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

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 and health 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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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. 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

[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, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

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/

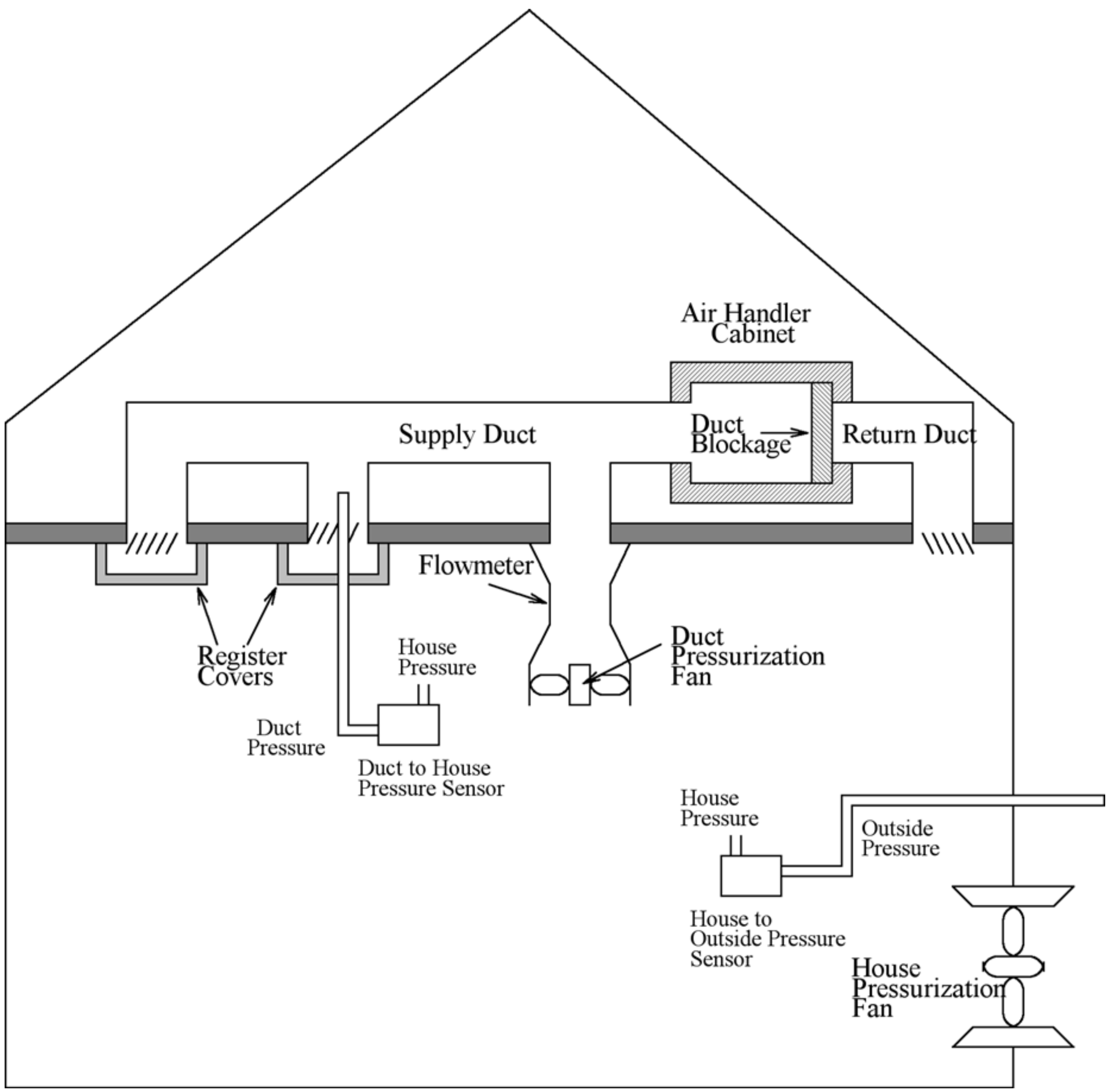

FIG. 1 Schematic of Method B—Distribution System and Building Pressurization Test (for Supply Leakage)

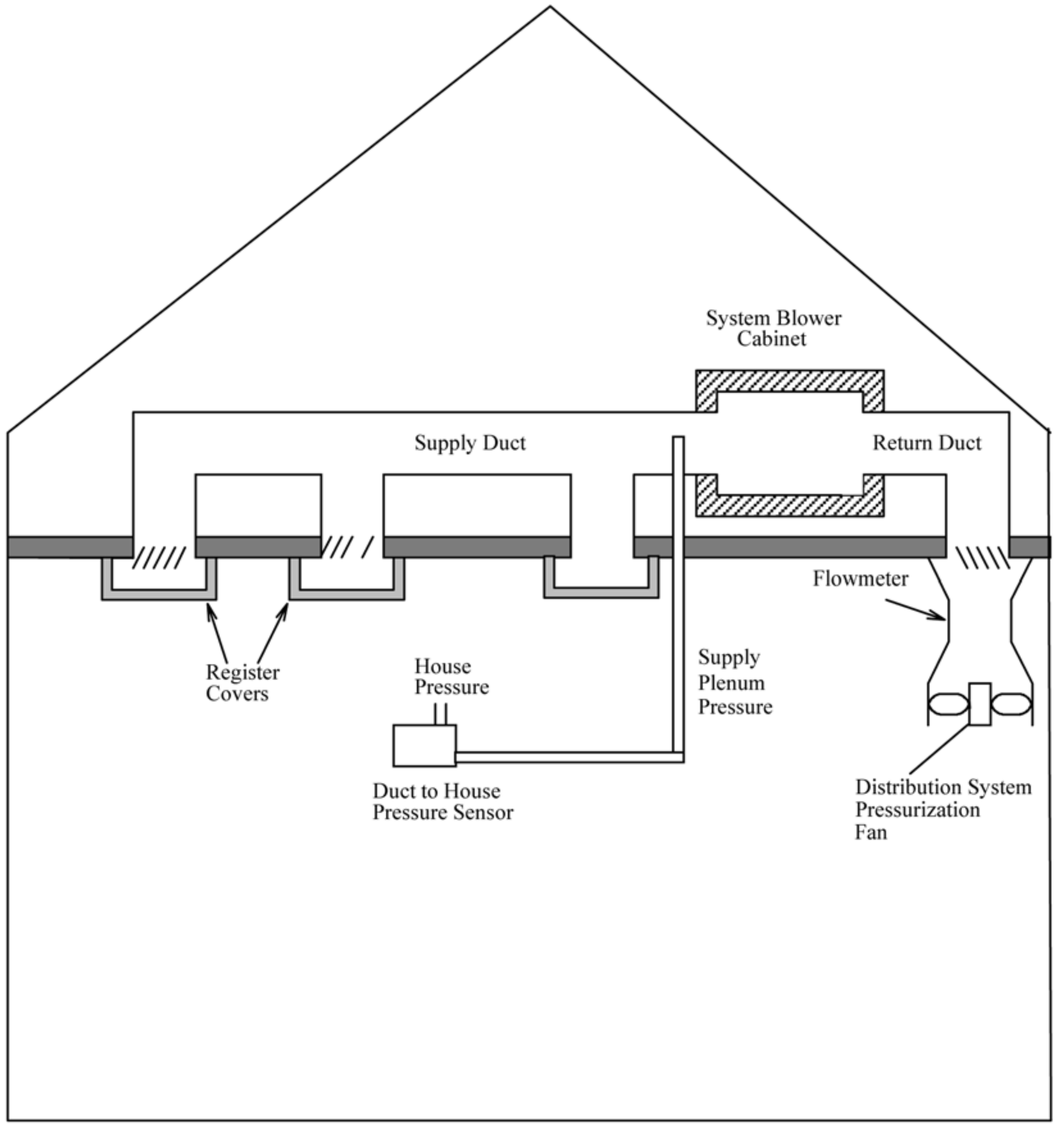

FIG. 2 Schematic of Method C—Distribution System Pressurization Test

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 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.

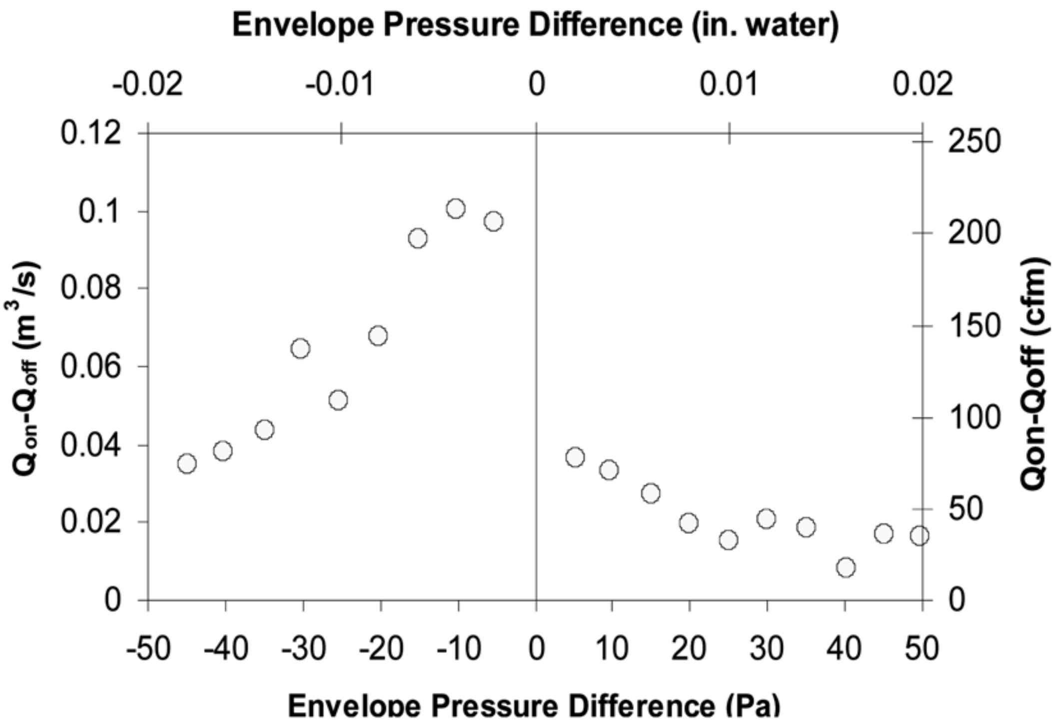

FIG. 3 Example of Air-Flow Difference and Envelope Pressure Plot for Test Method A.1

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.

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 ±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 ±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 ±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 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 seconds. 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, $\Delta P_{b,s}$ shall equal the average pressure in the buffer spaces containing supply distribution system ducts.

8.3.3.9 Attach the distribution system flow measuring and air moving equipment to the return side of the distribution system at the blower access panel if the blockage is on the supply side of the blower, or at the register selected in 8.3.3.5. Install a static pressure probe in a return register selected in 8.3.3.5. This return register shall not be the same as the register to which the distribution system flow measuring and air moving equipment is attached unless there is only a single return register for the system. Ensure that all other return registers are sealed and at least one supply register is open and supply registers are uncovered.

8.3.3.10 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 flowmeter ($Q_{test,\ r}$) and the envelope pressure: $P_{test,\ r}$.

8.3.3.11 Measure and record the pressure difference, $\Delta P_{b,r}$, between the buffer zone and the outside. If the return distribution system ducts are in more than one buffer zone, $\Delta P_{b,r}$ shall equal the average pressure in the buffer spaces containing return distribution system ducts.

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

8.4 *Procedure for Test Method C: Fan Pressurization of Distribution System and Building at a Fixed Reference Pressure for Combined Supply and Return Leaks:*

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

8.4.2 *Building Preparation:*

8.4.2.1 *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.

8.4.2.2 *Distribution System*—HVAC-balancing dampers shall be in their fully open position, and their original positions shall be recorded. Registers shall not be adjusted.

8.4.3 *Measurements: Fan Pressurixation of Distribution System and Building at a Fixed Reference Pressure:*

8.4.3.1 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.

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

8.4.3.3 Select a supply location for the static pressure probe and a return location for the distribution system pressurization device. These locations shall be selected to have the lowest possible resistance to the supply and return plemums, respectively.

8.4.3.4 Attach the distribution system flow measuring and air moving equipment to the return side of the distribution system at the blower access panel or at the register selected in 8.4.3.3. Install a distribution system pressure probe at a supply register selected in 8.4.3.3 or the supply plenum. Ensure that all other supply and return registers are sealed.

8.4.3.5 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}). Also record the envelope pressure: ΔP_{test}).

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

8.5 *Procedure for Test Method D: Fan Pressurization of Distribution System for Total Leakage*

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

8.5.2 *Building Preparation:*

8.5.2.1 *Envelope*—Open all interconnecting doors in the building. If the blower cabinet is located in a closet, the closet door shall be closed during the testing. The condition of openings to outside for spaces that contain ducts (for example, garage doors or basement windows) shall be recorded.

8.5.2.2 *Distribution System*—HVAC-balancing dampers shall be in their normal operating position.

8.5.3 *Measurements: Fan Pressurization of Distribution System:*

8.5.3.1 Install the static pressure probe at the supply plenum.

8.5.3.2 For the reference pressure, either open a door or window to outside and use the building as the reference location.

8.5.3.3 Attach the flow measuring and air moving equipment to the distribution system at a return grille or at the blower cabinet access.

8.5.3.4 Ensure that all other supply and return grilles are sealed.

8.5.3.5 Adjust the flow measuring and air moving equipment to maintain 25 Pa [0.1 in. of water] at the supply plenum. Record the air flow through the measuring device and the temperature of the air flow. If 25 Pa [0.1 in. of water] cannot be achieved, measure and record the maximum airflow and pressure difference ($Q_{test}$and ΔP_{test}).

8.5.3.6 Unseal all return and supply registers, and remove all test equipment and close any open doors or windows.

8.6 *Blower Fan Measurements:*

8.6.1 The blower fan flow is determined by blowing air through the system with flow measuring and air moving equipment at the same flow rate as under normal operating conditions. Normal operating conditions are determined by the pressure difference between the supply plenum and the building.

8.6.2 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 the building, ΔP_{sp}. 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. The static pressure probe shall be firmly attached to ensure that it does not move during the fan flow test.

8.6.3 There are two options for attaching the distribution system flow measuring and air moving equipment to the distribution system. The first option is to connect to the blower cabinet access and block the air return system from the return plenum upstream of the blower fan. The second option may be used if there is a single return grille, and the return leakage (or combined supply and return leakage for test methods D and E) is less than 5 % of the blower air flow. For the second option, the flow measuring and air moving equipment may be connected to the return grille. When using the second option, the return leakage must be added to the measured air flow at the return grille to obtain the blower flow.

8.6.4 Turn on the blower fan and wait for at least one minute for the blower to reach its operating speed. Turn on the distribution system flow measuring and air moving equipment and adjust the flow until the pressure between supply plenum and the building matches ΔP_{sp} (Pa [inches water]) as closely as possible. If ΔP_{sp} cannot be reached, record the maximum flow and pressure attainable with the test equipment.

8.6.5 Record the flow through the flowmeter, Q_{meas} and the coincident pressure difference ΔP_{meas}.

9. Calculation

9.1 *Test Methods A.1 and A.2: Flow Difference:*

9.1.1 Unless the airflow measuring system gives volumetric flows at the barometric pressure and the temperatures of the air flowing through the flowmeter during the test, then these readings shall 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) to volumetric air flows at the temperature and barometric pressure (due to elevation changes only) of the outside air for depressurization tests or of the inside air for pressurization tests (see Annex A1). To convert the airflow rate through the air flow meter to air leakage rate through the envelope for depressurization, Eq 1 shall be used.

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

where:

ρ_{in} = the indoor air density, kg/m^3 (lb/ft^3);
ρ_{out} = the outdoor air density, kg/m^3 (lb/ft^3);
Q = the volumetric flow through the air flow meter; and
Q_0 = the volumetric flow through the envelope.

To convert the airflow rate to air leakage rate for pressurization, Eq 2 shall be used.

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

9.1.3 Subtract ΔP_{zero} from the measured envelope pressures at each pressure station (ΔP_{env}) to determine the corrected envelope pressures (ΔP).

9.1.4 For Test Method A.2, bin data for each of the four ramps separately using the envelope pressure difference. The bins shall not be larger than 5 Pa [0.02 in. of water] wide. Within each bin, average the envelope flows and pressures.

9.1.5 Determine the envelope leakage coefficient and pressure exponent, n_{env}, by fitting the blower fan off pressure and flow data to the power law function using the same analysis as for building pressurization leakage testing in Test Method E779.

9.1.6 For Test Method A.2, bin data for each of the four ramps separately using the envelope pressure difference. The bins shall not be larger than 5 Pa [0.02 in. of water] wide. For Test Method A.2, each bin shall have at least five data points for both blower on and blower off.

9.1.7 Adjust the flows to be at exactly the same pressures. For Test Method A.1, the measured flow with the blower off shall be corrected to the flow at the same pressure as when the blower is on at each pressure station, using Eq 3.

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

For Test Method A.2, there are two alternatives for adjusting flows to be at exactly the same envelope pressures. The first is to average the envelope pressures and flows in each bin. The measured flow with the blower off shall be corrected to the flow at the same pressure as when the blower is on at each pressure station, using Eq 3. The second alternative is to perform a linear regression to the data in each bin and determine the flow at the mid-point pressure of each bin from this linear regression.

9.1.8 Calculate the flow difference (ΔQ) at each pressure station/bin by subtracting Q_{off} from Q_{on}.

9.1.9 Do a least squares fit of the ΔP and ΔQ pairs from each pressure station/bin to Eq 4 to determine supply leakage (Q_s) and return leakage (Q_r), and the characteristic pressures (ΔP_s and ΔP_r). Note that some of the pressure ratios (and 1 ± the pressure ratios) will be negative. In these cases take the absolute value to the power 0.6 in Eq 4 and carry the sign outside the exponent term. The least squares fitted pressures shall be constrained to a low limit of twice the lowest ΔP pressure station/bin and a high limit of 100 Pa [0.4 in. of water].

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

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

9.1.10 Plot the flow difference and envelope pressures. For Test Method A.1, an example plot is shown in Fig. 3.

9.1.11 For Test Method A.2, an example plot is shown in Fig. 4.

9.2 *Test Method B: Fan Pressurization of Distribution System and Building:*

9.2.1 Unless the airflow measuring system gives volumetric flows at the pressure and the temperatures of the air flowing through the flowmeter during the test, then these readings shall be converted using information obtained from the manufacturer for the change in calibration with these parameters.

9.2.2 The 25 Pa [0.1 in. of water] distribution system leakage flows ($Q_{25,\ s}$ and $Q_{25,\ r}$ [$Q_{0.1,\ s}$ and $Q_{0.1,\ r}$]) shall be converted to leakage flows at operating conditions using Eq 5 and Eq 6.

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

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

9.3 *Test Method C: Fan Pressurization of Distribution System and Building at a Reference Pressure:*

9.3.1 Unless the airflow measuring system gives volumetric flows at the pressure and the temperatures of the air flowing through the flowmeter during the test, then these readings shall be converted using information obtained from the manufacturer for the change in calibration with these parameters.

9.3.2 If 25 Pa [0.1 in. of water] was not achieved, adjust the measured airflow and pressure difference (Q_{test} and P_{test}) to 25 Pa [0.1 in. of water] using Eq 7 and Eq 8.

$$Q_{25} = Q_{test}\left(\frac{25}{\Delta P_{test}}\right)^{0.6} \quad (7)$$

$$Q_{0.1} = Q_{test}\left(\frac{0.1}{\Delta P_{test}}\right)^{0.6} \quad (8)$$

9.4 *Test Method D: Fan Pressurization of Distribution System for Total Leakage*

9.4.1 Unless the airflow measuring system gives volumetric flows at the pressure and the temperatures of the air flowing through the flowmeter during the test, then these readings shall be converted using information obtained from the manufacturer for the change in calibration with these parameters.

9.4.2 If 25 Pa [0.1 in. of water] was not achieved, adjust the measured airflow and pressure difference (Q_{test} and P_{test}) to 25 Pa [0.1 in. of water] using Eq 7 and Eq 8.

9.5 *Blower Flow:*

9.5.1 Unless the airflow measuring system gives volumetric flows at the pressure and the temperatures of the air flowing through the flowmeter during the test, then these readings shall be converted using information obtained from the manufacturer for the change in calibration with these parameters.

9.5.2 Using the first measurement option, with Q_{meas} determined at the blower access, the measured flow and coincident plenum pressures shall be used to determine the distribution-system flow at operating conditions using Eq 9:

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

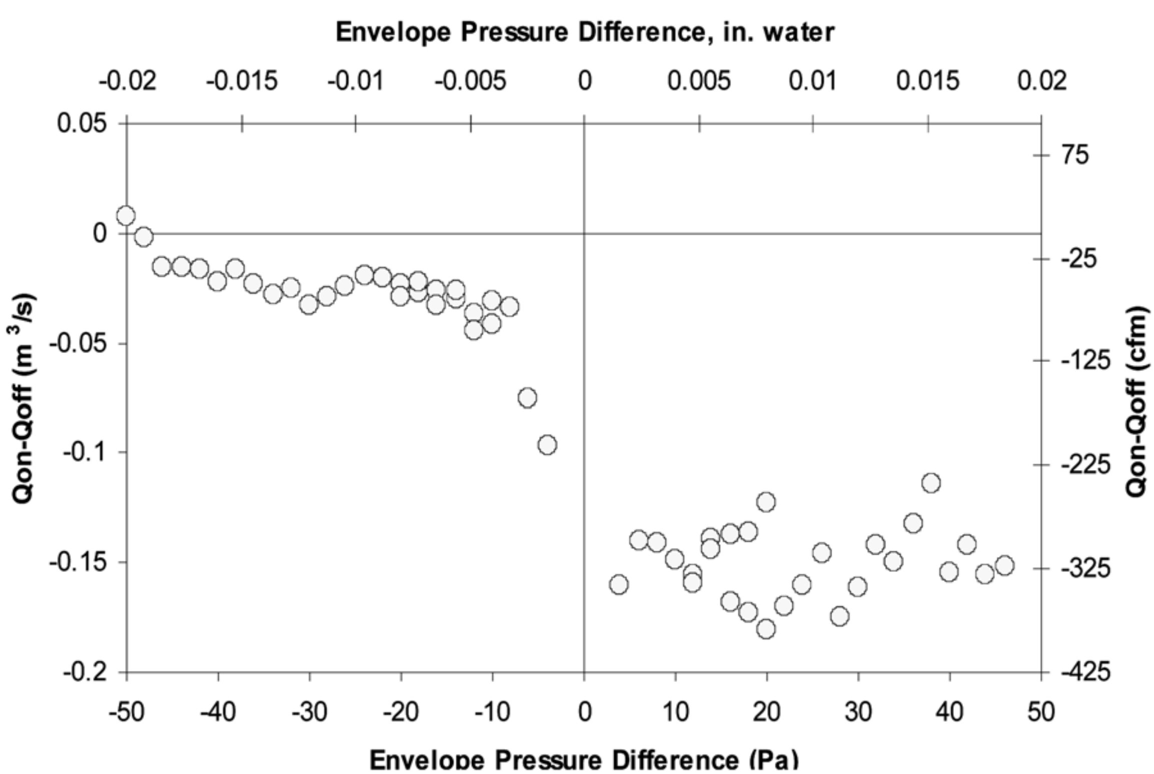

FIG. 4 Example of Air-Flow Difference and Envelope Pressure Plot for Test Method A.2

9.5.3 Using the second measurement option, with Q_{meas} determined at the return grille, the measured blower flow, coincident plenum pressures and duct leakage flow shall be used to determine the distribution-system flow at operating conditions using Eq 10 for Test Methods A and B, and Eq 11 and Eq 12 for test Methods C and D.

$$Q_e = Q_{meas}\left(\frac{\Delta P_{sp}}{\Delta P_{meas}}\right)^{0.5} + Q_r \quad (10)$$

$$Q_e = Q_{meas}\left(\frac{\Delta P_{sp}}{\Delta P_{meas}}\right)^{0.5} + \frac{Q_{25}}{2} \quad (11)$$

$$Q_e = Q_{meas}\left(\frac{\Delta P_{sp}}{\Delta P_{meas}}\right)^{0.5} + \frac{Q_{0.1}}{2} \quad (12)$$

10. Report

10.1 Report at least the following information:

10.1.1 *Building Description:*

10.1.1.1 *Location and Construction:*

(1) Date built (estimate if unknown),

(2) Street address (including city, state/province/county and country),

(3) Floor area of building, attic, basement, and crawlspace,

(4) Volume of building, attic, basement, and crawlspace, and

(5) Elevation above sea level.

10.1.1.2 *Condition of Openings in Exterior Shell:*

(1) Doors (including storm doors),

(2) Windows (including storm windows), latched or unlatched,

(3) Ventilation openings, dampers closed or open,

(4) Chimneys, dampers closed or open, and

(5) Condition of openings during test (for example, broken windows, HVAC-louver settings, and so forth).

(6) Condition of openings to outside for spaces that contain ducts (for example, garage doors or basement windows).

10.2 *HVAC System:*

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

(2) Status of heating or cooling equipment during testing, and

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

10.3 *Leakage Measurements:*

10.3.1 Technique employed (Test Method A, B, C, or D),

10.3.2 Equipment used,

10.3.3 Calibration of air flow meter, and

10.3.4 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). A list of conversion factors used in 9.1.2 (For test Method A only).

10.4 *Air Leakage Results:*

10.4.1 *Test Method A: Flow Difference:*

10.4.1.1 A tabular listing of all air leakage data (including time, flows and all pressures).

10.4.1.2 Plot(s) of change in flow with changing envelope pressure difference.

10.4.1.3 A list of conversion factors used in 9.1.2.

10.4.1.4 Supply and return distribution-system leakage flows.

10.4.1.5 Flow difference and envelope pressure plot.

10.4.2 *Test Method B: Fan Pressurization of Distribution System and Building:*

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

10.4.2.2 Supply and return distribution system operating pressures.

10.4.2.3 Supply and return distribution system leakage flows at operating conditions.

10.4.3 *Test Method C: Fan Pressurization of Distribution System at a Reference Pressure:*

10.4.3.1 Measured total leakage to outside at 25 Pa [0.1 in. of water].

10.4.4 *Test Method D: Fan Pressurization of Distribution System:*

10.4.4.1 Measured total leakage at 25 Pa [0.1 in. of water].

10.4.5 *Blower Flow:*

10.4.5.1 Measured system operating pressure difference between supply plenum and building.

10.4.5.2 Measured flow required to match this pressure, or the maximum flows and pressures achieved during the test.

10.4.5.3 Calculated blower flow if pressure matching not achieved. If pressure match is not achieved, this must be clearly stated in the report.

10.5 *Test Identification:*

10.5.1 Date the test was performed.

10.5.2 Name and address of organization performing the test.

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

11. Precision and Bias

11.1 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 Test Methods A and B, the precision will be worse for tests conducted at higher wind speeds due to greater fluctuation in envelope air flows and pressures. For Test Method A, the precision will be worse for leakier buildings. For test method A two correction factors have been developed to reduce biases at high leakage (Dickerhoff et al, 2004).[4] These correction factors are discussed in Annex A2.

12. Keywords

12.1 air distribution; air leakage; distribution system; ducts; field method

[4] Dickerhoff, D.J., Walker, I.S. and Sherman, M.H. (2004), "Validating and Improving the DeltaQ Duct Leakage Test", ASHRAE Transactions, Vol. 110, Pt. 2., pp.741-751, ASHRAE, Atlanta, GA., LBNL 53959.

ANNEXES

(Mandatory Information)

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

A1.1 Use Eq A1.1 and Eq A1.2 to calculate inside air density. 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.

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

where:

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

$$\rho = 0.07517\left(1 - \frac{0.0035666 \cdot E}{528}\right)^{5.2553}\left(\frac{528}{T+460}\right) \quad (A1.2)$$

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 A1.3.

$$\mu = \frac{1.458 \times 10^{-5}\,(T+273)^{1.5}}{T+383} \quad (A1.3)$$

A1.3 For IP units, the dynamic viscosity μ, in lb/(ft·h), at temperature T, in °F, can be obtained from Eq A1.4:

$$\mu = \frac{2.629 \times 10^{-3}\,(T+460)^{1.5}}{T+659} \quad (A1.4)$$

A2. CORRECTION FACTORS FOR TEST METHOD A

A2.1 For Test Method A, two correction factors have been developed to reduce biases at high leakage. The first accounts for imbalances between supply and return leakage. A pressure offset shall be calculated using Eq A2.1.

$$P_{offset} = \left(\frac{Q_r - Q_s}{C_{env}}\right)^{\frac{1}{n_{env}}} \quad (A2.1)$$

A2.1.1 Where Q_r and Q_s are from the calculations in 9.1.7. C_{env} is the envelope leakage coefficient and n_{env} is the envelope pressure exponent. C_{env} and n_{env} are determined from a least squares fit to the blower off envelope flows and pressures using Eq A2.2 and the calculation procedures given in Test Method E779.

$$Q_{off} = C_{env}(P_{off})^{n_{env}} \quad (A2.2)$$

A2.2 P_{offset} shall be used in Eq A2.3 and Eq A2.4 to determine corrected values for supply and return leakage.

$$Q_{s,corrected} = Q_s\left(1 + \frac{P_{offset}}{P_s}\right)^{0.6} \quad (A2.3)$$

$$Q_{r,corrected} = Q_r\left(1 + \frac{P_{offset}}{P_r}\right)^{0.6} \quad (A2.4)$$

A2.3 The second correction factor accounts for pressure changes in the duct system due to the air flow resistance of the duct system. At each pressure station, a pressure correction shall be calculated for both the blower on and blower off, and for both supply and return for a total of four pressure correction terms: δP_s^{on}, δP_r^{on}, δP_s^{off}, and δP_r^{off}.

A2.4 For the blower off corrections, Eq A2.5 and Eq A2.6 shall be used to calculate the pressure correction terms at each pressure station.

$$\delta P_s^{off} = \frac{P\left(\frac{Q_s}{Q_e}\right)^{\frac{1}{0.6}}}{\left(1 - \frac{Q_s}{Q_e}\right)^{\frac{1}{0.6}} + \left(1 - \frac{Q_s}{Q_e}\right)^{\frac{1}{0.6}}} \quad (A2.5)$$

$$\delta P_r^{off} = \frac{P\left(\frac{Q_r}{Q_e}\right)^{\frac{1}{0.6}}}{\left(1 - \frac{Q_r}{Q_e}\right)^{\frac{1}{0.6}} + \left(1 - \frac{Q_r}{Q_e}\right)^{\frac{1}{0.6}}} \quad (A2.6)$$

A2.5 For the blower on corrections, Eq A2.7 and Eq A2.8 shall be used to calculate the pressure correction terms at each pressure station.

$$\frac{\delta P_s^{on}}{P_s} = 1 - \left(\frac{\left(2 - 2\frac{Q_s}{Q_e}\right) - \left[\left(2\frac{Q_s}{Q_e} - 2\right)^2 - 4\left(1 - 2\frac{Q_s}{Q_e}\right)\left(1 - \left(\frac{Q_s}{Q_e}\right)^2 \frac{P}{P_s}\right)\right]^{0.5}}{2\left(1 - 2\frac{Q_s}{Q_e}\right)}\right)^2 \quad (A2.7)$$

$$\frac{\delta P_r^{on}}{P_r} = \left(\frac{\left(2 - 2\frac{Q_r}{Q_e}\right) - \left[\left(2\frac{Q_r}{Q_e} - 2\right)^2 - 4\left(1 - 2\frac{Q_r}{Q_e}\right)\left(1 - \left(\frac{Q_r}{Q_e}\right)^2 \frac{P}{P_r}\right)\right)^{0.5}}{2\left(1 - 2\frac{Q_r}{Q_e}\right)} \right)^2 - 1 \quad \text{(A2.8)}$$

Where the notation [) is defined in Eq A2.9.

$$[x)^n = x(|x|)^{(n-1)} \quad \text{(A2.9)}$$

A2.6 The blower on and off correction terms shall be used in Eq A2.10. Eq A2.10 shall be used in place of Eq 4.

$$\Delta Q(P) = \left[\left[1 + \frac{P - \delta P_s^{on}}{P_s}\right)^{n_s} - \left[\frac{P - \delta P_s^{off}}{P_s}\right)^{n_s}\right] \quad \text{(A2.10)}$$

$$-Q_r\left[\left[1 - \frac{P - \delta P_r^{on}}{P_r}\right)^{n_r} + \left[\frac{P - \delta P_r^{off}}{P_r}\right)^{n_r}\right]$$

A2.7 Because Q_s and Q_r are used in the correction factors, the corrections require an iterative solution. In practice, only a couple of iterations are required.