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Standard Test Method for DETERMINING AIR LEAKAGE RATE BY FAN PRESSURIZATION[1]

This standard is issued under the fixed designation E 779; 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 This test method describes a standardized technique for measuring air-leakage rates through a building envelope under controlled pressurization and de-pressurization.

1.2 This test method is applicable to small temperature differentials and low-wind pressure conditions. For tests conducted in the field, it must be recognized that field conditions may be less than ideal. Nevertheless, strong winds and large indoor-outdoor temperature differentials should be avoided.

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

1.4 This test method is intended to produce a measure of air tightness of a building envelope. Because of differences between natural load and test conditions, however, such measurements cannot be interpreted as direct measurements of air change rates that would occur under natural conditions.

1.5 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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 Document

2.1 *ASTM Standard:*

E 741 Test Method for Determining Air Leakage Rate by Tracer Dilution[2]

3. Definitions

3.1 *air-change rate*—air-leakage in volume units per hour divided by the building space volume with identical volume units (normally expressed as air changes per hour, ACH or ACPH).

3.2 *air-leakage rate*—the volume of air movement per unit time across the building envelope.

NOTE—This movement includes flow through joints, cracks, and porous surfaces, or combination thereof. The driving force for such an air leakage in service can be either mechanical pressurization and de-pressurization, natural wind pressures, or air temperature differentials between the building interior and the outdoors, or combination thereof.

3.3 *air-leakage graph*—the graph that shows the relationship of measured air flow rates to the corresponding measured pressure differences (usually plotted on a log-log scale).

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

NOTE—For the purpose of this test method, the interior volume is the deliberately conditioned space within a building, generally not including the attic space, basement space, and attached structures, unless such spaces are connected to the heating and air conditioning system, such as a crawl space plenum.

3.5 *test pressure difference*—the actual pressure difference across the building envelope, expressed in pascals (inches of water or pounds-force per square foot or inches of mercury).

4. Summary of Test Method

4.1 This test method consists of mechanical

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[2] *Annual Book of ASTM Standards*, Vol 04.07.

pressurization or de-pressurization of a building and measurements of the resulting air flow rates at given indoor-outdoor static pressure differences. From the relationship between the air flow rates and pressure differences, the air leakage characteristics of a building envelope can be evaluated.

5. Significance and Use

5.1 Air leakage accounts for a significant portion of the thermal space conditioning load. It affects occupant comfort and indoor air quality.

5.2 In most commercial or industrial buildings, outdoor air is often introduced by design with air circulation systems. In most residential buildings, indoor-outdoor air exchange is attributable primarily to air leakage through cracks and construction joints and can be induced by pressure differences caused by temperature differences, wind, and the operation of combustion equipment in the building.

5.3 Air leakage under natural conditions is very difficult to calculate, since it depends not only on wind speed and direction and indoor-outdoor temperature differences and operation of combustion equipment, but also on workmanship in construction, and on other building elements. Although there are standard formulas to estimate air leakage, they are only approximations.

5.4 Air infiltration may be measured directly using the tracer dilution method (see Test Method E 741). The fan pressurization method provides an indirect way to relate the infiltration rate to the leakage area of a structure.

5.5 The fan-pressurization method has several advantages over the tracer dilution method. The fan-pressurization method is a simpler measurement and produces a result that characterizes the air tightness of the building envelope. It can be used: (*1*) to compare the relative air tightness of several similar buildings, (*2*) to identify the leakage sources and rates of leakage from different components of the same building envelope, and (*3*) to determine the air leakage reduction for individual retrofit measures applied incrementally to an existing building.

5.6 When the absolute infiltration rate is needed, the tracer dilution method should be used over a wide range of wind speeds and directions and indoor-outdoor temperature differences. However, the measuring equipment and techniques for the tracer dilution method are relatively complicated. Also, the data analysis and correlation are more involved. It is better to use the fan-pressurization method for diagnostic purposes and measure the absolute infiltration rate with the tracer dilution method.

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.

6.2 *Major Components* (see Fig. 1):

6.2.1 *Air-Moving Equipment*—A fan, blower, or blower door assembly that is capable of moving air into and out of the conditioned space at required flow rates under a range of test pressure differences. 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. In large buildings, the HVAC systems can be used.

6.2.2 *Pressure-Measuring Device*—A manometer or pressure indicator to measure pressure difference with an accuracy of ±2.5 Pa (±0.01 in H_2O).

6.2.3 *Air Flow or Velocity-Measuring System*—A device to measure air flow within ±6 % of the average value. The calibration of this air flow-measuring system shall follow the manufacturer's instructions, and be recorded as such. The instrument may also be calibrated in a calibrating wind tunnel.

6.2.4 *Wind Speed-Measuring Device*, to give an accuracy within ±0.25 m/s (0.5 mph) at 2.5 m/s (5 mph). Perform wind speed measurements at a distance three to five building heights away from the buildings. List the height above ground at which wind speed is measured.

6.2.5 *Temperature-Measuring Device*, to give an accuracy of ±0.5°C (1°F).

6.2.6 *Air Flow-Regulating System*—A device such as a damper, or variable motor speed control, that will regulate and maintain air flow and pressure difference to specific limits.

6.2.7 The air moving equipment shall be able to accomplish both pressurization and de-pressurization.

6.2.8 The size of the air duct and the capacity of the fan or blower shall be matched so that the linear flow velocity within the air duct falls within the range of measurement of the air flow meter.

6.3 Blower Door Assembly (Fig. 2) is an accepted variation. Components peculiar to this assembly are:

6.3.1 *Blower Door*—A door mount for fan or blower. It must be adjustable to fit common door openings.

6.3.2 The fan or blower should possess a variable-speed motor to accommodate the wide range of required flow rates up to 1.4 m^3/s (3000 ft^3/min).

7. Hazards

7.1 Glass should not break at the 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 The test is most likely conducted in the field. Therefore, safety equipment required for general field work also applies, such as safety shoes, hard hats, etc.

7.3 Because air-moving equipment is involved in this test, provide 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 When the blower or fan is operating, a large volume of air is being forced into or out of a building. Provide proper shields or guards at the inlet or outlet of the air duct.

7.5 Noise may be generated by moving air. Therefore, make available hearing protection for personnel who must be close to the noise.

7.6 Care should be exercised not to damage plants, pets, occupants, or internal furnishings due to influx of cold or warm air. Similar cautions should be exercised for sucking debris or exhaust gases from fireplaces and flues into the interior of the building.

8. Procedure

8.1 All interconnecting doors (except for closets, which should be closed) in the conditioned space should be opened such that a uniform pressure will be maintained within the conditoned space to within a range of less than 10 % of the measured inside/outside pressure difference. This condition should be verified by selected differential pressure measurements throughout the structure at the highest pressure contemplated.

8.2 HVAC balancing dampers and registers should not be adjusted. Fireplace and other operable dampers should be closed unless they are used to pass air to pressurize or de-pressurize the building.

8.3 Make general observations of the condition of the building. Take notes on the windows, doors, opaque walls, roof, and floor.

8.4 Measure and record the wind speed and direction, and outdoor temperatures at the beginning and the end of the test.

8.5 Measure and record the indoor temperature and relative humidities at the beginning and the end of the test so that their average values can be estimated.

8.6 Connect the air duct or blower door assembly to the building envelope, using a window, door, or vent opening. Seal or tape openings to avoid leakage at these points.

8.7 If a damper is used to control air flow, it should be in a fully closed position at the beginning of a test. Turn on the fan or blower, adjust the damper or air flow regulator to increase the air flow, take readings of air flow rate and induced pressure difference.

8.7.1 When the blower door assembly is used, the determination of the revolutions per minute and pressure differentials from the control panel enables flow to be measured. Interpolation shall be used for other pressure differentials than those recorded in the calibration procedure.

8.8 The range of the induced pressure difference shall be from 12.5 to 75 Pa (0.05 to 0.3 in. H_2O) depending on the capacity of the air-handling equipment. Since the capacity of the air handling equipment, 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 a partial range encompassing at least five data points shall be the substitute.

8.9 Increments of 12.5 Pa (0.05 in. H_2O) shall be used for the full range of induced pressure differences.

8.10 At each pressure increment, measure the air flow rate in cubic metres per second (cubic feet per minute).

8.11 A maximum variation of pressure due to external influences such as wind or thermal stack effect, or both, shall be no more than 10 % of the measured inside and outside pressure difference.

8.12 Preferred test conditions are wind speed of 0 to 2 m/s (0 to 4 mph) and an outside temperature from 5 to 35°C (41 to 95°F).

8.13 For each test, collect data for both pressurization and de-pressurization.

9. Data Analysis and Calculations

9.1 All the measured air leakages shall be converted to air flow rates in cubic metres per second (cubic feet per minute) at reference conditions.

9.2 If the air leakage is not measured directly from a flow meter, then additional calculations are needed to convert, for instance, pitot tube pressure to linear velocity and then volume flow rate. In the case of a calibrated motor fan, the flow rate can be obtained through the calibration curve of the motor fan. However the fan should be used in a manner consistent with the calibration method.

9.3 Plot the measured air leakage against the corresponding pressure differences on a log-log plot to complete the air leakage graph for both pressurization and de-pressurization (see Fig. 3).

9.4 *Calculation of Effective Leakage Area:*

9.4.1 The data as calculated in 9.1 and 9.2 shall be used to determine the coefficients C and n using a least square technique as follows:

$$Q = C\,(dP)^n$$

where:

Q = flow rate, m³/s, and
dP = differential pressure, Pa.

In determining the fit of the above equation, the coefficient of correlation r^2 should be calculated.

9.4.2 The effective leakage area in square metres, L, can be calculated from the leakage coefficient, C, the exponent n, a reference pressure, dP_r, and the air density δ at the indoor temperature and pressure as follows:

$$L = C\,(dP_r)^{(n-\frac{1}{2})}\,(\delta/2)^{\frac{1}{2}}$$

The conventional reference pressure is 4 Pa, but other values may be used if the value is included in the report section. If the conditions of 8.12 are not observed, the leakage area shall not be calculated.

10. Report

10.1 Report at least the following information:

10.1.1 *Building Description:*

10.1.1.1 *Location and Construction:*

(*a*) Date built (estimate if unknown),

(*b*) Floor area of conditioned space, attic, and basement/crawl space, and

(*c*) Volume of conditioned space, attic, and basement/crawl space.

10.1.1.2 *Condition of Openings in Exterior Shell:*

(*a*) Doors (including storm doors), locked or unlocked,

(*b*) Windows (including storm windows), latched or unlatched,

(*c*) Ventilation openings, dampers closed or open,

(*d*) Chimneys, dampers closed or open, and

(*e*) Condition of openings during test (for example, broken windows, HVAC louver settings, etc.).

10.1.1.3 *HVAC System:*

(*a*) Furnace,

(*b*) Blower capacity, and

(*c*) Duct location.

10.1.2 *Pressurization Measurements:*

10.1.2.1 Technique employed,

10.1.2.2 Equipment used,

10.1.2.3 Calibration of air flow meter, and

10.1.2.4 Measurement results.

10.1.3 *Weather:*

10.1.3.1 Off-site conditions (nearby weather station),

10.1.3.2 On-site conditions (measurement location),

10.1.3.3 Apparatus,

10.1.3.4 Wind speed/direction,

10.1.3.5 Temperature (indoor and outdoor),

10.1.3.6 Humidity (indoor and outdoor), if obtainable, and

10.1.3.7 Barometric pressure.

10.1.4 *Plot of Air Leakage Graph (see Fig. 3).*

10.1.5 The leakage coefficient and exponent for both pressurization and de-pressurization in accordance with 9.4.1. The leakage coefficient and exponent can be used to calculate the flows at the other pressures. If estimates are made outside of the measurement range, an estimate of the extrapolation error should be included.

10.1.6 The effective leakage area for both pressurization and de-pressurization, as well as the average. If a reference pressure other than 4 Pa is used, it shall also be reported.

10.1.7 Correlation coefficient r^2 of the fit to equation in 9.4.1 for both pressurization and de-pressurization.

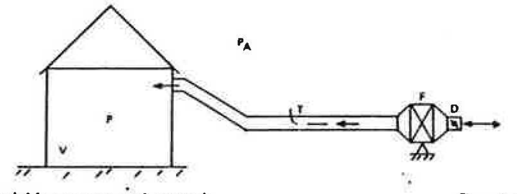
10.1.8 Standard error of the effective leakage area.

11. Precision and Bias

11.1 At present, the precision and bias of this test method is largely dependent on the instrumentations and apparatus used and on the ambient conditions under which the data are taken. A precision statement is currently being developed.

11.2 It is more precise to take data at a higher pressure difference than at lower differences. Therefore, special care should be exercised when measurements are taken at low pressure differences.

11.3 While the correlation coefficient r^2 measures the goodness of the fit to a power law of the flow versus pressure data, the standard error of the calculated effective leakage area should also be explicitly presented in the report, as it gives a measure of the standard error of the estimate.



D—Damper or variable motor speed control
F—Fan or blower
P—Inside pressure
P_A—Ambient pressure
T—Air flow meter
V—Test space

FIG. 1 Major Components of Apparatus

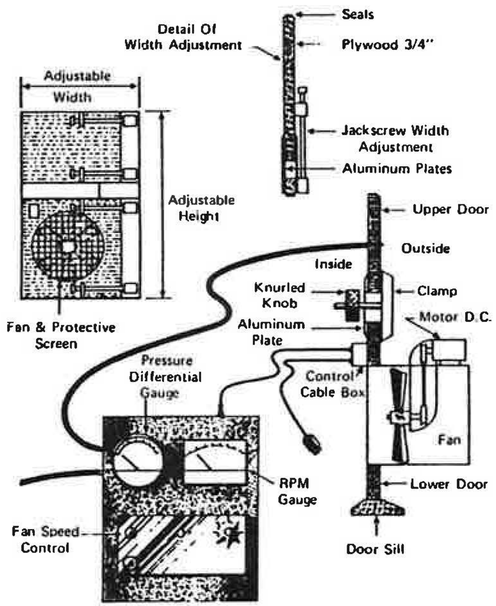


FIG. 2 Blower Door Assembly

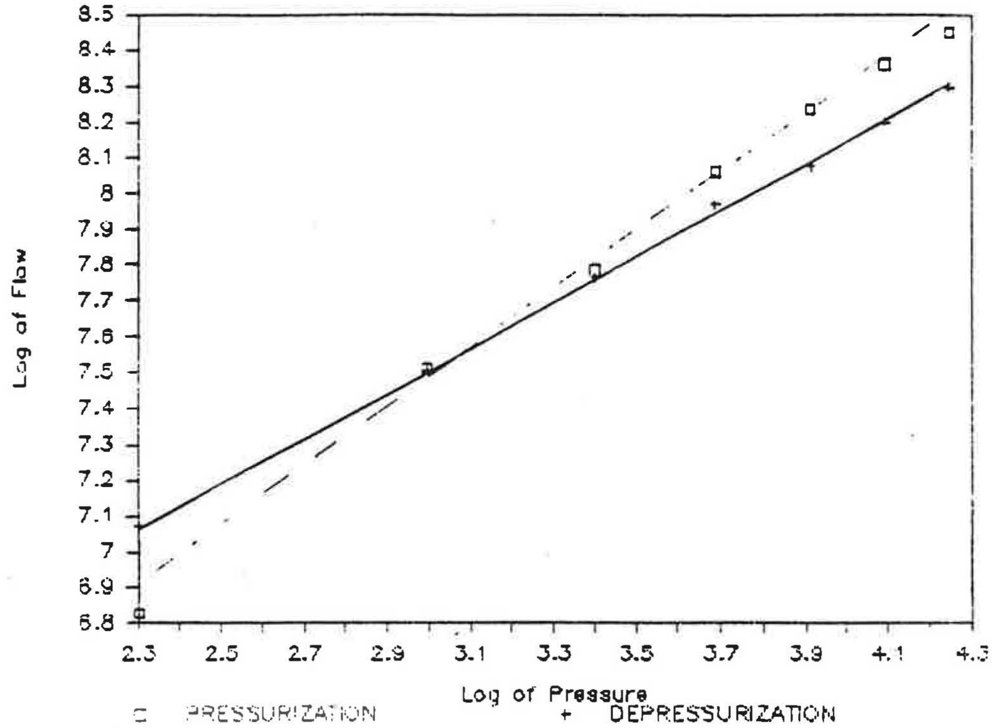


FIG. 3 Example of Air Leakage Log-Log Plot