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Standard Test Methods for Determining Air Leakage of Air Distribution Systems by Fan Pressurization¹

This standard is issued under the fixed designation E1554/E1554M; 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 The test methods included in this standard are applicable to the air distribution systems in low-rise residential and commercial buildings.

1.2 These test methods cover four techniques for measuring the air leakage of air distribution systems. The techniques use air flow and pressure measurements to determine the leakage characteristics.

1.3 The test methods for two of the techniques also specify the auxiliary measurements needed to characterize the magnitude of the distribution system air leakage during normal operation.

1.4 A test method for the total recirculating air flow induced by the system blower is included so that the air distribution system leakage can be normalized as is often required for energy calculations.

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

1.6 Three of these test methods are intended to produce a measure of the air leakage from the air distribution system to outside. The other test method measures total air leakage including air leaks to inside conditioned space.

1.7 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 7.

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

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1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

E631 Terminology of Building Constructions

E779 Test Method for Determining Air Leakage Rate by Fan Pressurization

E1258 Test Method for Airflow Calibration of Fan Pressurization Devices

2.2 *ASME Standard:*³

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

3. Terminology

3.1 *Definitions*—For definitions of general terms related to building construction used in these test methods, refer to Terminology E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *building envelope*—the boundary or barrier separating the interior volume of a building from the outside environment. Even when a garage is conditioned, for this standard it is considered to be outside the building envelope.

3.2.2 *blower*—the air moving device for a forced air space conditioning and/or ventilation system.

4. Summary of Test Methods

4.1 Four alternative measurement and analysis methods are specified and labeled A through D. Test Methods A and B give separate values for supply and return leakage to outside. Test Methods C and D do not separate supply and return leakage.

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 Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

Test Methods A, B, and C determine leakage to outside, but Test Method D measures total leakage, including leakage to inside. Test Method A is based upon changes in flow through distribution system leaks to outside due to blower operation over a range of envelope pressure differences. The envelope pressure differences are generated by a separate air moving fan and both pressurization and depressurization measurements are performed. Test Methods B and C are based upon pressurizing the distribution system at the same time as the building in order to isolate the leaks that are outside the building envelope. For Test Method B, measured system operating pressures are then used to estimate leakage under operating conditions. Test Method C determines the leakage to outside at a uniform reference pressure of 25 Pa [0.1 in. of water] instead of operating pressure, and does not separate supply and return leaks. Test Methods B and C are shown schematically in Fig. 1 and Fig. 2. Unlike Methods A, B, and C, Method D does not attempt to measure the leakage to outside under normal

operating conditions, but measures the total system leakage at a uniform reference pressure of 25 Pa [0.1 in. of water]. The schematic in Fig. 3 applies to Method D.

4.2 These test methods also include specifications for the auxiliary measurements to interpret the air leakage measurements.

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 the entry rate of 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

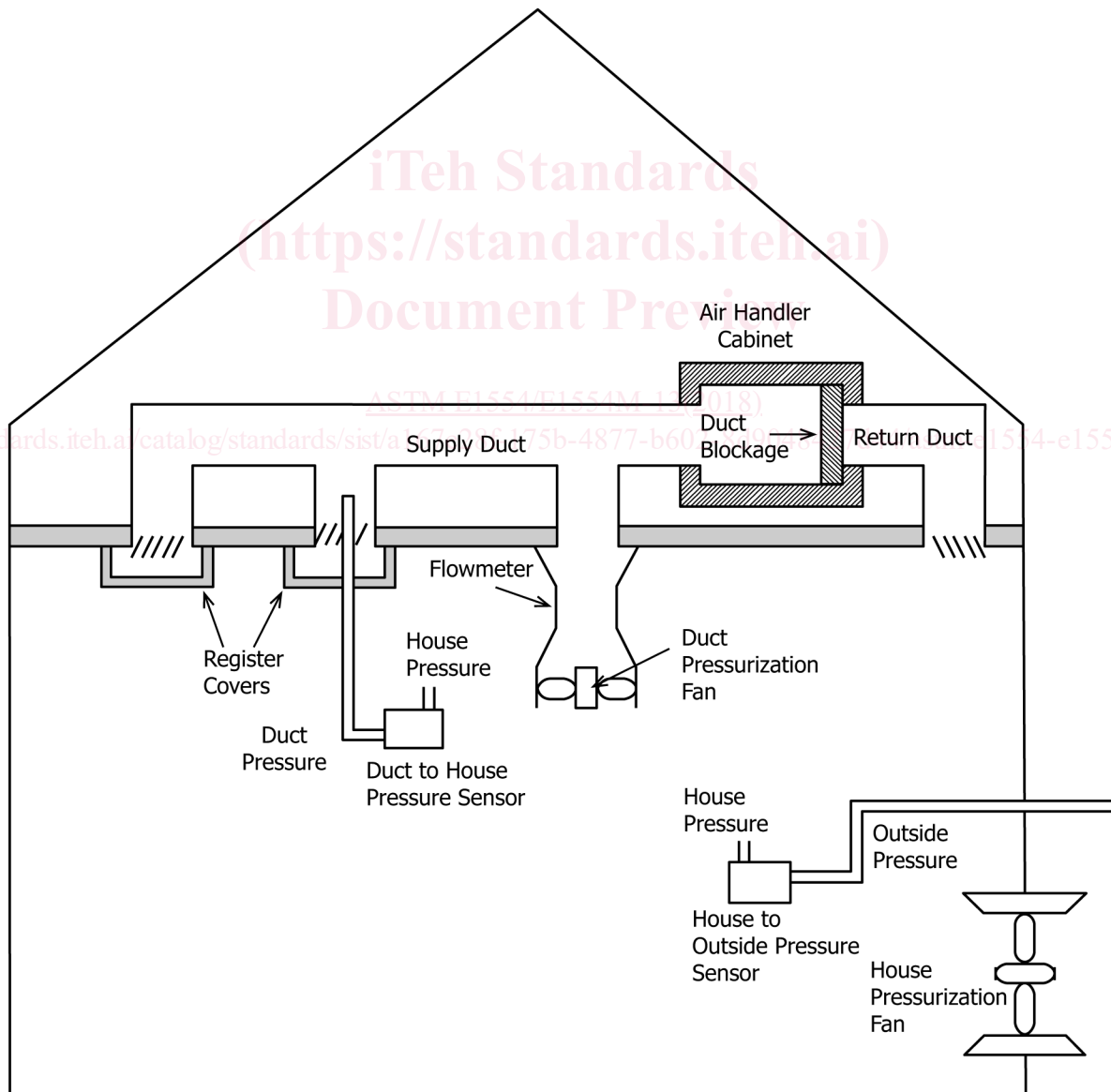


FIG. 1 Schematic of Method B—Distribution System and Building Pressurization Test (for Supply Leakage)

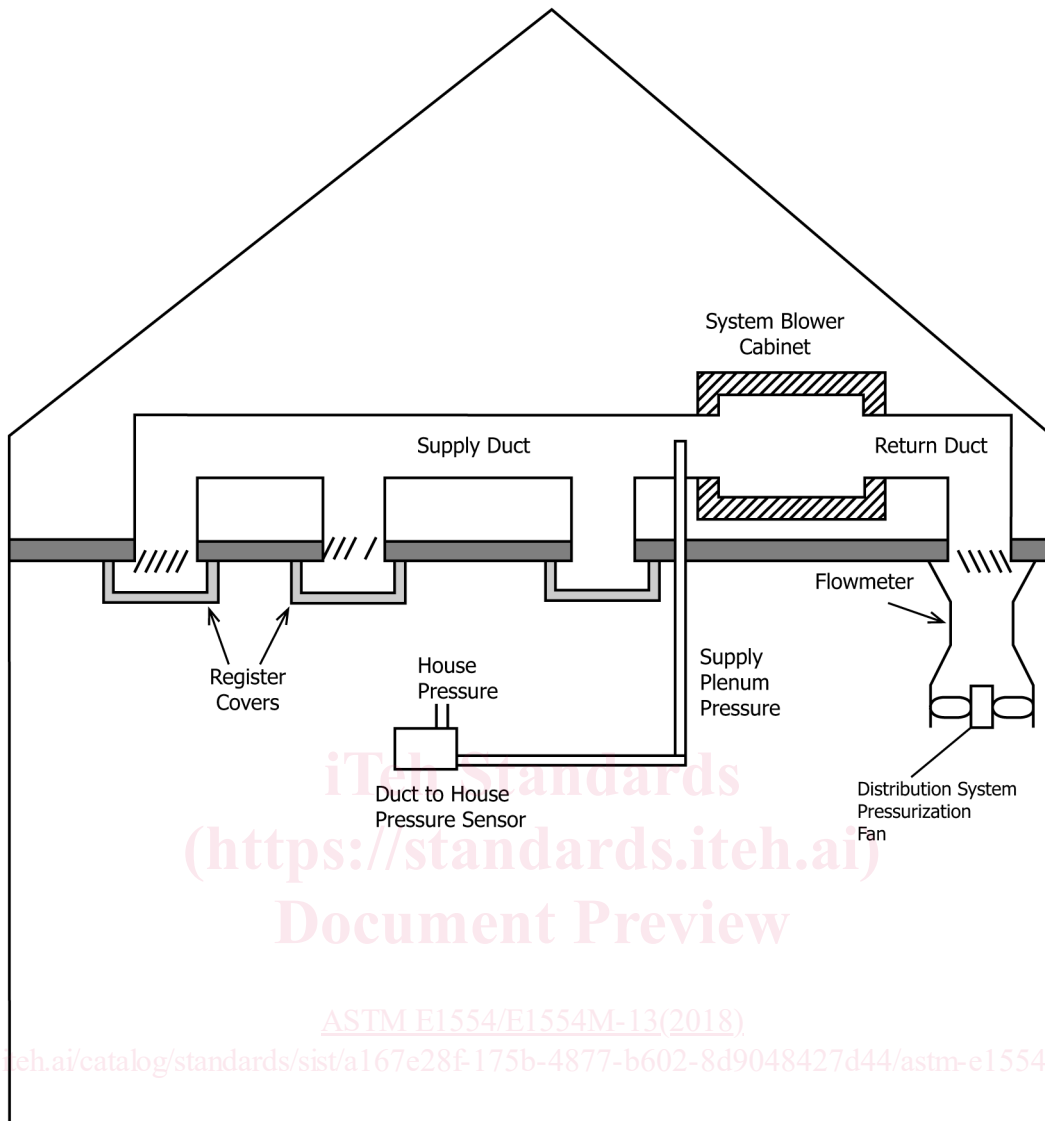


FIG. 2 Schematic of Method C—Distribution System Pressurization Test

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 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 E779). However, when the system blower is on, the pressures across the air distribution system leaks are usually significantly larger than those driving natural infiltration. Depending on the size of the leaks, these pressures can induce much larger flows than natural infiltration. Thus, it is important to be able to isolate these leaks from building envelope leaks. The leakage of air distribution systems must be

measured in the field, because it has been shown that workmanship and installation details are more important than design in determining the leakage of these systems.

5.4 For codes, standards, and other compliance or quality control applications, the precision and repeatability at meeting a specified target (for example, air flow at reference pressure) is more important than air leakage flows at operating conditions. Some existing codes, standards, and voluntary programs require the use of a simpler test method (Test Method D) that does not separate supply from return leakage, leakage to inside from leakage to outside, or estimate leakage pressures at operating conditions.

5.5 Test Methods A, B, and C can be used for energy use calculations and compliance and quality control applications. Test Method D is intended for use in compliance and quality control only.

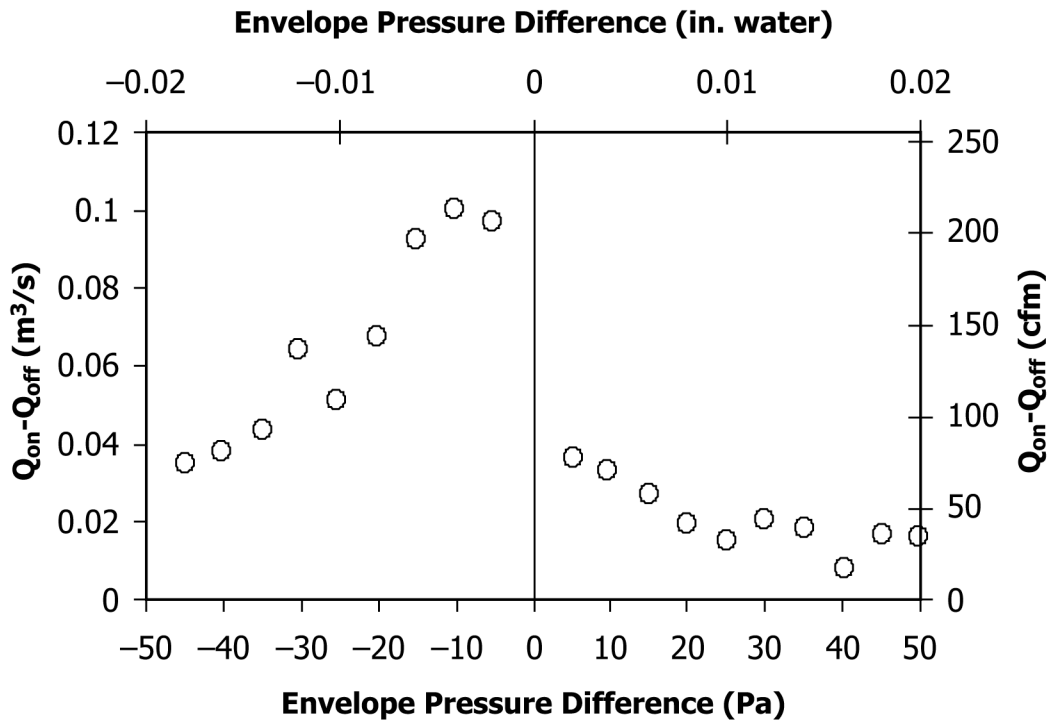


FIG. 3 Example of Air-Flow Difference and Envelope Pressure Plot for Test Method A.1

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. The items are labeled for each test method.

6.2 Major Components:

6.2.1 *Air-Moving Equipment* (A, B, and C)—A fan, blower, or blower door assembly that is capable of moving air into and out of the building at the flow rates required to create the full range of test pressure differences. The air moving equipment shall be able to accomplish both pressurization and depressurization of the building and distribution system.

6.2.2 *Air Flow-Regulating System* (A, B, and C)—A device such as a damper or variable speed motor control to regulate and maintain air flow through the air moving equipment (see 6.2.1).

6.2.3 *Air Flow Measuring Device* (A)—A device to measure airflow with an accuracy of $\pm 5\%$ of the measured flow through air moving equipment in 6.2.1. The air flow measuring system shall be calibrated in accordance with Test Method E1258 or ASME MFC-3M, whichever is applicable. The temperature dependence and range of the calibration shall be explicitly reported.

6.2.4 *Distribution System Flow Measurement Device* (B, C, and D)—A device to measure airflow with an accuracy of $\pm 5\%$ of the measured flow. The airflow measuring system shall be calibrated in accordance with Test Method E1258 or ASME MFC-3M, whichever is applicable. The temperature dependence and range of the calibration shall be explicitly reported.

6.2.5 *Pressure-Measuring Device* (All methods)—A device to measure pressure differences with an accuracy of ± 0.25 Pa [± 0.001 in. of water] or $\pm 1\%$ of measured pressure, whichever is greater.

6.2.6 *Distribution System Pressure Measuring Probe* (B, C, and D)—A probe to measure the static pressure within a distribution system under flow conditions.

6.2.7 *Air-Temperature Measuring Device* (All methods)—To give an accuracy of ± 0.5 °C [0.9 °F].

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, 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 shall 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 the building, the air-distribution system, or both. Precautions shall be undertaken such that 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 extinguishing pilot lights, flame rollout for combustion appliances and drawing sewer gas into 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.

8.1.1 *Test Method A (Flow Difference) for Air Leakage Determination*—This technique is based upon changing the flow through distribution system leaks by operating the blower fan and simultaneously pressurizing (or depressurizing) the building envelope and distribution system. There are two alternatives for gathering the required test data utilizing the same analysis procedure. Test Method A.1 records data at fixed envelope pressure stations. Test Method A.2 records data continuously as the envelope air flows and pressure are gradually changed by the envelope air moving equipment. The blower speed and heating or cooling function shall be the same for all steps of the test procedure.

8.1.2 *Test Method B: Fan Pressurization of Distribution System and Building for Air Leakage Determination*—This technique is based upon sealing the registers of the distribution system and pressurizing the system to measure the flow through the leaks at the imposed pressure difference. With the building 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 pressures. Often air distribution systems are located outside the conditioned space of a building, but are not completely outside. Example locations include attics, crawlspaces, and garages. These locations are defined as buffer zones.

8.1.3 *Test Method C: Fan Pressurization of Distribution System and Building for Air Leakage Determination at a Reference Pressure*—This technique is based upon sealing the registers of the distribution system and pressurizing the system to measure the flow through the leaks at a reference pressure difference of 25 Pa [0.1 in. of water]. With the building pressurized to the same pressure, this test isolates the leaks that are to outside only, but does not separate supply and return leaks or convert results to operating pressures.

8.1.4 *Test Method D: Fan Pressurization of Distribution System for Total Air Leakage Determination*—This technique is based upon sealing the registers of the distribution system and pressurizing the system to measure the flow through the leaks at the imposed pressure difference. The result is a total distribution system leakage at a single reference pressure difference of 25 Pa [0.1 in. of water]. This test does not separate supply and return leaks, convert to operating pressures, or isolate leaks to outside from those to inside.

8.2 *Procedure for Test Method A: Air Flow Difference*: Test Method A has four parts to the test:

- (1) Building pressurized, blower off.
- (2) Building pressurized, blower on.
- (3) Building depressurized, blower on.
- (4) Building depressurized, blower off.

8.2.1 *Environmental Measurements*—At the beginning and the end of each test, measure the outdoor temperature, indoor temperature, and barometric pressure.

8.2.2 *Building Preparation*:

8.2.2.1 *Envelope*—Open all interconnecting doors in the building. 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. The condition of openings to outside for spaces that contain ducts (for example, garage doors or basement windows) shall be recorded.

8.2.2.2 *Distribution System*—HVAC-balancing dampers and registers, in general, shall not be adjusted. However, for multiple zoned systems, the position of zonal dampers should be fixed for the duration of the test. Several tests may be performed with zone dampers fixed at different settings, but at least one of the tests shall have all zone control dampers in the fully open position.

8.2.3 *Air Flow Difference Measurements*:

8.2.3.1 Connect the air moving/flow-regulating/flow measurement assembly to the building envelope using a window or door opening. Seal or tape openings to avoid leakage at these points.

8.2.3.2 Install the envelope pressure difference sensor. The outside pressure measurement location shall be sheltered from wind and sunshine. The inside pressure measurement location shall be as far away as possible from the localized air flows induced by the air moving apparatus. All the envelope pressures use the outside pressure as the reference.

8.2.3.3 With air moving fan opening blocked, air moving fan off and blower off measure pressure difference across envelope: ΔP_{zero} .

8.2.3.4 For Test Method A.1 (Pressure Stations) follow 8.2.3.5 through 8.2.3.9. For Test Method A.2 (Ramping) follow 8.2.3.10 through 8.2.3.13.

8.2.3.5 With the blower off, turn on the air moving device and adjust the flow until there is 5 Pa [0.02 in. of water] envelope pressure difference relative to ΔP_{zero} , with the building at a higher pressure than outside (for pressurization testing). Record the envelope pressure difference (ΔP_{env}) and flow (Q_{off}) through the air-moving device at this pressure station. Only record pressure and flow readings when the pressure reading is within 1.0 Pa [0.004 in. of water] of the 5 Pa [0.02 in. of water] operating point. Multiple pressure and flow readings shall be recorded at each operating point and averaged for use in the calculation procedure. A minimum averaging time of 10 s shall be used. The ΔP_{zero} offset pressure shall be added to all target pressures. For example, if ΔP_{zero} is 2 Pa, then the first target pressure for pressurization is 7 Pa and -3 Pa for depressurization. All the air-moving device flows are positive into the building and negative if out of the building.

8.2.3.6 Repeat step 8.2.3.5, but with the envelope pressure difference, ΔP_{env} , incremented by 5 Pa each time until the envelope pressure difference is 50 Pa. At each ΔP_{env} pressure station the pressure difference must be within 1 Pa [0.004 in. of water] of the required operating point. Record the envelope pressure difference with the blower 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. At each pressure station, the blower on and off conditions must both have the same target pressure.

8.2.3.7 Turn on the blower fan and wait at least one minute for the blower to reach its operating speed. Repeat the measurements in sections 8.2.3.5 and 8.2.3.6, recording Q_{on} and ΔP_{on} at each pressure station.

8.2.3.8 Repeat 8.2.3.7, but with the building depressurized, that is, for the first point, adjust the flow through the air-moving device until there is a -5 Pa envelope pressure difference relative to ΔP_{zero} , with the building at a lower pressure than outside.

8.2.3.9 Repeat 8.2.3.8, but with the blower fan off.

8.2.3.10 With the blower off, turn on the air moving device and gradually increase the flow to a maximum envelope pressure of at least 50 Pa [0.2 in. of water] with the building at a higher pressure than outside. Continuously record the envelope pressure difference (ΔP_{env}) and flow (Q_{off}) through the air-moving device. Data may be recorded either as a single ramp up to the maximum flow or as a ramp up followed by a ramp down. The total time to acquire the data for either recording method shall be at least 90 s. Because the tightness of the building affects the maximum achievable envelope pressure, the maximum envelope pressure might not be achievable. In such cases, use the maximum envelope pressure achievable with the test equipment being used.

8.2.3.11 Turn on the blower fan and wait at least one minute for the blower to reach its operating speed. Repeat the measurements in 8.2.3.10. The ramping method (either a single ramp up or a ramp up followed by a ramp down) shall be the same for both the blower off and blower on data.

8.2.3.12 Repeat 8.2.3.11, but with the building depressurized.

8.2.3.13 Repeat 8.2.3.10, but with the blower fan off.

8.3 Procedure for Test Method B: Fan Pressurization of Distribution System and Building:

8.3.1 *Environmental Measurements*—At the beginning and the end of each fan pressurization test, measure the outdoor temperature, indoor temperature, and barometric pressure.

8.3.2 *Building Preparation:*

8.3.2.1 *Envelope*—Open all interconnecting doors in the building. 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. The condition of openings to outside for spaces that contain ducts (for example, garage doors or basement windows) shall be recorded.

8.3.2.2 *Distribution System*—HVAC-balancing dampers shall be in their fully open position during the fan pressurization tests, and their original positions shall be recorded. Registers shall not be adjusted.

8.3.3 *System and Building Pressure and Flow Measurements:*

8.3.3.1 For the system operating pressure measurements, all registers shall be unsealed and there shall be no blocking between the supply and return. Turn on the blower and insert a static pressure probe into the supply plenum, with the tip facing

into the airflow. Keep the probe clear of the direct blower discharge in the supply plenum, or any point in the plenum where excessive turbulence may be found. Measure the pressure difference between the supply plenum and outside, ΔP_s . Should a negative reading be found in the supply plenum select another measurement location, preferably further away from the blower. The pressure readings shall be averaged for a minimum of five seconds. Insert a static pressure probe into the return plenum, with the tip facing into the airflow. Keep the probe clear of any point in the plenum where excessive turbulence may be found. Measure the pressure difference between the return plenum and outside, ΔP_r . Should a positive reading be found in the return plenum, select another measurement location. The pressure readings shall be averaged for a minimum of five seconds.

8.3.3.2 Install the envelope pressure difference sensor. The outside pressure measurement location shall be sheltered from wind and sunshine. The inside pressure measurement location shall 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 window or door opening.

8.3.3.4 Separate the supply and return sections of the distribution system by inserting an air-tight blockage. If filters are installed near the entrance to the equipment or the exit of the blower cabinet, then install the blockage in the filter slot (after removing the filter). Alternatively, a blockage may be installed within the blower cabinet.

8.3.3.5 Select two supply locations: one for the distribution system 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 shall be selected to have the lowest possible air flow resistance to the supply and return plenums, respectively.

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

8.3.3.7 Adjust the distribution system flow measuring and air moving equipment to provide 25 Pa [0.1 in. of water] pressure difference between the distribution system and outside. Adjust the envelope air moving device to maintain 25 Pa (± 5 Pa) [0.1 in. of water (± 0.02 in. of water)] between the building and outside. Adjust the distribution system flow measuring and air moving equipment to maintain these pressure differences. This step may require several iterations. Record the flow through the distribution system flow measuring device ($Q_{test,s}$). Also record the envelope pressure: $\Delta P_{test,s}$.

8.3.3.8 Measure and record the pressure difference, $\Delta P_{b,s}$, between the buffer zone and the outside. If the supply distribution system ducts are in more than one buffer zone, $\Delta P_{b,s}$