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Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door[1]

This standard is issued under the fixed designation E 1827; 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 describe two techniques for measuring air leakage rates through a building envelope in buildings that may be configured to a single zone. Both techniques use an orifice blower door to induce pressure differences across the building envelope and to measure those pressure differences and the resulting airflows. The measurements of pressure differences and airflows are used to determine airtightness and other leakage characteristics of the envelope.

1.2 These test methods allow testing under depressurization and pressurization.

1.3 These test methods are applicable to small indoor-outdoor temperature differentials and low wind pressure conditions; the uncertainty in the measured results increases with increasing wind speeds and temperature differentials.

1.4 These test methods do not measure air change rate under normal conditions of weather and building operation. To measure air change rate directly, use Test Methods E 741.

1.5 The text of these test methods reference notes and footnotes that provide explanatory material. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of the standard.

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:*

E 456 Terminology Relating to Quality and Statistics[2]

E 631 Terminology of Building Constructions[3]

E 741 Test Methods for Determining Air Change in a Single Zone by Means of Tracer Gas Dilution[3]

E 779 Test Method for Determining Air Leakage Rate by Fan Pressurization[3]

E 1186 Practice for Air Leakage Site Detection in Building Envelopes[3]

E 1258 Test Method for Airflow Calibration of Fan Pressurization Devices[3]

2.2 *ISO International Standard:*

ISO 9972 Thermal Insulation—Determination of Building Airtightness—Fan Pressurization Method[4]

2.3 *Other Standard:*

ANSI/ASME PTC 19.1—Part 1, Measurement Uncertainty, Instruments, and Apparatus[4]

3. Terminology

3.1 *Definitions*—Refer to Terminology E 456 for definitions of accuracy, bias, precision, and uncertainty.

3.1.1 ACH_{50}, *n*—the ratio of the air leakage rate at 50 Pa (0.2 in. H_2O), corrected for a standard air density, to the volume of the test zone (1/h).

3.1.2 *air leakage rate,* Q_{env}, *n*—the total volume of air passing through the test zone envelope per unit of time (m^3/s, ft^3/min).

3.1.3 *airtightness*, *n*—the degree to which a test zone envelope resists the flow of air.

NOTE 1—ACH_{50}, air leakage rate, and effective leakage area are examples of measures of building airtightness.

3.1.4 *blower door*, *n*—a fan pressurization device incorporating a controllable fan and instruments for airflow measurement and building pressure difference measurement that mounts securely in a door or other opening.

3.1.5 *building pressure difference,* P, *n*—the pressure difference across the test zone envelope (Pa, in. H_2O).

3.1.6 *fan airflow rate,* Q_{fan}, *n*—the volume of airflow through the blower door per unit of time (m^3/s, ft^3/min).

3.1.7 *nominal airflow rate,* Q_{nom}, *n*—the flow rate indicated by the blower door using the manufacturer's calibration coefficients (m^3/s, ft^3/min).

[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] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 04.11.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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3.1.8 *orifice blower door*, *n*—a blower door in which airflow rate is determined by means of the pressure drop across an orifice or nozzle.

3.1.9 *precision index of the average*, *n*—the sample standard deviation divided by the square root of the number of samples.[4]

3.1.10 *pressure station*, *n*—a specified induced change in the building pressure difference from the initial zero-flow building pressure difference (Pa, in. H_2O).

3.1.11 *single zone*, *n*—a space in which the pressure differences between any two places, as indicated on a manometer, differ by no more than 2.5 Pa (0.01 in. H_2O) during fan pressurization at a building pressure difference of 50 Pa (0.2 in. H_2O) and by no more than 5 % of the highest building pressure difference achieved.

NOTE 2—A multiroom space that is interconnected within itself with door-sized openings through any partitions or floors is likely to satisfy this criterion if the fan airflow rate is less than 3 m^3/s ($6 \times 10^3 ft^3/min$) and the test zone envelope is not extremely leaky.

3.1.12 *test zone*, *n*—a building or a portion of a building that is configured as a single zone for the purpose of this standard.

NOTE 3—For detached dwellings, the test zone envelope normally comprises the thermal envelope.

3.1.13 *test zone envelope*, *n*—the barrier or series of barriers between a test zone and the outdoors.

NOTE 4—The user establishes the test zone envelope at such places as basements or neighboring rooms by choosing the level of resistance to airflow between the test zone and outdoors with such measures as opening or closing windows and doors to, from, and within the adjacent spaces.

3.1.14 *zero-flow building pressure difference*, *n*—the natural building pressure difference measured when there is no flow through the blower door.

3.2 *Symbols*—The following is a summary of the principal symbols used in these test methods:

Alt = altitude at site, m (ft),
C = flow coefficient at standard conditions, m^3/s (Pa^n) ft^3/min (in. H_2O^n),[5]
L = effective leakage area at standard conditions, m^2(in.^{2}),
n = envelope flow exponent (dimensionless),
P = building pressure difference (see 3.1.5),
P_1 = average pressure, $\bar{P}_{sta}$, at the primary pressure station, Pa (in. H_2O),
P_2 = average pressure, $\bar{P}_{sta}$, at the secondary pressure station, Pa (in. H_2O),
P_{ref} = the reference pressure differential across the building envelope, Pa (in. H_2O),
P_{sta} = station pressure, Pa (in. H_2O),
P_{test} = test pressure, Pa (in. H_2O),
P_{zero1} = zero-airflow pressure before test, Pa (in. H_2O),
P_{zero2} = zero-airflow pressure after test, Pa (in. H_2O),
Q_{env} = the air leakage rate, m^3/s (ft^3/min),
Q_{env1} = average air leakage rate, $\bar{Q}_{env}$, at the primary pressure station, m^3/s (ft^3/min),
Q_{env2} = average air leakage rate, $\bar{Q}_{env}$, at the secondary pressure station, m^3/s (ft^3/min),
Q_{fan} = fan airflow rate (see 3.1.6),
Q_{nom} = nominal airflow rate (see 3.1.7),
T = temperature,° C (°F),
t = value from a two-tailed student t table for the 95 % confidence level,
δn = measurement uncertainty of the envelope flow exponent (dimensionless),
V_{zone} = volume of the test zone, m^3(ft^3),
δQ_{env} = measurement uncertainty of the average air leakage rate, m^3/s (ft^3/min),
δQ_{50} = the measurement uncertainty of Q_{50}, m^3/s (ft^3/min),
δQ_{bias} = estimated bias of the flow rate, m^3/s (ft^3/min),
δQ_{bias1} = estimated bias of the flow rate at the primary pressure station, m^3/s (ft^3/min),
δQ_{bias2} = estimated bias of the flow rate at the secondary pressure station, m^3/s (ft^3/min),
$\delta Q_{precision}$ = precision index of the average measured flow rate, m^3/s (ft^3/min),
δQ_{prec1} = precision index of the average measured flow rate at the primary pressure station, m^3/s (ft^3/min),
δQ_{prec2} = precision index of the average measured flow rate at the secondary pressure station, m^3/s (ft^3/min),
δP = measurement uncertainty of the average measured pressure differential across the building envelope, Pa (in. H_2O),
δP_{bias} = estimated bias of the pressure differential across the building envelope, Pa (in. H_2O),
δP_{bias1} = estimated bias of the pressure differential across the building envelope at the primary pressure station, Pa (in. H_2O),
δP_{bias2} = estimated bias of the pressure differential across the building envelope at the secondary pressure station, Pa (in. H_2O),
$\delta P_{precision}$ = precision index of the average measured pressure differential across the building envelope, Pa (in. H_2O),
δP_{prec1} = precision index of the average measured pressure differential across the building envelope at the primary pressure station, Pa (in. H_2O),
δP_{prec2} = precision index of the average measured pressure differential across the building envelope at the secondary pressure station, Pa (in. H_2O),
δV_{zone} = measurement uncertainty of the zone volume, m^3(ft^3),
μ = dynamic viscosity, kg/m·s (lbm/ft·hr),
ρ = air density, kg/m^3(lbm/ft^3), and

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ρ_{cal} = air density at which the calibration values are valid, kg/m^3(lbm/ft^3).

4. Summary of Test Methods

4.1 *Pressure versus Flow*—These test methods consist of mechanical depressurization or pressurization of a building zone during which measurements of fan airflow rates are made at one or more pressure stations. The air leakage characteristics of a building envelope are evaluated from the relationship between the building pressure differences and the resulting airflow rates. Two alternative measurement and analysis procedures are specified in this standard, the single-point method and the two-point method.

4.1.1 *Single-Point Method*—This method provides air leakage estimates by making multiple flow measurements near $P_1 = 50$ Pa (0.2 in. H_2O) and assuming a building flow exponent of $n = 0.65$.

4.1.2 *Two-Point Method*—This method provides air leakage estimates by making multiple flow measurements near $P_1 = 50$ Pa (0.2 in. H_2O) and near $P_2 = 12.5$ Pa (0.05 in. H_2O) that permit estimates of the building flow coefficient and flow exponent.

5. Significance and Use

5.1 *Airtightness*—Building airtightness is one factor that affects building air change rates under normal conditions of weather and building operation. These air change rates account for a significant portion of the space-conditioning load and affect occupant comfort, indoor air quality, and building durability. These test methods produce results that characterize the airtightness of the building envelope. These results can be used to compare the relative airtightness of similar buildings, determine airtightness improvements from retrofit measures applied to an existing building, and predict air leakage. Use of this standard in conjunction Practice E 1186 permits the identification of leakage sources and rates of leakage from different components of the same building envelope. These test methods evolved from Test Method E 779 to apply to orifice blower doors.

5.1.1 *Applicability to Natural Conditions*—Pressures across building envelopes under normal conditions of weather and building operation vary substantially among various locations on the envelope and are generally much lower than the pressures during the test. Therefore, airtightness measurements using these test methods cannot be interpreted as direct measurements of natural infiltration or air change rates that would occur under natural conditions. However, airtightness measurements can be used to provide air leakage parameters for models of natural infiltration. Such models can estimate average annual ventilation rates and the associated energy costs. Test Methods E 741 measure natural air exchange rates using tracer gas dilution techniques.

5.1.2 *Relation to Test Method E 779*—These test methods are specific adaptations of Test Method E 779 to orifice blower doors. For nonorifice blower doors or for buildings too large to use blower doors, use Test Method E 779.

5.2 *Single-Point Method*—Use this method to provide air leakage estimates for assessing improvements in airtightness.

5.3 *Two-Point Method*—Use this method to provide air leakage parameters for use as inputs to natural ventilation models. The two-point method uses more complex data analysis techniques and requires more accurate measurements (Tables X1.1 and X1.2) than the single-point method. It can be used to estimate the building leakage characteristics at building pressure differences as low as 4 Pa (0.016 in. H_2O). A variety of reference pressures for building envelope leaks has been used or suggested for characterizing building airtightness. These pressures include 4 Pa (0.016 in. H_2O), 10 Pa (0.04 in. H_2O), 30 Pa (0.12 in. H_2O), and 50 Pa (0.2 in. H_2O). The ASHRAE *Handbook of Fundamentals* uses 4 Pa.

5.4 *Depressurization versus Pressurization*—Depending on the goals of the test method, the user may choose depressurization or pressurization or both. This standard permits both depressurization and pressurization measurements to compensate for asymmetric flow in the two directions. Depressurization is appropriate for testing the building envelope tightness to include the tightness of such items as backdraft dampers that inhibit infiltration but open during a pressurization test. Combining the results of depressurization and pressurization measurements can minimize wind and stack-pressure effects on calculating airtightness but may overestimate air leakage due to backdraft dampers that open only under pressurization.

5.5 *Effects of Wind and Temperature Differences*—Calm winds and moderate temperatures during the test improve precision and bias. Pressure gradients over the envelope caused by inside-outside temperature differences and wind cause bias in the measurement by changing the building pressure differences over the test envelope from what would occur in the absence of these factors. Wind also causes pressure fluctuations that affect measurement precision and cause the data to be autocorrelated.

6. Apparatus

6.1 *Blower Door*—An orifice blower door (see Fig. 1).

6.2 *Measurement Precision and Bias*—Appendix X1 lists recommended values for the precision and bias of the measurements of airflow, pressure difference, wind speed, and temperature to obtain the precision and bias for test results described in 11.2 for the single-point method and 11.3 for the two-point method.

6.2.1 *Fan with Controllable Flow*—The fan shall have sufficient capacity to generate at least a 40 Pa (0.20 in. H_2O) building pressure difference in the zone tested and be controllable over a calibrated range sufficient to generate the building pressure differences required by this standard.

NOTE 5—For testing most single family houses, a range of airflows from 0.1 to 3 m^3/s (200 to 6000 ft^3/min) is usually adequate.

6.2.2 *Airflow Measurement*—The procedure for calibrating the airflow measurement device shall be provided with the instrument together with estimates of the precision and bias of the instrument. The air density (ρ_{cal}) for which any calibration equations or tables were calculated shall be reported. If the instrument automatically compensates for changes in air density, the instructions shall note this fact.

[5] Historically, a variety of other units have been used.

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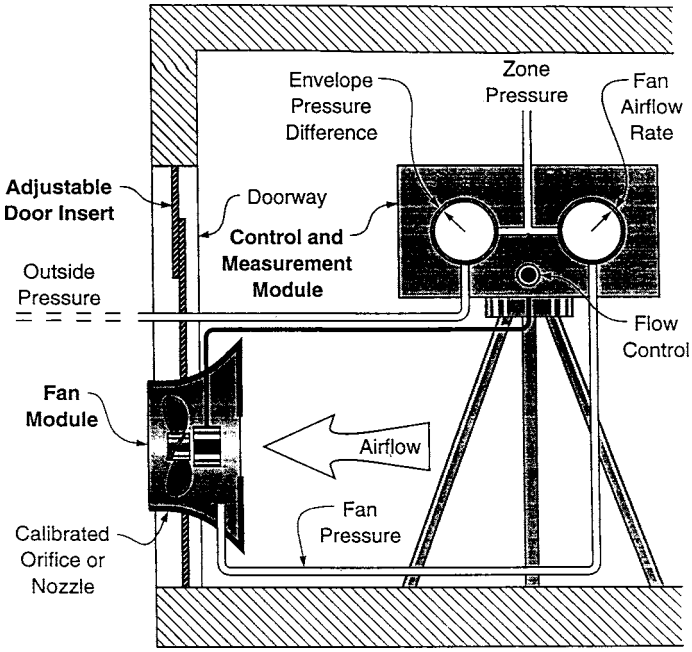

FIG. 1 Blower Door Assembly

6.2.3 *Pressure Measurement*—The procedure for calibrating the pressure measurement device shall be provided with the instrument together with estimates of the precision and bias of the instrument.

6.3 *Wind Speed Measurement (two-point method only)*—A device to measure the site wind speed.

6.4 *Air Temperature Measurement*—A thermometer or electronic sensor with readout.

6.5 *Barometer (optional)*—A device to measure the site barometric pressure.

6.6 *Data Acquisition (optional)*—Automated data acquisition equipment to record (in machine readable form) data on airflow and building pressure differences within 10 s of each other and (optionally) temperature, wind speed, and barometric pressure.

6.7 *Pressure and Flow Measurement System (two-point method only)*—The flow and pressure measurement system shall measure flow and pressure differentials within 20 s of each other.

6.8 *Wind Pressure Averaging System (optional)*—A system to reduce the effect of pressure variations from static probes outside the building envelope and of pressure fluctuations over time. It shall have a manifold that accepts multiple tubes of equal lengths sufficient to reach representative surfaces of the building.

7. Hazards

7.1 *Eye Protection*—Glass should not break at the building pressure differences normally applied to the test structure. However, for added safety, adequate precautions such as the use of eye protection should be taken to protect the personnel.

7.2 *Safety Clothing*—Use safety equipment required for general field work, including safety shoes and hard hats.

7.3 *Equipment Guards*—The air-moving equipment shall have a proper guard or cage to house the fan or blower and to prevent accidental access to any moving parts of the equipment.

7.4 *Noise Protection*—Make hearing protection available for personnel who must be close to the noise that may be generated by the fan.

7.5 *Debris and Fumes*—The blower or fan forces a large volume of air into or out of a building while operating. Exercise care not to damage plants, pets, occupants, or internal furnishings due to influx of cold or warm air. Exercise similar cautions against sucking debris or exhaust gases from fireplaces and flues into the interior of the building. Active combustion devices require a properly trained technician to shut them off or to determine the safety of conducting the test.

8. Procedure

8.1 *Establish Test Objectives*—Determine the configuration of the building envelope to be tested. The most common objectives are to evaluate the effect of construction quality on leaks in the building envelope (hereafter called closed) or to assess the envelope's impact on natural air change rates (hereafter called occupied). Choose the envelope condition appropriate to the objective.

8.1.1 *Residential Construction*—Use Table 1 to determine the recommended test envelope conditions for residential construction.

8.1.1.1 *Closed*—Close all operable openings and seal other intentional openings to evaluate envelope airtightness without including intentional openings.

8.1.1.2 *Occupied (default)*—Leave all operable openings in the conditions typical of occupancy to assess the envelope's effect on natural air change rates. This shall be the default option if no compelling reason exists to choose 8.1.1.1.

8.2 *Ancillary Measurements*:

8.2.1 *Environmental Measurements*—Measure and record the wind speed 2 m (6 ft) above the ground and 10 m (30 ft) upwind from the building, when practical, outside temperature, and inside temperature at the beginning of each fan pressurization test. Circle or otherwise emphasize the readings if wind speed is greater than 2 m/s (4 mph) or outside temperature is outside the bounds of 5 to 35°C (41 to 95°F).

8.2.2 *Determine Site Altitude*—Determine the altitude of the measurement site, *Alt* in m or ft, above mean sea level within 100 m (3×10^2 ft).

8.3 *Building Preparation*:

8.3.1 *Establish Test Zone Envelope*—Define the test zone envelope appropriate for the goals of the test. Open all doors, windows, and other openings that connect portions of the building outside the test zone envelope with the outdoors.

NOTE 6—For example, if the first floor is to be the lower boundary of the test zone envelope, open basement doors and windows. If the floor and the basement are part of the test zone envelope, close those doors and windows.

8.3.2 *Establish Test Zone*—All interior building doors in the test zone shall be open to create a uniform inside pressure. If door-sized openings are not present within the test zone

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