests, and measure the flow rate in cubic metres per second (cubic feet per second) at the local air density into the return register. In the case of multiple return registers, the volumetric flows into each register and their individual indoor air temperatures original positions shall be measured, and any change recorded. Registers, in velocity at the other return registers due to the installation of the duct air flow measuring device general, shall not be recorded. adjusted.

8.3.3 *Building PreparationTest Method B: Fan Pressurization of Distribution System and Building*:

8.3.3.1 *Envelope*—Open all interconnecting doors in the conditioned space (except for closet doors, which

8.3.3.1 The system operating pressures shall be closed) so that a uniform measured by using the half plenum pressure w technique. For the system operating pressure tests, all registers shall be maintained within unsealed and there shall be no blocking between the conditioned space to within supply and return. Turn on the air handler fan, and measure ΔP_s by inserting a static pressure probe into the supply plenum, with the tip facing into the airflow. Keep the probe clear of less than 10 % of the m direct asuir handler fan discharge in the supply plenum, or any point in the plenum where excessive turbulence may be found. Should a ne/gative reading be found in the supply plenum, select another measurement location, preferably further away from the air handler fan. The pressure difference. Verify this condition readings shall be averaged for five seconds. Measure ΔP_r by selected differential inserting a static pressure measurements throughout probe into the building at return plenum, with the tip facing into the airflow. Keep the probe clear of the air handler fan inlet, or any point in the plenum where a venturi or excessive turbulence may be found. Should a positive reading be found in the return plenum, select another measurement location, preferably further away from the air handler fan. The pressure differential contemplated. Fireplace and other operable dampers readings shall be averaged for five seconds.

8.3.3.2 Install the envelope pressure difference sensor. I The outside pressure measurement location should be sheltered from wind and sunshine. The inside pressure measurement location should be as far away as possible from the localized air flows induced by the air moving apparatus.

8.3.3.3 Connect the envelope air moving/flow-regulating/flow measurement assembly to the building envelope using a significant fraction window or door opening.

8.3.3.4 Separate the supply and return sections of the distribution duct system being measured passes through by inserting an unconditioned basement, open air-tight blockage. If filters are installed near the windows entrance to the equipment or outside door the exit of the air handler cabinet, then install the blockage in the filter slot (after removing the filter). Alternatively, a blockage may be installed within the air handler cabinet.

8.3.3.5 Select two supply locations (one for the duct pressurization device and one for the static pressure probe) and two return locations (unless there is only a single return for the system under test). These locations should be selected to provide at least 0.3 m^2 (3.3 ft^2) have the lowest possible resistance to the supply and return plenums, respectively.

8.3.3.6 Attach the duct flow measuring and air moving equipment to the supply side of open area, the duct system at the register selected in 8.3.3.5 or at the air handler access panel if the blockage is on the return side of the air handler fan. Install a duct pressure probe at a supply register selected in 8.3.3.5 (other than that to which the fan/flowmeter is connected) or the supply plenum. Ensure that all other supply registers are sealed and at least one return register is open.

8.3.3.7 Adjust the envelope air-moving fan to provide 25 Pa [0.1 in. of water] pressure difference between the basement building and outside is less than 5 % of outside. Adjust the duct flow measuring and air moving equipment to maintain zero pressure difference (±0.5 Pa [±0.002 in. water]) between supply ducts and the conditioned space building, and outside. If adjust the envelope air moving device to maintain 25 Pa (±5 Pa) [0.1 in. water (±0.02 in. water)] between the building and outside. This step may require several iterations. Record the flow through the duct flow measuring device ($Q_{25,\ s}$[$Q_{0.1,\ s}$])—this is located in a closet, the closet door shall be closed during testing.

8.3.3.2 *Distribution System*—HVAC-balancing dampers shall be in their fully open position during supply leakage flow at 25 Pa [0.1 in. water]. Also record the fan pressurization tests, envelope pressure: $P_{test,s}$.

8.3.3.8 Record the pressure difference, $\Delta P_{b,\ s}$, between the buffer zone and their original positions shall be recorded. Remove the return-air filter for outside. If the fan pressurization tests. Registers, supply ducts are in general, more than one buffer zone, $\Delta P_{b,\ s}$ shall not be adjusted. Seal equal the average pressure in the buffer spaces containing supply ducts (average $\Delta P_{b,\ s}$).

8.3.3.9 Attach the duct flow measuring and air moving equipment to the return side from of the duct system at the air handler access panel if the blockage is on the supply side of the air handler fan, or at the d register selected in 8.3.3.5. Install a static pressure probe in a return register selected ion- 8.3.3.5. Thisy return register shall not be the same as the register to which the duct flow measurin. Sg and air moving equipment is attached unless there is only a single return register for the system. Ensure that all other return registers except one supply are sealed and at least one return. The unsealed supply shall be register is open.

8.3.3.10 Adjust the one with envelope air-moving fan until the pressure between the buildingh and outside is 25 Pa [0.1 in. water]. Adjust the duct flow rate during normal operation of measuring and air moving equipment to maintain zero pressure (±0.5 Pa [±0.002 in. water]) between return ducts and the distribution system building and the envelope air moving fan (often to maintain 25 Pa (±5 Pa) [0.1 in. water (±0.02 in. water)] between the building and outside. This step may require several iterations. Record thae flow through the flowmeter ($Q_{25,\ r}$[$Q_{0.1,\ r}$])—this is closest to the supply plenum). The unsealed return shall be leakage flow at 25 Pa [0.1 in. water]. Also record the one with envelope pressure: $P_{test, r}$.

8.3.3.11 Record the highest flow rate during normal operation of pressure difference, $\Delta P_{b, r}$, between the distribution-system fan (often buffer zone and the outside. If the return ducts are in more than one that is closest to buffer zone, $\Delta P_{b, r}$ shall equal the average pressure in the buffer spaces containing return plenum).

8.3.4 *Fan Pressurization* *ducts (average* $\Delta P_{b, s}$*).*

8.3.3.12 Unseal all return and supply registers, and replace the air filter (if removed).

8.4 *Air Handler Fan Flow Measurements* :

8.3.4.1 Connect the air-moving/flow-regulation equipment to the building envelope using a window, door, or vent opening.

8.3.4.2 Install a duct

8.4.1 The air handler fan flow measuring device on the unsealed supply register. Install duct pressure measuring probes in the unsealed supply duct, in the supply plenum, and in the supply duct furthest from the supply plenum. Reference the duct-pressure probes to the unconditioned zone in which that duct section is located.

NOTE 1—Supply-side and return-side distribution-system leakage can be measured simultaneously determined by using two duct blowing air through the system with flow measuring devices and two sets of duct pressure measuring probes and also following steps 8.3.4.8 and 8.3.4.9 air moving equipment at this point.

8.3.4.3 Vary the same flow through rate as under normal operating conditions. Normal operating conditions are determined by the air-moving equipment installed in the building envelope to create a range of average induced pressure differences across difference between the supply side of plenum and the distribution system. The range of this average induced conditioned space.

8.4.2 With the air handler fan on, measure the pressure difference shall be from 10 between supply plenum and conditioned space (ΔP_{sp}). The static pressure probe must be firmly attached to 60 Pa (0.04 to 0.24 in. H_2O) in increments of 10 Pa (0.04 in. H_2O).

8.3.4.4 When ensure that it does not move during the full range of induced pressure differences cannot be achieved, substitute a partial range encompassing at least five data points, with fan flow test.

8.4.3 Block the size return duct from the return plenum upstream of pressure increments suitably adjusted.

8.3.4.5 At each supply-side pressure differential, measure the air flow rate through handler fan.

8.4.4 Attach the duct air flow measuring device in cubic metres per second (cubic feet per second) simultaneously with and air moving equipment to the duct pressure measuring probe readings using one of system at the measurement techniques described in 6.2.9.

8.3.4.6 A maximum variation of pressure differences across air handler. Do not mount the two different supply duct sections shall be no more than 20 % of flow measuring and air moving equipment directly on the measured average of those pressure differences. When the unconditioned space through which the distribution system (or a part thereof) passes is at a pressure differential relative to outside air handler cabinet. Ensure that there is not at least 80 % six feet of connecting duct between the indoor-outdoor pressure differential, duct air moving fan and the unconditioned zone pressure shall be made connection to meet this requirement, or that pressure differential shall be separately monitored and reported.

8.3.4.7 Collect data for both pressurization and depressurization.

8.3.4.8 Install a duct the air flow measuring device handler cabinet.

8.4.5 Turn on the unsealed return register. Install air handler fan followed by the duct pressure flow measuring probes in and air moving equipment and adjust the unsealed return duct, in flow until the pretssure between supply plenum, and conditioned space matches ΔP_{sp}(Pa [in. water]) as closely as possible. If ΔP_{sp} cannot be reached, record the return duct furthest from maximum flow and pressure attainable with the return plenum. Reference test equipment.

8.4.6 Record the duct-pressure probes to flow through the unconditioned zone in which that duct section is located.

8.3.4.9 Repeat 8.3.4.3 (substitute return for supply), 8.3.4.5, 8.3.4.6 (substitute return for supply), flowmeter, Q_{meas} , (m^3/s [cfm]), and 8.3.4.7.

8.3.4.10 Unseal all return and supply registers, as well as the distribution-system fan.

8.3.4.11 Return all HVAC dampers to their original positions, and replace return-air filter. coincident pressure difference ΔP_{meas}.

9. Calculation

9.1 *Auxiliary* *Test Method A: Flow Difference Measurements*:

9.1.1 The pressure differentials measured in step 8.2.2.1 or 8.3.2.1 shall be reported, as shall an average pressure differential, computed as

9.1.1 Unless the airflow measuring system gives volumetric flows at the three barometric pressure differentials (across and the plenum, across temperatures of the near supply duct, and across air flowing through the far supply duct) divided by three.

9.1.2 The local flow rates measured in step 8.2.2.2 or 8.3.2.2 shall flowmeter during the test, then these readings must be converted using information obtained from the manufacturer for the change in calibration with these parameters.

9.1.2 Convert the readings of the airflow measuring system (corrected as in 9.1.1, if necessary) to equivalent flow rates volumetric air flows at an average indoor-air the temperature and then summed barometric pressure (due to yield a total recirculating-air flow rate.

9.2 *Test Method A*:

9.2.1 Convert all the measured air flow rates to cubic metres per second (cubic feet per second) at the condition elevation changes only) of the outside air passing through the envelope and distribution-system leaks. The calibration for depressurization tests or of the inside air flow measuring device (or blower door) shall provide for pressurization tests (see Annex A1). To convert the volume flow airflow rate at through the density of the air passing flowmeter to air leakage rate through the device. Calculate the volume flow through the leaks from the following equation: envelope for depressurization, use

$$Q_{leak} = Q_{device} \frac{T_{leak}}{T_{device}} \quad (1)$$

$$Q_0 = Q\left(\frac{\rho_{in}}{\rho_{out}}\right) \quad (1)$$

Tdevice

where:

Q_{leak} ρ_{in} = the flow rate through the leaks, m indoor air density, kg/m^3/s (ft (lb/ft^3/s),), and
Q_{device} ρ_{out} = the flow rate through the fan pressurization device, m outdoor air density, kg/m ^{3}/s (ft (lb/ft^3/s),
T_{leak} = the absolute temperature of the air passing through the leaks, which shall be assumed for pressurization to be the indoor air temperature and for depressurization the duct-area-weighted average temperature of the unconditioned zones through which the ducts pass, K (R), and
T_{device} = the absolute temperature of the air passing through the device, K (R).).

Use linear interpolation of before and after temperature measurements if real-time values are not available.

9.2.2 If

To convert the airflow rate is not measured directly with a flow meter, then additional calculations are needed to convert, for instance, pitot tube pressure to linear velocity and then to volume flow rate.

9.2.3 Plot the corrected air flow rates (9.2.1) against the corresponding envelope pressure differences on a log-log plot to complete the air leakage graph rate for both pressurization and depressurization for tests 8.2.4.9, 8.2.4.11, and 8.2.4.13 (see Fig. 3).

9.2.4 *Calculation of Flow Exponent, Flow Coefficient, and Effective Leakage Area*:

9.2.4.1 Use the data as calculated in 9.2.1 to determine the parameters *C* and *n* for the three measurement conditions, where: pressurization, use

$$Q_{leak} = C(\Delta P)^n \quad (2)$$

$$Q_0 = Q\left(\frac{\rho_{out}}{\rho_{in}}\right) \quad (2)$$

where:
C = flow coefficient, (m^3/s Pa^n

9.1.3 Subtract ΔP^{zero} (ft^3/s (in. H_2O)^n)),

n = flow exponent (−), and
ΔP = differential from the measured envelope pressures at each pressure station (ΔP_{env}) to determine the corrected envelope pressures (ΔP).

9.1.4 Determine the envelope leakage coefficient and pressure across exponent, n_{env}, by fitting the building envelope, (Pa (in. H_2O)).

9.2.4.2 Use linear least squares air handler fan off pressure and flow data to determine the paower law function using the samet analysis as for house pressurization leakage testing in Test Method Eq 2 779.

9.1.5 Adjust the flows to exactly match pressures. The measured flow with the system off is accomplished by taking corrected to the logarithm of both sides of flow at the equation, same pressure as when the resulting equation being: system is on at each pressure station, using Eq 3.

$$\ln Q_{leak} = \ln C + n \ln(\Delta P)$$

$$Q_{off,\,corrected} = Q_{off}\left(\frac{\Delta P_{on}}{\Delta P_{off}}\right)^{n_{env}} \quad (3)$$

9.2.4.3 Determine

9.1.6 Calculate the flow exponent, *n*, directly, difference (ΔQ) at each pressure station by subtracting Q_{off} from Q_{on}. For flow differences during pressurization, use Q_{off} from 8.2.3.6 and determine the Q_{on} from 8.2.3.4 and 8.2.3.5. For flow coefficient, *C*, differences during depressurization data, use Q_{off} from the inverse logarithm of the intercept of Eq 3. Calculate 8.2.3.8 and report the coefficient Q_{on} from 8.2.3.7.

9.1.7 Do a least squares fit of correlation squared, R^2, as well as the standard error of ΔP and ΔQ pairs from each of the parameters.

9.2.4.4 Calculate the effective pressure station to Eq 4 to determine supply leakage area in square metres (square feet), *L*, from the (Q_s) and return leakage coefficient, *C*, the exponent *n*, a reference pressure, ΔP (Q_r), and the characteristic pressures (ΔP_s, and ΔP_r). Note that some of the air density ρ at pressure ratios (and 1 ± the temperature and pressure of ratios) will be negative. In these cases take the flow through absolute value to the leaks as follows: power 0.6 in Eq 3 and carry the sign outside the exponent term.

$$L = C(\Delta P_r)^{(n-1/2)}(\rho/2)^{1/2}A \quad (4)$$

$$\Delta Q(P) = \quad (4)$$

where:
L = effective leakage area, (m^2 (ft^2)),
ρ = air density in leaks, (kg/m^3 (lbm/ft^3)), and
A = unit conversion factor, (1 (0.0775)).

The conventional reference pressure for building envelope leaks is 4 Pa, however, the leakage flow at a pressure of 25 Pa is more precisely determined and is more appropriate for air distribution system leaks while the system is operating. The 4-Pa number is appropriate for comparing the size of distribution-system leaks to building envelope leaks, whereas the 25-Pa leakage flow is appropriate for estimating the impacts of distribution-system leakage during system operation. Report the 4 Pa effective leakage area values, as well as the leakage exponents and 25-Pa flows for each of the three tests (all registers open, return registers sealed, and all registers sealed) for both pressurization and depressurization in the report section. In addition, report the density of the air flowing through the leaks for each test.

9.2.4.5 The pressure differentials between the isolated sections of the duct system (that is, those that have been sealed) and their surroundings shall be equal to zero for the second and third fan pressurization tests. If this is not the case, the likely cause is leakage between the building and the sealed portion of the ductwork through improper register or fan seals or leaky duct sections that pass through conditioned spaces. A non-zero pressure differential thus corresponds to a negative bias in the duct leakage being measured.[4] Correct for this bias by multiplying

1 1 − ΔP ductΔPbuilding n

$$Q_s\left[\left(1 + \frac{\Delta P}{\Delta P_s}\right)^{0.6} - \left(\frac{\Delta P}{\Delta P_s}\right)^{0.6}\right] - Q_r\left[\left(1 - \frac{\Delta P}{\Delta P_r}\right)^{0.6} + \left(\frac{\Delta P}{\Delta P_r}\right)^{0.6}\right]$$

where:
ΔP_{duct} = pressure differential between

9.1.8 Plot the duct flow difference and its surrounding zone during envelope pressures. An example plot is shown in

9.2 *Test Method B: Fan Pressurization Measurements*:

9.2.1 Unless the sealed duct test airflow measuring system gives volumetric flows at the maximum pressure differential relative to outside, Pa (in. H_2O),

$\Delta P_{building}$ = maximum pressure differential between the building and outside, Pa (in. H_2O).

9.2.4.6 Determine the effective leakage area temperatures of the return side, L_{ret}, and air flowing through the return leakage flow at 25 Pa, Q_{ret25}, from flowmeter during the effective leakage areas and 25-Pa flows test, then these readings must be converted using information obtained by Eq 2 and Eq 4 from the results of manufacturer for the f change in calibration with these parameters.

9.2.2 The 25 Pa [0.1 in. water] duct leakage flows ($Q_{25, s}$ and second fan pressurization tests, 8.2.4.9 $Q_{25, r}$[$Q_{0.1, s}$ and 8.2.4.11, by means of $Q_{0.1, r}$]) shall be converted to leakage flows at operating conditions using the following equation (in which L can be replaced by Q_{25}): equations.

For SI:

$$Q_s = Q_{25,s}\left(\frac{\Delta P_s}{2(P_{test,s} - P_{b,s})}\right)^{0.6} \quad (5)$$

$$L_{ret} = \frac{(L_{first} - L_{second})}{(1 - (\Delta P_{duct(second)}(\Delta P_{building(second)})^n} \quad (6)$$

$$Q_r = Q_{25,r}\left(\frac{\Delta P_r}{2(P_{test,r} - P_{b,r})}\right)^{0.6} \quad (6)$$

where:
L_{first} = leakage area computed for the first fan pressurization test (8.2.4.9) using Eq 4 (m^2 (ft^2)),
L_{second} = leakage area computed for the second fan pressurization test (8.2.4.11) using Eq 4 (m^2(ft^2)),
$\Delta P_{duct(second)}$ = pressure differential between the duct and its surrounding zone (measured with the return plenum duct pressure measuring probe) during the second pressurization test at the maximum pressure differential between the building and outside (Pa(in H_2O)),
$\Delta P_{building(second)}$ = maximum pressure differential between the building and outside during the second pressurization test (Pa(in H_2O)).

The reported flow exponents for the return side shall be the averages of the flow exponents determined for the first and second fan pressurization tests.

9.2.4.7 The effective leakage area of the supply side, L_{sup}, and the supply leakage flow at 25 Pa, Q_{sup25}, shall be determined from the effective leakage areas and 25-Pa flows obtained by Eq 2 and Eq 4 from the results of the first and third fan pressurization tests, 8.2.4.9 and 8.2.4.13, as well as the return-duct leakage computed with Eq 6. The leakage area and 25-Pa leakage flow of the supply ducts shall be determined by means of the Eq 7 (in which L can be replaced by Q_{25}). If L_{ret} or Q_{ret25} is less than zero, they shall be set to zero in Eq 7.

For IP:

$$L_{sup} = \frac{(L_{first} - L_{third})}{\left(1 - \left(\frac{\Delta P_{duct(third)}}{\Delta P_{building\ (third)}}\right)\right)^{n}} - L_{ret} \quad (7)$$

$$Q_s = Q_{0.1,\,s}\left(\frac{\Delta P_s}{2(P_{test,\,s} - P_{b,\,s})}\right)^{0.6} \quad (7)$$

where:

L_{first} = leakage area computed for the first fan pressurization test (Section 8.2.4.9) using Eq 4 (m^2 (ft^2)),
L_{third} = leakage area computed for the third fan pressurization test (Section 8.2.4.13) using Eq 4 (m^2 (ft^2)),
$\Delta P_{duct(third)}$ = pressure differential between the duct and its surrounding zone (measured with the return plenum duct pressure measuring probe) during the third pressurization test at the maximum pressure differential between the building and outside (Pa (in. H_2O)),
$\Delta P_{building(third)}$ = maximum pressure differential between the building and outside during the third pressurization test (Pa (in. H_2O)).

The reported flow exponents for the supply side shall be the averages of the flow exponents determined for the first and third fan pressurization tests.

9.2.4.8 The flow coefficients for the supply and return sides, C_{sup}, and C_{ret}, shall be computed using the following equation:

$$C = \frac{L}{(\Delta P_r)^{(n-1/2)}(\rho/2)^{1/2}A} \quad (8)$$

$$Q_r = Q_{0.1,\,r}\left(\frac{\Delta P_r}{2(P_{test,\,r} - P_{b,\,r})}\right)^{0.6} \quad (8)$$

where:

L = computed leakage area of the supply or return side (m^2 (ft^2)),
n = computed flow exponent of the supply or return side (m^2 (ft^2)),
ΔP_r = pressure differential at which the leakage area was computed (Pa (in. H_2O)),
ρ = air density in leaks (kg/m^3 (lbm/ft^3)), and
A = unit conversion factor (1 (0.0775)).

9.3 *Test Method B*Air Handler Fan Flow:

9.3.1 Convert all

9.3.1 Unless the measured air flow rates to cubic metres per second (cubic feet per second) airflow measuring system gives volumetric flows at the condition of the air passing through the envelope pressure and distribution-system leaks. The calibration of the duct flow measurement apparatus shall provide the volume flow rate at the density temperatures of the air passing flowing through the device. Calculate flowmeter during the volume flow through the leaks test, then these readings must be converted using information obtained from the manufacturer for the change in calibration with these parameters.

9.3.2 The measured flow and coingcideent plenum pressures are used to determine the distribution-system flow at operating conditions using Eq 9:

(9) $Qleak = Qdevice\ T\ leakTdevice$

where:

Q_{leak} = the flow rate through the leaks, m^3/s (ft^3/s),
Q_{device} = the flow rate through the duct flow measurement apparatus, m^3/s (ft^3/s),
T_{leak} = the absolute temperature of the air passing through the leaks, which shall be assumed for pressurization to be the indoor air temperature (that is, T_{device}), and for depressurization the duct-area-weighted average temperature of the unconditioned zones through which the ducts pass, K (R), and
T_{device} = the absolute temperature of the air passing through the device, K (R).

Use linear interpolation of before and after temperature measurements if real-time values are not available.

9.3.2 If the air flow rate is not measured directly with a flow meter, then additional calculations are needed to convert, for instance, pitot tube pressure to linear velocity and then to volume flow rate.

9.3.3 Plot the corrected distribution-system leakage air flow rates (9.3.1) against the corresponding distribution-system pressure differences (average of far-supply and supply plenum, or average of (far-)return and return plenum) on a log-log plot to complete the air leakage graph for both pressurization and depressurization for 8.3.4.7 and 8.3.4.9 (see Fig. 3).

9.3.4 *Calculation of Flow Exponent, Flow Coefficient, and Effective Leakage Area*:

9.3.4.1 Use the data as calculated in Eq 6 to determine the parameters C and n for both the supply and return, where:

$$Q_{leak} = C(\Delta P)^n \quad (10)$$

$$Q_e = Q_{meas}\left(\frac{\Delta P_{sp}}{\Delta P_{meas}}\right)^{0.5} \quad (9)$$

where:
C = flow coefficient, (m^3/s Pa^n (ft^3/s (in. $H_2O)^n$)),
n = flow exponent (−), and
ΔP = differential pressure across the distribution system (see 9.3.3), (Pa (in. H_2O)).

9.3.4.2 Use linear least squares to determine the parameters in Eq 7. This is accomplished by taking the logarithm of both sides of the equation, resulting equation being:

$$\ln Q_{leak} = \ln C + n \ln (\Delta P) \quad (11)$$

9.3.4.3 The flow exponent, *n*, is determined directly, and the flow coefficient, *C*, is determined from the inverse logarithm of the intercept of Eq 8. Calculate and report the coefficient of correlation squared, R^2, as well as the standard error of each of the parameters.

9.3.4.4 Calculate the effective leakage area in square metres, *L*, from the leakage coefficient, *C*, the exponent *n*, a reference pressure, ΔP_r, and the air density ρ at the temperature and pressure of the flow through the leaks as follows:

$$L = C(\Delta P_r)^{(n-1/2)}(\rho/2)^{1/2}A \quad (12)$$

where:
L = effective leakage area, (m^2 (ft^2)),
ρ = air density in leaks, (kg/m^3 (lbm/ft^3)), and
A = unit conversion factor, 1 (0.0775).

The conventional reference pressure for building envelope leaks is 4 Pa; however, the leakage flow at a pressure of 25 Pa is more precisely determined and is more appropriate for air distribution system leaks while the system is operating. The 4-Pa number is appropriate for comparing the size of distribution-system leaks to building envelope leaks, whereas the 25-Pa leakage flow is appropriate for estimating the impacts of distribution-system leakage during system operation. Report the effective leakage area values, as well as the leakage exponents and 25-Pa flows computed with Eq 7, for the supply and return sections for both pressurization and depressurization. In addition, report the density of the air flowing through the leaks for each test.

10. Report

10.1 Report at least the following information:

10.1.1 *Building Description*:

10.1.1.1 *Location and Construction*:

(a)(1) (*a*) DateDate built (estimate if unknown),

(b)(2) (*b*) Floor area of conditioned space, attic, basement,Street address (including city, state/province/county and crawlspace. country),

(c)(3) (*c*) VolumeFloor area of conditioned space, attic, basement, and crawlspace,

(4) Volume of conditioned space, attic, basement, and crawlspace, and

(5) Elevation above sea level.

10.1.1.2 *Condition of Openings in Exterior Shell*:

(a)(1) (*a*) DoorsDoors (including storm doors),

(b)(2) (*b*) WindowsWindows (including storm windows), latched or unlatched,

(c)(3) (*c*) VentilationVentilation openings, dampers closed or open,

(d)(4) (*d*) Chimneys,Chimneys, dampers closed or open, and

(e)(5) (*e*) ConditionCondition of openings during test (for example, broken windows, HVAC-louver settings, etc.).

10.1.1.3 and so forth).

10.2 *HVAC System*:

(a)(1) (*a*)Furnace/Air-conditioner/Heat-pump type and capacity,

(b)(2) (*b*) Indicated blower capacity (most likely just pressure and horsepower), Status of heating or cooling equipment during testing, and

(c)(3) (*c*) Measured recirculating-air flow rate from 9.1.1,

(d) (*d*) All measured characteristic leakage pressures for return and supply sides of the distributionDistribution system $\Delta P_{retplen}$, $\Delta P_{retnear}$, ΔP_{retfar} , $\Delta P_{supplen}$, $\Delta P_{supnear}$, and ΔP_{supfar} (from 9.1.2), and

(e) (*e*) Distribution system location (supplies, returns, plenums, and air-handling unit).

10.1.2 *Pressurization*

10.3 *Leakage Measurements*:

10.1.23.1 Technique employed (that is, Test Method A or Test Method B),

10.1.23.2 Equipment used,

10.1.23.3 Calibration of air flowmeter, and

10.13.2.4 Measurement results. A tabular listing of all air leakage data (including time, flows, and all pressures); plot(s) of change in flow with changing envelope pressure difference (for test Method A only); and a list of conversion factors used in 9.1.2 (For test Method A only).

10.1.34 *WAir Leathkager Results*:

10.1.3.1 Off-site conditions (nearby weather station),

10.1.3.2 On-site conditions (height and position of weather tower),

10.1.3.3 Measurement apparatus,

10.1.3.4 Wind speed,

10.1.3.5 Temperature (indoor, outdoor, and unconditioned spaces) before and after each fan pressurization test, as well as before and after auxiliary measurements,

10.1.3.6 Humidity (indoor and outdoor) and barometric pressure (optional), and

10.1.3.7 Altitude.

10.1.4 *Air Leakage Data*

10.4.1 *Test Method A: Flow Difference* :

10.1.4.1 Tabular listing of all air leakage data (including time, flows

10.4.1.1 Supply and all pressures).

10.1.4.2 Plots of air return distribution-system leakage flows.

10.4.1.2 Flow difference and envelope pressure plota (see Fig. 3).

10.1.5 *Air Leakage Results* 2).

10.4.2 *Test Method B: Fan Pressurization* :

10.1.5.1 Supply-side

10.4.2.1 Supply and return-side return distribution-system leakage flow coefficients flows at 25 Pa.

10.4.2.2 Supply and exponents for both pressurization return distribution system operating pressures.

10.4.2.3 Supply and depressurization in accordance with 9.2.4.8 or 9.3.4.3. For Test Method A, also report the flow coefficients and exponents for each fan pressurization test (in accordance with 9.2.4.3) and any correction factors (in accordance with 9.2.4.5).

10.1.5.2 Supply-side and return-side distribution-system return distribution system leakage flows at 25 Pa based upon determined leakage coefficients operating conditions.

10.4.3 *Air Handler Fan Flow*:

10.4.3.1 Measured system operating pressure difference between supply plenum and exponents (in accordance with 9.2.4.6, 9.2.4.7, or 9.3.4.4). If extrapolations outside of conditioned space.

10.4.3.2 Measured flow required to match this pressure, OR the measurement range are made, include an estimate of the extrapolation error. For Test Method A, also report the maximum flows at 25 Pa from each fan pressurization test (in accordance with 9.2.4.1) and any correction factors (in accordance with 9.2.4.4).

10.1.5.3 The effective leakage areas of supply and return sides for both pressurization and depressurization, as well as pressures achieved during the average (in accordance with 9.2.4.5 or 9.3.4.4). For Test Method A, also report the effective leakage areas from each test.

10.4.3.3 Calculated air handler fan pressurization test (in accordance with 9.2.4.4).

10.1.5.4 Correlation coefficient squared, R^2, and standard error or flow coefficient and exponent for each fit to Eq 3 or Eq 8 for both pressurization and depressurization.

10.1.6 if pressure matching not achieved. If pressure match is not achieved, this must be clearly stated in the report.

10.5 *Test Identification*:

10.1.65.1 Date the test was performed.

10.1.65.2 Name and address of organization performing the test.

10.1.65.3 Name(s) of individual(s) performing the test.

11. Precision and Bias

11.1 *Precision*—At present, the—The precision and bias of these test methods is largely dependent on the instrumentation and apparatus used, and on the ambient conditions under which the data are taken. For both test methods, the precision will be worse for larger houses/duct systems and for tests conducted at higher wind speeds. For Test Method A, the precision is based principally upon the fraction of the fan-pressurization flow passing through the ducts. A fan pressurization has been estimated from field test following the procedures outlined in these test methods with well-calibrated equipment at reasonable windspeeds should produce effective leakage area results that are repeatable within 2 to 9 %. As an example, where the measurement systems were tested several times. The results of supply-side or return-side leakage area these tests indicate that represents 10 % of the overall leakage area, would have an uncertainty of $\sqrt{2^* (0.02 \textit{ to } 0.09)^2}/0.1 = 28$ to 127 % . The uncertainty precision errors are in the flow at 25 Pa is approximately one third of that at 4 Pa, corresponding to an uncertainty range of 0.0009 to 42 % for the same example. The uncertainty for 0.0047 m^3/s (2 to 10 cfm). For Test Method B will in general be considerably lower than that for Test Method A, however, careful attention needs to be paid to B, the pressure nonuniformities in precision has been estimated from field test results where the ducts, as such nonuniformities can create biased results. A more complete systems were tested several times. The results of these tests indicate that the precision and bias statement is currently being developed.

11.2 It is more precise to take data at higher pressure differences than at lower differences. Therefore, exercise special care when measurements errors are taken at low pressure differences.

11.3 0.0024 to 0.0071 m^3/s (5 to 15 cfm).

11.2 *Bias*—Both Test Method A and Test Method B will be negatively biased by leaks between the air distribution system and the conditioned space. For Test Method—For test method A, the flow through those leaks is elevated when the distribution system is sealed biases have been estimated from the building, thereby reducing the calculated flow through the leaks between the distribution system and unconditioned spaces. field studies that compared test method leakage predictions to known measured leakage values. The correction procedure outlined in 9.2.4.6 helps typical bias is 5 to reduce this bias. Test Method B essentially assumes that all 10 % of the flow passing through leaks between the distribution system and unconditioned spaces (external leaks) is passing through the duct measured leakage air flow measurement device, which is not the case when there are distribution-system leaks to the conditioned space. There is no correction factor for flow. Higher biases generally occur at higher measured leakage values. For Test Method B, however, the magnitude bias has been estimated from field test data and analyses of the un effect of operating pressures on calculated leakage. The typical bias is much less than that associated with Test Method A. 40 % of the measured leakage air flow.

12. Keywords

12.1 air distribution; air leakage; ducts; field method

ANNEX

(Mandatory Information)

A1. DEPENDENCE OF AIR DENSITY AND VISCOSITY ON TEMPERATURE AND BAROMETRIC PRESSURE (ELEVATION)

A1.1 Use Eq A1.1 to calculate inside air density. Use Eq A1.2 to calculate outside air density. Use Eq A1.3 and A1.4 for inch-pound units.

$$\rho_{in} = 1.2041\left(1 - \frac{0.0065 \cdot E}{293}\right)^{5.2553}\left(\frac{293}{T_{in} + 273}\right) \quad (A1.1)$$

$$\rho_{out} = 1.2041\left(1 - \frac{0.0065 \cdot E}{293}\right)^{5.2553}\left(\frac{293}{T_{out} + 273}\right) \quad (A1.2)$$

where:
E = elevation above sea level (m),
ρ = air density (kg/m^3), and
T = temperature (°C).

NOTE A1.1—The standard conditions used in calculations in this standard are 20°C (68°F) for temperature, 1.2041 kg/m^3 (0.07517 lbm/ft^3) for air density, and mean sea level for elevation.

$$\rho_{in} = 0.07517\left(1 - \frac{0.0035666 \cdot E}{528}\right)^{5.2553}\left(\frac{528}{T_{in} + 460}\right) \quad (A1.3)$$

$$\rho_{out} = 0.07517\left(1 - \frac{0.0035666 \cdot E}{528}\right)^{5.2553}\left(\frac{528}{T_{out} + 460}\right) \quad (A1.4)$$

where:
E = elevation above sea level, ft,
ρ = air density, lbm/ft^3, and
T = temperature, °F.

A1.2 The dynamic viscosity μ, in Poise (gm/cm·s), at temperature T, in °C, can be obtained from Eq A1.5.

$$\mu = \frac{1.458 \times 10^{-5}\,(T + 273)^{1.5}}{T + 383} \quad (A1.5)$$

A1.3 For IP units, the dynamic viscosity μ, in lb/(ft·h), at temperature T, in °F, can be obtained from Eq A1.6:

$$\mu = \frac{2.629 \times 10^{-3}\,(T + 460)^{1.5}}{T + 659} \quad (A1.6)$$