Designation: E 1680 – 95

An American National Standard

Standard Test Method for Rate of Air Leakage Through Exterior Metal Roof Panel Systems[1]

This standard is issued under the fixed designation E 1680; 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 covers the determination of the resistance of exterior metal roof panel systems to air infiltration resulting from either positive or negative air pressure differences. The test method described is for tests with constant temperature and humidity across the specimen. This test method is a specialized adaption of Test Method E 283.

1.2 This test method is applicable to any roof area. This test method is intended to measure only the air leakage associated with the field of the roof, including the panel side laps and structural connections; it does not include leakage at the openings or perimeter or any other details.

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

1.4 The text of this test method references notes and footnotes excluding tables and figures, which provide explanatory material. These notes and footnotes shall not be considered to be requirements of the test method.

1.5 The values stated in inch-pound units are to be regarded as the 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 precautionary statements, see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*

E 283 Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors[2]

E 631 Terminology of Building Construction[2]

E 1592 Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference[2]

E 1646 Test Method for Water Penetration of Exterior Metal Roof Panel Systems by Uniform Static Air Pressure Difference[2]

2.2 *Other Standard:*

AAMA 501 Methods of Test for Metal Curtain Walls[3]

3. Terminology

3.1 *Definitions*—For definitions of general terms relating to building construction used in this test method, see Terminology E 631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *air leakage (Q)*—the volume of air flowing per unit of time through the assembled specimen under a test pressure difference, expressed in cubic feet per minute (cubic metres per second).

3.2.2 *extraneous air leakage* (Q_L)—the difference between the metered air flow (Q_m) and air leakage (Q); the leakage of the remainder of the test chamber.

3.2.3 *metered air flow* (Q_m)—the volume of air flowing per unit of time through the air flow metering system, expressed in cubic feet per minute (cubic metres per second).

3.2.4 *rate of air leakage*—the air leakage per unit of specimen area (A), expressed in cubic feet per minute per square foot (cubic metres per second per square metre).

3.2.5 *reference standard conditions*—dry air at a pressure of 29.92 in. Hg (101.3 kPa), temperature of 69.4°F (20.8°C), and air density of 0.075 lb/ft^3 (1.2 kg/m^3).

3.2.6 *specimen*—the entire assembled unit submitted for testing as described in Section 8.

3.2.7 *specimen area (A)*—the area determined by the overall dimensions of the test specimen expressed in square feet (square metres). The dimensions used to determine area shall not include exterior framework.

3.2.8 *test pressure difference*—the specified difference in static air pressure across the fixed specimen, expressed in pounds-force per square foot (pascals).

4. Summary of Test Method

4.1 The test procedure consists of sealing and fixing a test specimen into or against one face of an air chamber, supplying air to or exhausting air from the chamber at the rate required to

[1] This test method is under the jurisdiction of ASTM Committee E-6 on Performance of Buildings and is the direct responsibility of Subcommittee E06.57 on Performance of Metal Roofing Systems.

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

[3] Available from Architectural Aluminum Manufacturers Association (AAMA), 35 East Wacker Dr., Chicago, IL 60601.

maintain the specified test pressure difference across the specimen, and measuring the resultant air flow through the specimen.

5. Significance and Use

5.1 This test method is a standard procedure for determining air leakage characteristics under specified air pressure differences.

NOTE 1—The air pressure differences acting across a building envelope vary greatly. The slope of the roof and other factors affecting air pressure differences and the implications of the resulting air leakage relative to the environment within buildings are discussed in the literature.[4,5,6] These factors shall be considered fully when specifying the test pressure difference to be used.

NOTE 2— When applying the results of tests by this test method, note that the performance of a roof or its components, or both, may be a function of proper installation and adjustment. The performance in service will also depend on the rigidity of supporting construction, the presence of interior treatments, the roof slope, and the resistance of components to deterioration by various causes: corrosive atmospheres, aging, ice, vibration, thermal expansion, and contraction, etc. It is difficult to simulate the identical complex environmental conditions that can be encountered in service, including rapidly changing pressures due to wind gusting. Some designs are more sensitive than others to these environmental conditions.

5.2 Rates of air leakage are sometimes used for comparison purposes. The comparisons are not always valid unless the components being tested and compared are of essentially the same size, configuration, and design.

NOTE 3—The specimen construction discussed in 1.2 and required in 8.1 isolates a source of leakage. The rate of air leakage measured during the test method has units of cubic feet per minute per square foot (litres per second per square metre). Openings and details such as end laps or roof curbs are excluded since leakage is measured more appropriately in cubic feet per minute per foot (litres per second per metre) at these conditions. The test specimen area is relatively small; the inclusion of details will give unrealistic import to the detail's presence when compared to actual roof constructions. This test method shall not be relied on singularly to form conclusions about overall air leakage through metal roofs. A roof contains many details. Although prescribed modifications are outside the scope of this test method, an experienced testing engineer is able to use the principles presented in the test method and to generate significant data by isolating specific details and measuring leakage.

Additional leakage sources are introduced if details are included. If total leakage is then measured, the results will generally be conservative relative to tests without details. To minimize the number of tests, the specifier may allow details such as end laps when qualitative or general quantitative results are desired and the isolation of sources is not required for performance. Only one panel end lap shall be allowed. The user shall be aware of the bias when comparing alternate systems if end laps are included.

NOTE 4—This is a test procedure. It is the responsibility of the specifying agency to determine the specimen construction, size, and test pressures after considering the test methods' guidelines. Practical considerations suggest that every combination of panel thickness, span, and design load need not be tested in order to substantiate product performance.

[4] *ASHRAE Handbook of Fundamentals*, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., 1972, Chapter 25.

[5] *Fluid Meters—Their Theory and Application*, 5th edition, 1959.

[6] *ASME—Power Test Code*, 2nd edition, 1956, Part 5, Chapter 4, "Flow Measurements."

6. Apparatus

6.1 This description of the apparatus is general in nature, and any arrangement of equipment capable of performing the test procedure within the allowable tolerances is permitted.

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

6.2.1 *Test Chamber*—A well-sealed chamber or box with either an opening, a removable mounting panel, or one open face in which or against which the specimen is installed and sealed. The specimen shall be installed horizontally. At least one static pressure tap shall be provided to measure the chamber pressure. All pressure taps shall be located so that the reading is unaffected by the air supply either to or from the chamber. The air supply opening into the chamber shall be arranged so that air does not impinge directly on the test specimen with any significant velocity. When required, a means of access shall be provided into the chamber to facilitate adjustments and observations after the specimen has been installed.

6.2.2 *Air System*—A controllable blower, compressed air supply, exhaust system, or reversible blower designed to provide the required air flow at the specified test pressure difference. the system shall provide constant air flow at a fixed pressure for the period required to obtain readings of air flow and pressure difference, and it shall be capable of maintaining positive and negative pressures.

6.2.3 *Pressure Measuring Apparatus*—A device for measuring the test pressure difference within a tolerance of ± 2 %, or ± 0.01 in. (± 2.5 Pa), of water column, whichever is greater. The device must measure positive and negative pressures.

6.2.4 *Air-Flow Metering System*—A device to measure the air flow within the limitations of error prescribed in 6.3. (The publications listed in Footnotes 5 and 6 [5,6]present background information on fluid metering practices.)

6.3 The air flow through the test specimen shall be determined with an error not greater than ± 5 % when this flow equals or exceeds 2 ft^3/min (0.94 L/s) or ± 10 % when the air flow is below 2 ft^3/min but more than ½ ft^3/min (0.24 L/s).

NOTE 5—A greater percentage of error will usually be acceptable at lower flows. Special flow-measuring techniques are necessary if higher precision is required. The accuracy of the specimen leakage flow measurement is affected by the accuracy of the flowmeter and amount of extraneous leakage of the apparatus (see Annex A1 of Test Method E 283).

7. Safety Precautions

7.1 Glass breakage and specimen failure will not normally occur at the small pressure differences applied in this test procedure. Larger or excessive pressure differences occur during preload, due to error in operation, or when the apparatus is used for other purposes such as structural testing; therefore exercise adequate precautions to protect personnel.

8. Test Specimen

8.1 The roof specimen shall be of sufficient size to determine the performance of all typical parts of the roof system. For roofs constructed with prefabricated or preformed units or panels, the specimen width shall be equivalent to or greater than the width of three typical units plus the side rail supporting elements at each edge. The specimen shall contain at least three assembled side lap seams; this allows partial

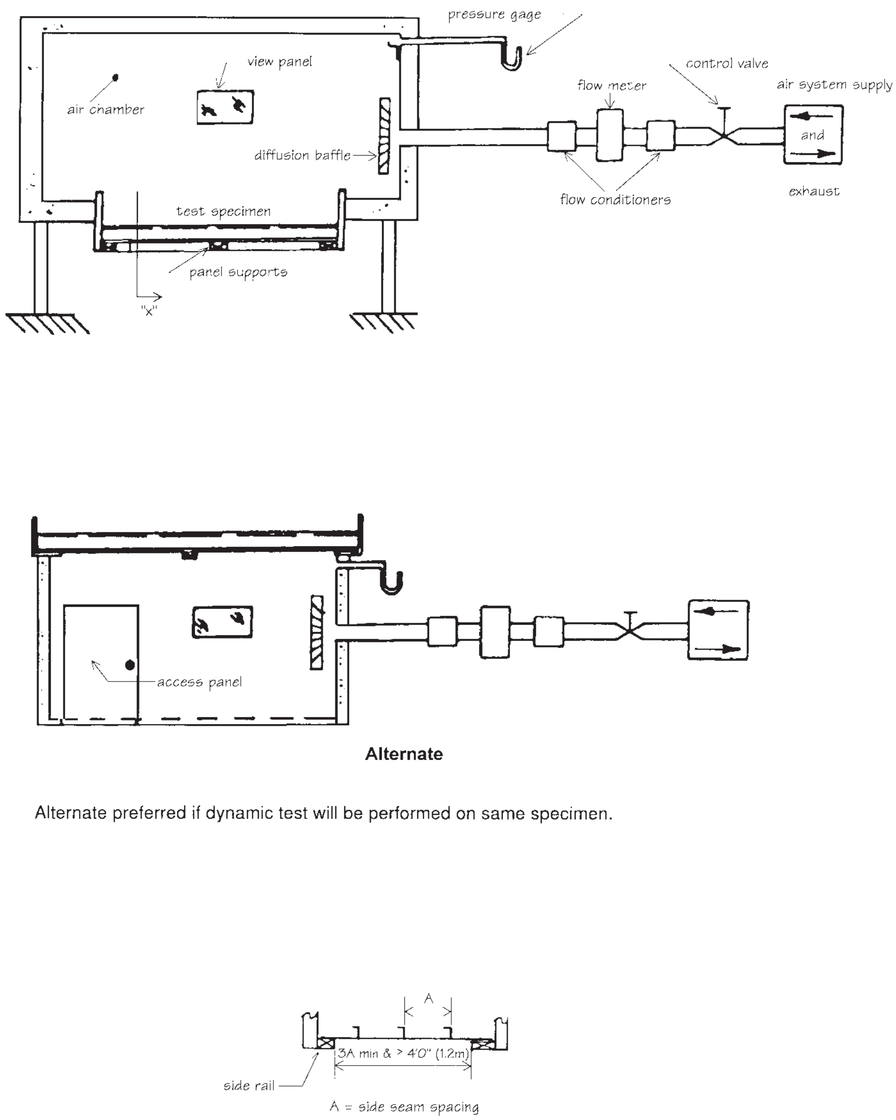

FIG. 1 General Arrangement of Air Leakage Apparatus

width units. The specimen width shall be sufficient to provide loading on at least one typical unit (see Fig. 1). When partial width units are used at the specimen sides, the maximum portion to be used in calculating the specimen area shall be one half of the unit. The specimen shall be of sufficient length to develop a multispan condition unless the panel is used only in single-span applications. If two spans are used, they shall be unequal, with the shorter being 75 % of the longer. Building perimeter details need not and interior details, other than typical side seams, shall not be inlcuded (see Note 3 for commentary and exceptions). The specimen perimeter shall be well sealed.

NOTE 6—The unbalanced span criterion more closely simulates multi-span panel deflection curvature. This works the panel sidelap while minimizing the specimen length.

8.1.1 All parts of the roof test specimen shall be full size, using the same materials, details, and methods of construction and anchorage as those on actual buildings.

8.1.2 The condition of structural support shall be simulated as accurately as possible. If the roof accommodates thermal expansion parallel to the panel length, this detail must be included in the test specimen, and the interior support must be able to slide parallel to the panel or its attachment, or both.

8.2 If insulation is an optional component of the roof system, it shall not be included in the test specimen.

8.3 If only one specimen is to be tested, the selection shall be determined by the specifying authority.

NOTE 7—Air leakage is likely to be a function of size, geometry, and stiffness. Therefore, select specimens covering the range of sizes to be used in a building. In general, the largest size and least stiff of a particular design, type, construction, and configuration shall be tested (see Note 3 for related commentary).

9. Calibration

9.1 Calibration shall be accomplished by mounting a plywood or similar rigid blank to the test chamber in place of a test specimen, using the same mounting procedures as those used for standard specimens. The blank shall be ⅞ ± ⅛ in. (22 ± 3 mm) thick, with a 6-in. (150-mm) diameter hole over which calibrated orifice plates shall be mounted. The blank is not prohibited from accommodating more than one orifice plate.

9.2 Each calibration orifice plate shall be constructed of ⅛-in. (3-mm) thick stainless steel having an outside diameter of 8 in. (200 mm) and containing an interior diameter square-edged orifice, which has been calibrated traceable to the National Institute of Standards and Technology (NIST) at 0.57, 1.57, and 6.24 lbf/ft^2 (27, 75, and 298 Pa).

NOTE 8—Calibrated orifice plates traceable to NIST may be obtained by using the method in Annex A2 of Test Method E 283.

9.3 Fasten the calibration orifice plate to the blank, center the plate over a 6-in. (150-mm) diameter hole, and seal it with a suitable adhesive tape or mastic compound to prevent perimeter leakage.

NOTE 9—Chambers having a minimal depth dimension may create air flow patterns that affect the calibration results. A minimum chamber depth of four orifice diameters should be available to alleviate this condition, or multiple orifice plates should be used, with the distance between orifice plates being four orifice diameters at minimum.

9.4 Calibration shall consist of determining the flow through the meter system to be calibrated using at least one reference orifice plate within each of the following ranges:

ft^3/min (m^3/h)
0–10 (0–17)
10–20 (17–34)
20–40 (34–68)
40–80 (68–136)

The air-flow measuring system shall be considered within the limits of calibration when the maximum air-flow reading under test does not exceed the highest calibration performed by more then 20 %.

9.5 Performance of the flow measurements shall be made under normal operation conditions for the laboratory being calibrated. Provision must be made to account for extraneous chamber leakage so as not to compromise the integrity of the calibration procedure.

9.6 Flow readings shall be measured at each of the three pressure differentials given in 9.2. Reverse the calibration orifice plate if required, reseal the plate, and measure the flow readings at the negative value of each of the three pressure differentials given in 9.2.

9.7 The measured flow at each listed pressure for each orifice plate must be in accordance with the limits given in 6.3.

9.8 Calibration shall be performed every six months at a minimum.

10. Information Required

10.1 Unless otherwise specified, the test-pressure difference or differences at which air leakage is to be determined shall be − 1.57 lbf/ft^2 (−75 Pa). Unless otherwise specified, test-pressure differences shall be both + and −1.57 lbf/ft^2 for roof applications steeper then 30° from horizontal.

NOTE 10—This commentary is included to assist the specifier in the selection of test pressures. This test method is consistent with the Test Method E 283 default test pressure and the AAMA 501 Methods of Test for Metal Curtain Walls recommendations.

Shallow roofs rarely see large positive wind pressures unless the resultant pressure is caused by building openings. The Test Method E 283 default magnitude has been adopted for low sloped roofs, but a negative pressure has been chosen. Positive pressures are more probable at steeper slopes. Most model codes recognize this, and 30° from horizontal is generally selected as the slope above which positive external wind pressures must be considered. This test method selects the 30° slope as its break point. The test method adopts Test Method E 283 test pressure recommendations over the steeper slope range but requires both positive and negative pressure applications.

If a product will be used only on applications greater than 60° from horizontal, consider testing in accordance with Test Method E 283 while recognizing that steep roofs are subjected to positive and negative wind loads and that the preload criteria make this test method meaningful at the steepest slopes.

This test method's default test pressures recognize that service conditions of any duration are associated with lower velocity winds; this does not imply that air leakage associated with hurricanes would be acceptable. The test method provides a valid means of comparing systems. Do not exceed the default conditions unless unusual site conditions exist or "value added" benefits are required and have been considered.

10.2 The preload test pressure differences, positive and negative, are to be specified. The positive preload pressure difference shall be the greater of 75 % of the building live load or 50 % of the building design positive wind pressure difference. The positive test pressure shall be greater than or equal to 15 lb/ft^2 (720 Pa). The negative preload pressure difference shall be 50 % of the design wind uplift pressure difference.

NOTE 11—This is not a structural adequacy test; For example, among others, Test Method E 1592 is used for roofs. The preload test pressure requirement of 11.3 and the thermal movement requirement of 11.2 represent significant departures from the Test Method E 283 procedure. The requirements are included to work the side seams prior to imposing test pressures. The requirements illustrate a greater concern over roof leaks plus the greater panel lengths and consequent expansion in roofs. The recommended design pressures and number of applications do not overly tax the capacities of most test apparatus nor lengthen the time duration of tests since they simulate service life by repetitively preloading to approximately 75 % of the design snow load or design wind velocity.

If the design pressures vary from roof zone to roof zone on a particular project, select the wind pressure of the central field zone of the largest area as the building design pressure for the test. For balanced designs of equal stiffness throughout a roof, selection of the central field zone allows adequate working of the side seams and is representative of the entire roof. Even when stiffness conditions are not balanced throughout the roof, the recommended criteria work the seams, minimize the number of tests per project, and allow comparisons of alternate systems.

10.3 If the roof system accommodates thermal expansion parallel to the panel, the design differential movement capacity relative to purlin top flanges must be provided and specified.

10.4 The typical panel span on the actual building or the controlling published allowable span at the specified design pressures shall be determined and used in the specimen construction of 8.1 (see Notes 4 and 11 for further commentary).

10.5 The specifier shall indicate whether this test method will be run in sequence with Test Method E 1646. This test method shall precede Test Method E 1646.

NOTE 12—Specifications may be referenced that stipulate the required information listed in 10.1 and 10.2. The information required in 10.1 and 10.2 need not be supplied in such cases.

11. Procedure

11.1 Remove any sealing material or construction that is not normally a part of the typical panel assembly as installed in the field of the building, that is, the roof areas that are not attached to perimeter structural members, flashings, trim, or penetrations. The field performance is not influenced by these edge conditions. Note the field sealant type, geometry, and location. Fit the specimen frame into or against the chamber opening, with the outdoor side of the specimen facing the higher (positive or zero) pressure side of the chamber and in such manner that no joints or openings are obstructed. Seal the outer perimeter of the specimen frame to the chamber wall, and seal at no other points. The perimeter seals between the panels and the specimen frames do not have to duplicate actual building perimeter details. Clamp the specimen frame work to develop the chamber seal and to resist preload and test pressures.

NOTE 13—Non-hardening mastic compounds or pressure-sensitive tape is used effectively to seal the test specimen to the chamber opening, to seal the access door to the chamber, and to achieve air tightness in the construction of the chamber. These materials are also used to seal a separate mounting panel to the chamber. Rubber gaskets with clamping devices are also used for this purpose, provided that the gasket is highly flexible and has a narrow contact edge.

11.2 If the roof accommodates thermal movement parallel to the panel, slide the central support to traverse 75 % of the specified cycle of 10.3. The support shape shall be chosen and the sliding force shall be applied to prevent unusual twisting of the supports. The initial location of all thermal relief features shall be mid-range. Repeat this operation once for a total of two cycles. Attach or tighten the central support at the longitudinal frame work. Seal the test chamber access doors.

NOTE 14—Slotted clips are used to attach the central support to the framework and to act as a guide to accomplish this step. Prior to final torquing or clamping, these guides with slotted surfaces hold the clips in limited contact with both the frame and central support while allowing horizontal (longitudinal) movement and providing vertical bearing. Apply sliding forces without disturbing the seal between the specimen frame and test chamber and between the panel and frame.

11.3 Preload the test specimen to the positive static air pressure differential defined in 10.2. Apply the air pressure promptly, and maintain the pressure for a minimum of 10 s, and then remove the pressure. Allow recovery for 2 min. Preload the test specimen to the negative static air pressure differential defined in 10.2; hold the pressure for a minimum of 10 s, and then unload the pressure. Allow recovery for 2 min. Repeat this positive and negative preloading cycle two additional times for a total of three cycles.

11.4 Repair the test chamber seals if required. Adjust the air flow through the test chamber to provide the specified positive test pressure difference across the test specimen. Record the air flow through the flowmeter and the test pressure difference when the test conditions are stabilized. This measured air flow is designated the total metered air flow, Q_m. Measure the barometric pressure, temperature, and relative humidity of the air at the test specimen. Tests shall be conducted with ambient conditions at or near standard conditions because the air leakage through the specimen is affected by the density or viscosity, or both, of the air passing through the specimen. If positive and negative test pressures are specified, reverse the air flow and repeat this operation using the negative pressure.

11.5 Do not disturb the test specimen. Observe and record points of air leakage if possible (safety and detectability).

11.6 Eliminate extraneous chamber leakage, or, if this is impractical, measure the amount of such leakage with the specimen sealed at the air pressure difference(s) to be exerted during the air leakage tests. The metering equipment for the measurement of air leakage shall be used for measuring the extraneous leakage, or additional air metering equipment shall be provided for this purpose. This measured air leakage is designated the extraneous air leakage, Q_t. One value will be determined for each test pressure.

12. Calculation

12.1 Express the metered air flow, Q_m, and the extraneous leakage, Q_L, in terms of flow at standard conditions.

12.2 Express the air leakage, Q, through the test specimen as follows:

$$Q = Q_m - Q_L \quad (1)$$

12.3 Calculate the rate of air leakage in accordance with the following method:

$$\text{rate of air leakage per unit area} = Q/A \quad (2)$$

13. Report

13.1 Include the following information in the report:

13.1.1 Date of test and date of report.

13.1.2 Identification of the specimen (manufacturer, source of supply, dimensions, model, type, materials, and other pertinent information).

13.1.3 Detailed drawings of the specimen showing the dimensioned section profiles, framing location, panel arrangement, installation and spacing of anchorage and clips, accessories, sealants, and any other pertinent construction details. Any modifications made to the specimen to obtain the reported value shall be noted on the drawings.

13.1.4 A statement or tabulation of the pressure differences exerted across the specimen during preload and during the test and the corresponding rate of air leakage at each test pressure difference and as calculated in Section 12 for each specimen tested.

13.1.5 A statement of ambient temperature prior to and during the test.

13.1.6 A record of all observable points of air leakage as determined in 11.5.

13.1.7 When the test method is performed in sequence with other test methods on the same specimen, a statement of the other test method(s), the corresponding test report number(s), and the test sequence.

13.1.8 When the test is made to check the conformity of the specimen to a particular specification, an identification or description of that specification.

13.1.9 A statement that the test was conducted in accordance with this test method, including the last date of calibration or a complete description of any deviations from this test method.

13.2 If several identical specimens of a component are tested, the results for each specimen shall be reported, with each specimen being identified properly, particularly with respect to distinguishing features of differing adjustment. A separate drawing for each specimen shall not be required if all differences between specimens are noted on the drawings provided.

14. Precision and Bias

14.1 The precision and bias of this test method has not been determined.

14.2 The accuracy required in 6.3 is affected, and errors are compounded by the amount of extraneous air leakage. See Annex A1 in Test Method E 283.

15. Keywords

15.1 air; air flow; air pressure; endlap; flow; flow meter; infiltration; leakage; mastic; metal; panel; pressure; roof; roof panel; sidelap; side seam; structural; thermal expansion; wall