Designation: E 1554 – 03

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

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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.

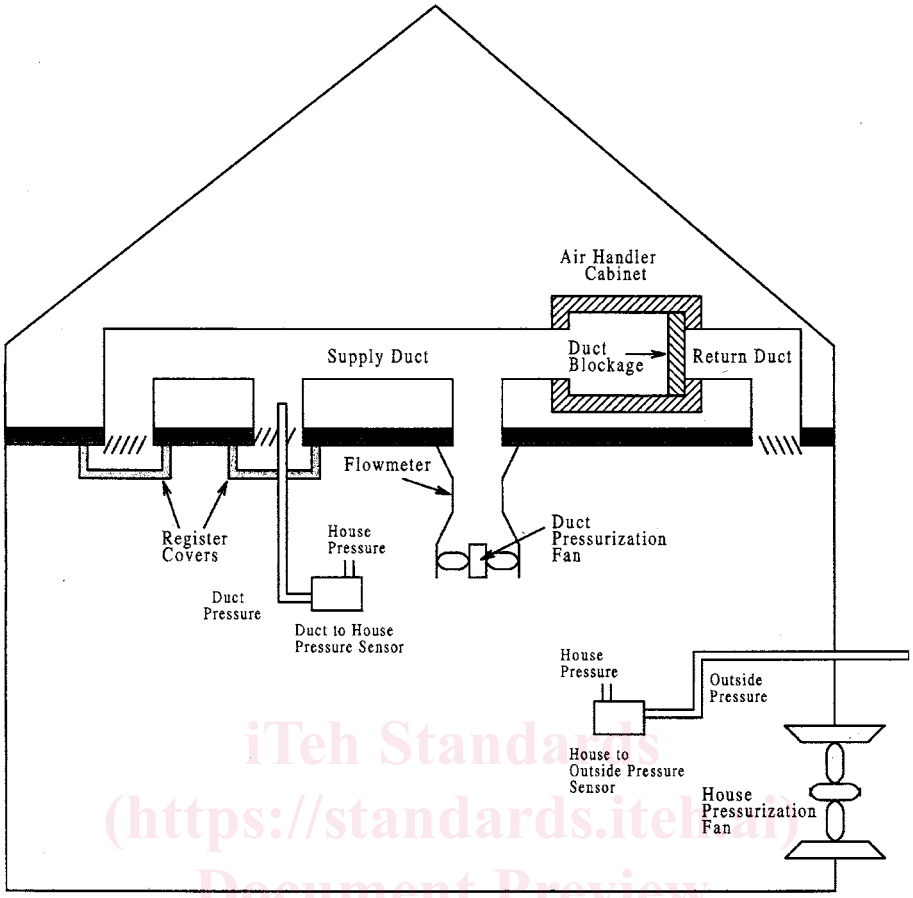

FIG. 1 Schematic of Method B—Duct Pressurization Test (for Supply Leakage)

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.