Designation: E 1554 – 03

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 air handler fan.

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

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

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

1.6 *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.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 631 Terminology of Building Constructions

E 741 Test Method 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.

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

3.1.4 *conditioned space*—the portion of a building whose air temperature or humidity is intentionally controlled for human occupancy.

4. Summary of Test Methods

4.1 Two alternative measurement and analysis procedures are specified. The first of these techniques, Test Method A, is based upon changes in 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 depressurization measurements are performed. The second technique, Test Method B, is based upon pressurizing the 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 Method B is shown schematically in Fig. 1.

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

[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.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

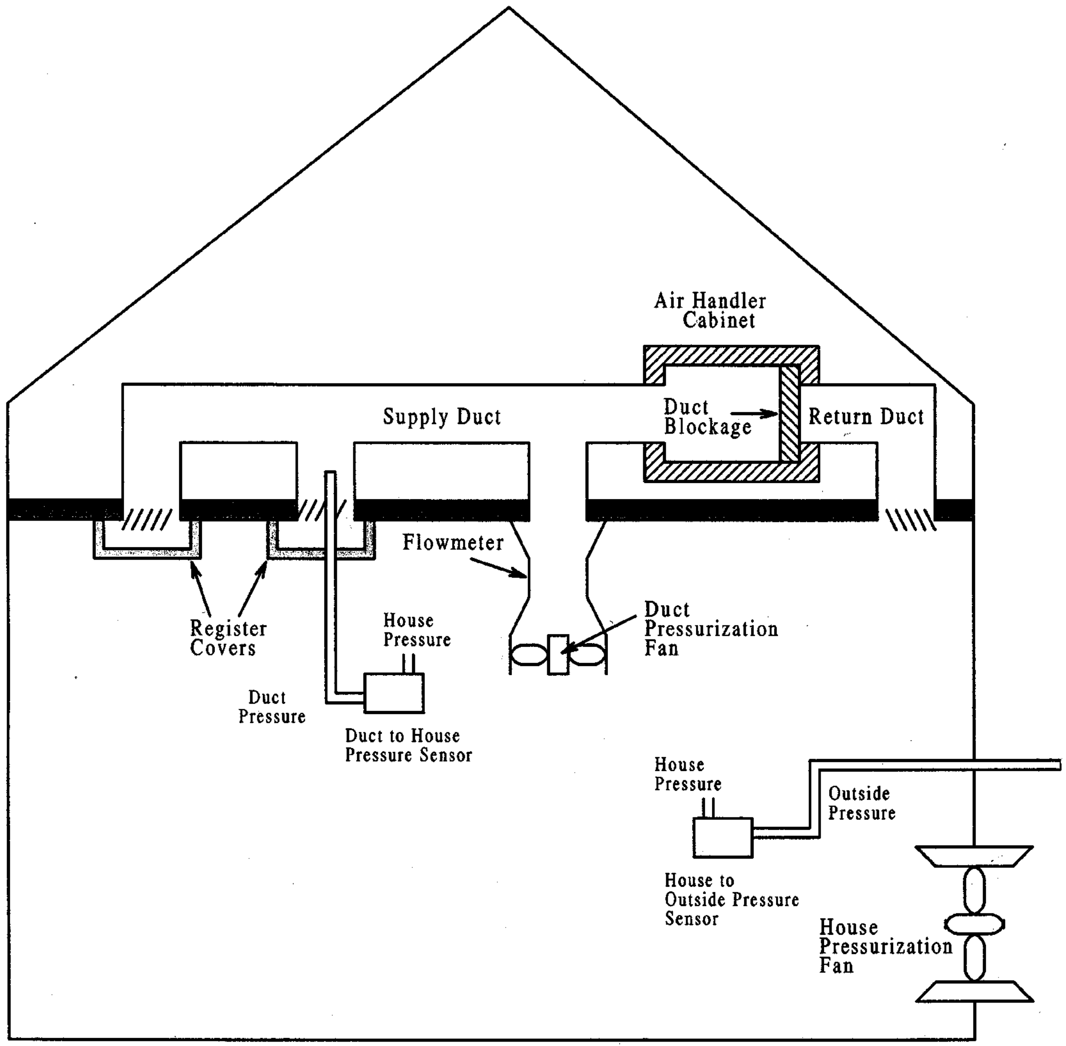

FIG. 1 Schematic of Method B—Duct Pressurization Test (for Supply Leakage)

distribution-system air leakage during normal system operation and measurement of the air handler fan 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 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 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 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. Due to the different impacts of supply-side and return-side distribution-system leaks, these two air leakage pathways 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. 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 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 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 Combined with the fan pressurization method for measuring envelope leakage (Test Method E 779) there are several advantages over the tracer dilution method. The methods described in this standard produce results that characterize the air tightness of the building envelope and the air distribution systems. The methods described in this standard are used to compare the relative air 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 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 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 (up to 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 *Air Flow Measuring Device* (A only)—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 E 1258 or ASME MFC-3M, whichever is applicable. The temperature dependence and range of the calibration shall be 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 shall be calibrated in accordance with Test Method E 1258 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* (A and B)—A manometer or pressure indicator to measure pressure differences with an accuracy of ±0.25 Pa (±0.001 in. H_2O) or ±1 % of measured pressure, whichever is greater.

6.2.6 *Duct Pressure Measuring Probe* (B only)—A probe to measure the static pressure within a duct under flow conditions.

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

6.2.8 *Simultaneous Pressure and Flow Measurement System* (A 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).

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 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 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 fan flows during normal 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 changing the flow through distribution system leaks by operating the air handler fan and simultaneously pressurizing (and depressurizing) the building envelope and distribution system.

8.1.2 *Test Method B (Fan Pressurization) for Air Leakage Determination*—This technique is based upon sealing the registers of the distribution system and pressurizing the system to measure the flow out through the leaks at the 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 will have lower operating condition air leakage flow uncertainties for leaky systems than Test Method B, due to uncertainties in Test Method B when converting to operating system pressures. Test Method B will be preferred for houses that have very leaky envelopes, where the changes in envelope pressures and flows used in Test Method A will result in greater uncertainties, or if testing to determine compliance with 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 test, measure the outdoor temperature and indoor temperature.

8.2.2 *Building Preparation*:

8.2.2.1 *Envelope*—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.

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 should have all zone control dampers in the fully open position.

8.2.3 *Test Method A: 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 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. 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 air handler fan off measure pressure difference across envelope: ΔP_{zero}.

8.2.3.4 With the air handler fan off, turn on the air moving device and adjust the flow until there is 5 Pa (0.02 in. of water) envelope pressure difference, with the house 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. It is recommended that multiple pressure and flow readings are recorded at each operating point and averaged for use in the calculation procedure. 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 out of the house and negative if into the house.

8.2.3.5 Repeat step 8.2.3.4, 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 air 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. At each pressure station, the air handler fan on and off conditions must both have the same target pressure.

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

8.2.3.7 Repeat 8.2.3.6, but with the house depressurized, that is, for the first point, adjust the flow through the air-moving device until there is a -5 Pa envelope pressure difference, with the house at a lower pressure than outside.

8.2.3.8 Repeat 8.2.3.7, but with the air 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 outdoor temperature and indoor temperature.

8.3.2 *Building Preparation*:

8.3.2.1 *Envelope*—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.

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, in general, shall not be adjusted.

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

8.3.3.1 The system operating pressures shall be measured by using the half plenum pressure technique. For the system operating pressure tests, all registers shall be unsealed and there shall be no blocking between the 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 the direct air handler fan discharge in the supply plenum, or any point in the plenum where excessive turbulence may be found. Should a negative reading be found in the supply plenum, select another measurement location, preferably further away from the air handler fan. The pressure readings shall be averaged for five seconds. Measure ΔP_r by inserting a static pressure probe into the 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 readings shall be averaged for five seconds.

8.3.3.2 Install the envelope pressure difference sensor. 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 window or door opening.

8.3.3.4 Separate the supply and return sections of the duct system by inserting an air-tight blockage. If filters are installed near the entrance to the equipment or 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 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 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 building and outside. Adjust the duct flow measuring and air moving equipment to maintain zero pressure (±0.5 Pa [±0.002 in. water]) between supply ducts and the building, and 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 the supply leakage flow at 25 Pa [0.1 in. water]. Also record the envelope pressure: $P_{test,s}$.

8.3.3.8 Record the pressure difference, $\Delta P_{b,\ s}$, between the buffer zone and the outside. If the supply ducts are in more than one buffer zone, $\Delta P_{b,\ s}$ shall 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 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 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 duct 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.

8.3.3.10 Adjust the envelope air-moving fan until the pressure between the building and outside is 25 Pa [0.1 in. water]. Adjust the duct flow measuring and air moving equipment to maintain zero pressure (±0.5 Pa [±0.002 in. water]) between return ducts and the building and the envelope air moving fan 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 flowmeter ($Q_{25,\ r}[Q_{0.1,\ r}]$)—this is the return leakage flow at 25 Pa [0.1 in. water]. Also record the envelope pressure: $P_{test,\ r}$.

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

8.4.1 The air handler 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 conditioned space.

8.4.2 With the air handler fan on, measure the pressure difference between supply plenum and conditioned space (ΔP_{sp}). The static pressure probe must be firmly attached to ensure that it does not move during the fan flow test.

8.4.3 Block the return duct from the return plenum upstream of the air handler fan.

8.4.4 Attach the duct flow measuring and air moving equipment to the duct system at the air handler. Do not mount the duct flow measuring and air moving equipment directly on the air handler cabinet. Ensure that there is at least six feet of connecting duct between the duct air moving fan and the connection to the air handler cabinet.

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

8.4.6 Record the flow through the flowmeter, Q_{meas}, (m^3/s [cfm]), and the coincident pressure difference ΔP_{meas}.

9. Calculation

9.1 *Test Method A: Flow Difference Measurements*:

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 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 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 flowmeter to air leakage rate through the envelope for depressurization, use

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

where:

ρ_{in} = the indoor air density, kg/m^3 (lb/ft^3), and
ρ_{out} = the outdoor air density, kg/m^3 (lb/ft^3).

To convert the airflow rate to air leakage rate for pressurization, use

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

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 Determine the envelope leakage coefficient and pressure exponent, n_{env}, by fitting the air handler fan off pressure and flow data to the power law function using the same analysis as for house pressurization leakage testing in Test Method E 779.

9.1.5 Adjust the flows to exactly match pressures. The measured flow with the system off is corrected to the flow at the same pressure as when the system is on at each pressure station, using Eq 3.

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

9.1.6 Calculate the flow 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 Q_{on} from 8.2.3.4 and 8.2.3.5. For flow differences during depressurization data, use Q_{off} from 8.2.3.8 and Q_{on} from 8.2.3.7.

9.1.7 Do a least squares fit of the ΔP and ΔQ pairs from each pressure station 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 3 and carry the sign outside the exponent term.

$$\Delta Q(P) = \tag{4}$$
$$Q_s\left[\left(1+\frac{\Delta P}{\Delta P_s}\right)^{0.6} - \left(\frac{\Delta P}{\Delta P_s}\right)^{0.6}\right] - Q_r\left[\left(1-\frac{\Delta P}{\Delta P_r}\right)^{0.6} + \left(\frac{\Delta P}{\Delta P_r}\right)^{0.6}\right]$$

9.1.8 Plot the flow difference and envelope pressures. An example plot is shown in Fig. 2.

9.2 *Test Method B: Fan Pressurization Measurements*:

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 must 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. water] duct 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 the following equations.

For SI:

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

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

For IP:

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

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

9.3 *Air Handler Fan Flow*:

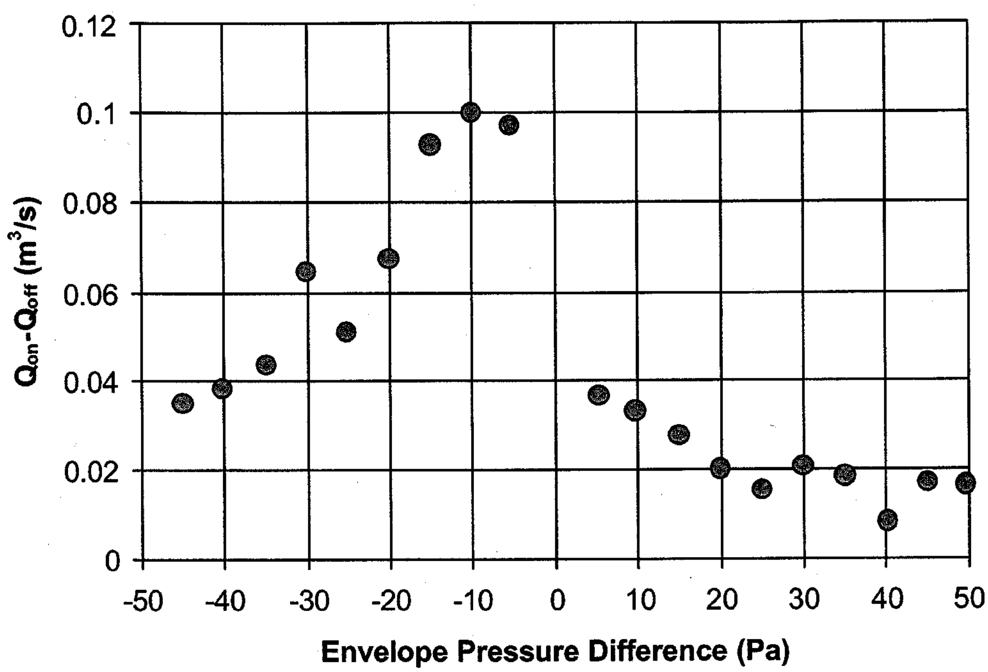

FIG. 2 Example of Air-Flow Difference and Envelope Pressure Plot for Test Method A

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 must be converted using information obtained from the manufacturer for the change in calibration with these parameters.

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

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

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 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*:

(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).

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 (that is, Test Method A or Test Method B),

10.3.2 Equipment used,

10.3.3 Calibration of air flowmeter, 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); and 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 Supply and return distribution-system leakage flows.

10.4.1.2 Flow difference and envelope pressure plot (see Fig. 2).

10.4.2 *Test Method B: Fan Pressurization*:

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 *Air Handler Fan Flow*:

10.4.3.1 Measured system operating pressure difference between supply plenum and conditioned space.

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

10.4.3.3 Calculated air handler fan 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 *Precision*—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 has been estimated from field test results where the systems were tested several times. The results of these tests indicate that the precision errors are in the range of 0.0009 to 0.0047 m^3/s (2 to 10 cfm). For Test Method B, the precision has been estimated from field test results where the systems were tested several times. The results of these tests indicate that the precision errors are 0.0024 to 0.0071 m^3/s (5 to 15 cfm).

11.2 *Bias*—For test method A, the biases have been estimated from field studies that compared test method leakage predictions to known measured leakage values. The typical bias is 5 to 10 % of the measured leakage air flow. Higher biases generally occur at higher measured leakage values. For Test Method B, the bias has been estimated from field test data and analyses of the effect of operating pressures on calculated leakage. The typical bias is 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.

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

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

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.

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

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

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.

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

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:

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