Standard Test Method for Quantification of Air Intrusion in Low-Sloped Mechanically Attached Membrane Roof Assemblies[1]

This standard is issued under the fixed designation D7586/D7586M; 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 provides a laboratory technique for determining the air intrusion in low-sloped mechanically attached membrane roof assemblies under specified negative air pressures differences.

1.2 This test method is intended to measure only air intrusion associated with the opaque roof assembly free from penetrations such as those associated with mechanical devices, roof junctions, and terminations.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1079 Terminology Relating to Roofing and Waterproofing

E283 Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen

E631 Terminology of Building Constructions

E2357 Test Method for Determining Air Leakage of Air Barrier Assemblies

3. Terminology

3.1 For definitions of general terms relating to roofing and building construction used in this test method, refer to Terminologies D1079 and E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *air intrusion*—the mechanism by which indoor air enters into a roof assembly but does not escape to the exterior environment.

3.2.2 *air leakage*—the movement/flow of air from one environmental condition to the other environmental condition through the building envelope assembly which is driven by either positive or negative pressure differences, or both across the envelope assembly.

3.2.3 *extraneous leakage,* L/s (ft^3/min)—the volume of air flowing per unit time into the bottom test chamber due to its leakiness, under a pressure difference.

3.2.4 *flow rate,* L/s—the volume of air flow per unit time.

3.2.5 *specimen air intrusion,* L (ft^3)—the volume of air intruding into the membrane assembly specimen under a test pressure difference.

3.2.6 *test pressure difference,* Pa (lbf/ft^2) —the specified difference in static air pressures across the membrane assembly specimen.

3.2.7 *standard conditions*—dry air at a pressure of 101 kPa (29 in. Hg), temperature of 21°C (69°F) and air density of 1.2 kg/m^3 (0.075 lb/ft^3).

4. Summary of Test Method

4.1 The test consists of installing a mechanically attached membrane assembly specimen between two chambers; specifically an airtight bottom chamber into which air flows and a top chamber that exhausts air at a rate required to maintain the specified negative pressure across the membrane assembly specimen. The resultant air intrusion into the membrane

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[1] This test method is under the jurisdiction of ASTM Committee D08 on Roofing and Waterproofing and is the direct responsibility of Subcommittee D08.20 on Roofing Membrane Systems.

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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.

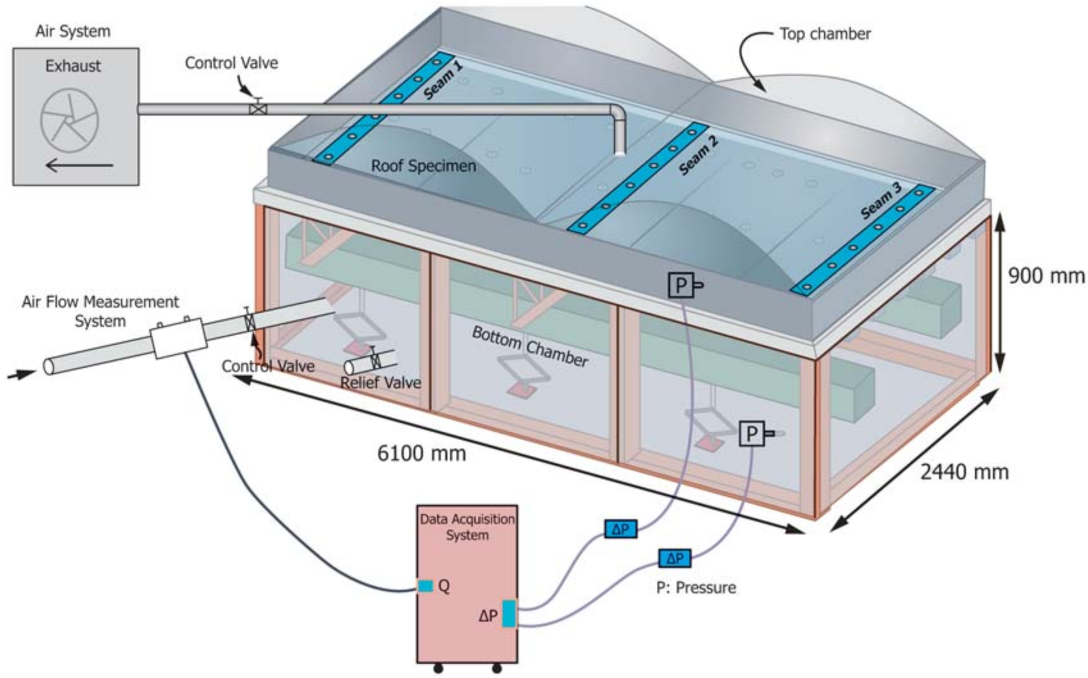

FIG. 1 Air Intrusion Test Apparatus

assembly specimen is measured from the airflow measurement system installed on the bottom chamber.

5. Significance and Use

5.1 This test method can be useful in understanding the response of low-sloped mechanically attached membrane roofing assemblies to air pressure differences induced across the assembly.

5.2 This test method can be useful in understanding the role of different roofing components in providing resistance to air intrusion into the membrane roofing assembly.

5.3 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.

5.4 This test method subjects the roof specimen to negative static pressures, as it is difficult to simulate the complex environmental conditions that can be encountered in service, including rapidly changing pressures due to wind gusting.

5.5 This test method does not purport to establish all criteria necessary for the consideration of air intrusion in the design of a roof assembly. The results are intended to be used for comparison purposes and may not represent the field installed performance of the roof assembly.

6. Test Apparatus

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

6.2 The major components of the test apparatus are (see Fig. 1):

6.2.1 *Pressure Box*—The pressure box shall consist of two test chambers designated as the top chamber and the bottom chamber.

6.2.1.1 *Top Chamber*—The interior length and width dimension of top chamber shall be 6.1 m (20 ft) long and 2.44 m (8 ft) wide, respectively. It shall have a minimum height of 0.9 m (3 ft) and should be movable. To measure the chamber pressure, it shall be fitted with at least one pressure tap. Provision shall be made for an opening on the top chamber through which the pipe network will be installed and connected to the blower. The pipe network shall have a control valve for creating different negative pressures on the membrane assembly specimen. The top chamber shall be provided with window openings to view the membrane assembly specimen response. To facilitate the control of test pressures that is applied over the membrane assembly specimen, the top chamber shall be well sealed by appropriate sealing products.

NOTE 1—Sealing products such as non-hardening mastic compounds or pressure-sensitive tape can be used to achieve the air tightness in the construction of the pressure chamber, to seal the membrane assembly specimen to the bottom chamber, to seal the access door to the chamber and at all other location where effective sealing is required.

6.2.1.2 *Bottom Chamber*—It is a closed chamber with the interior length and width dimension of 6.1 m (20 ft) long and 2.44 m (8 ft) wide, respectively. It shall have a minimum height of 0.9 m (3 ft) and shall be fixed to the ground. The membrane assembly specimen is installed horizontally at the top of the bottom chamber (see Fig. 3) supporting on a height adjustable lever, which can accommodate membrane roof assemblies with different thickness. At least one pressure tap shall be provided in the bottom chamber to measure the chamber pressures. It shall be fitted with a relief control valve to discharge the air

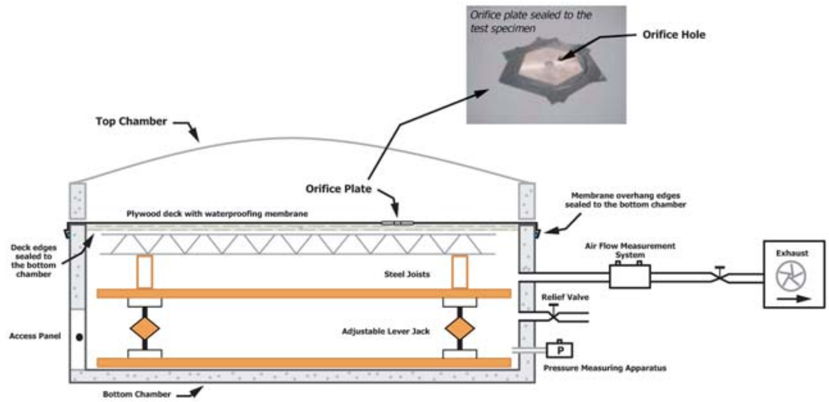

FIG. 2 Calibration Setup

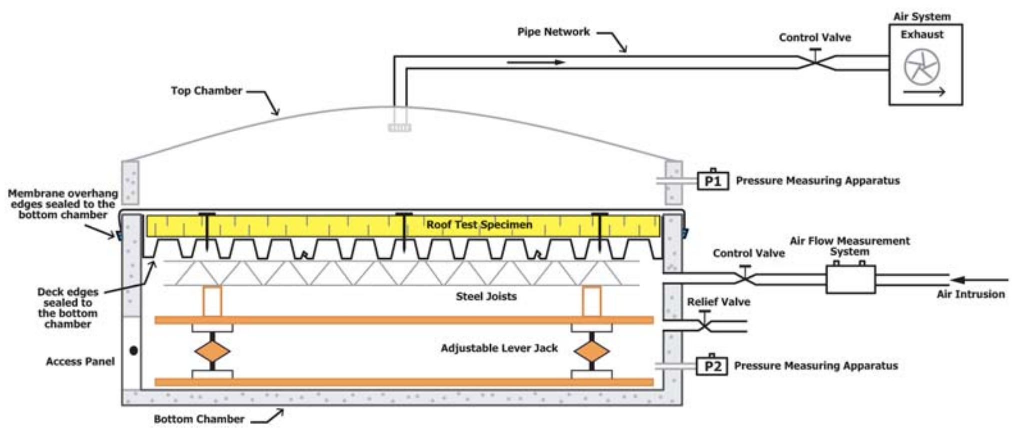

FIG. 3 Membrane Assembly Specimen Air Intrusion Setup

after the application of each differential pressure on the test specimen in the top chamber. Provision shall be made for an opening on the bottom chamber through which the airflow measurement system shall be installed. To facilitate adjustment and observations after the membrane assembly specimen has been installed, it shall be provided with means of access into the chamber. Extraneous leakage into the chamber should be minimized by applying suitable sealing products (see Note 1) to ensure that the airflow due to extraneous leakage does not exceed the airflow measured through the airflow measurement system.

6.2.2 *Air System*—A controllable blower designed to provide the required airflow at the specified negative pressures. The blower shall be capable of creating suction pressures of 5 kPa (100 psf).

6.2.3 *Pressure Measuring Apparatus*—A device for measuring the test pressure difference within a tolerance of ±2 % of the reading or ±2.5 Pa (0.05 psf), whichever is greater.

6.2.4 *Airflow Measurement System*—A flow-measuring device with a 2 in. diameter opening and a flow capacity of 18.8 L/s (40 cfm). It should be capable of measuring the airflow with an accuracy of 0.8 % of the reading.

6.2.5 *Data Acquisition System*—A computer based system capable of reading and recording the pressure and airflow measurements with time scale.

7. Test Specimen

7.1 Different components of the membrane assembly specimen shall be installed and constructed on the top of the bottom chamber (see Fig. 3) according to the recommendations of the party commissioning the test.

7.2 The perimeter edges of the structural deck shall be flush to the interior of the bottom chamber and shall be sealed to the bottom chamber using suitable sealing products as shown in Figs. 2 and 3. This is crucial to ensure that the deck seams or joints are the flow paths and not the deck edges.

7.3 When insulated membrane assembly specimens are tested, the top surface of the insulation board shall be flush with the top edges of the bottom chamber.

7.4 To ensure that edges of the waterproofing component or the roofing membrane are not the flow paths during the air intrusion testing, the roofing membrane shall have a minimum overhang of 600 mm (24 in.) on all the four sides and shall be sealed to the outside of the bottom chamber as shown in Figs. 2 and 3 by suitable sealing products (see Note 1).

8. Calibration

8.1 Perform calibration by installing a 19 ± 3 mm (¾ ± ⅛ in.) thick tongue and groove plywood deck in the bottom test chamber. The edge treatment shall be the same as those used for the membrane assembly specimens (see 7.2). Install a continuous sheet of waterproofing membrane on the plywood deck. The membrane(s) being tested may be used for calibration or at least as determined by the party commission the test. It shall be loose laid with its overhang edges sealed to the bottom chamber as shown in Fig. 2 by using suitable sealing products (see Note 1).

8.2 Make a 150 mm (6 in.) diameter hole through the membrane sheet and plywood for mounting a National Institute of Standards and Technology (NIST) traceable orifice plate.

8.3 The NIST traceable orifice plate shall be constructed of 3 mm (⅛ in.) thick stainless steel having an outside diameter of 200 mm (8 in.) and containing an interior square edge diameter of 25.40 mm (1 in.).

NOTE 2—Calibrated orifice plates traceable to NIST may be obtained by using the method in Annex 2 of Test Method E283.

8.4 The orifice plate with its hole centred over the 150 mm (6 in.) diameter hole made through the membrane and plywood, and seal the orifice plate with suitable sealing product (see Note 1) to prevent perimeter leakage as shown in Fig. 2.

8.5 Seal the orifice hole with a suitable sealing product (see Note 1).

8.6 Connect the air system and the airflow measurement system as shown in Fig. 2. With the relief valve closed, measure the extraneous leakage of the bottom chamber at the negative air pressure differences of 75 Pa (1.5 psf), 120 Pa (2.5 psf), 240 Pa (5.01 psf), 360 Pa (7.5 psf), 480 Pa (10 psf), and 600 Pa (12.5 psf).

8.7 Express the measured extraneous leakage of the bottom chamber in terms of flow at standard conditions. Using any graph plotting software tool, plot the data between airflow versus pressure difference and establish the relationship by fitting the data with power law trend line as given below:

$$Q_e = c(\Delta P)^n \tag{1}$$

where:

Q_e = air flow or extraneous leakage, L/s (ft^3/min),
c = flow coefficient,
ΔP = pressure difference, and
n = an exponent indicating the flow types or openings.

8.8 After determining the extraneous leakage, remove the seal on the orifice hole and repeat the calibration pressures as in 8.6 to determine the total measured airflow, Q_t.

8.9 Express the total measured flow, Q_t, in term of flow at standard conditions and determine the orifice flow, Q_o, as follows:

$$Q_o = Q_t - Q_e \tag{2}$$

8.10 Calibration shall consist of comparing the orifice flow, Q_o, determined through the airflow measurement system with the nominal flow of the reference 25.40 mm (1 in.) orifice plate as indicated in Table 1.

8.11 The airflow measurement system shall be considered within the limits of calibration when the maximum airflow reading in the airflow measurement system does not exceed the highest calibrated nominal orifice airflow value by 20 %.

TABLE 1 Nominal Orifice Flow

Differential Pressures Across Orifice Plate	Nominal Flow
1.5 psf (75 Pa)	3.82 L/s (8.09 ft^3/min)
2.5 psf (120 Pa)	4.84 L/s (10.26 ft^3/min)
5.01 psf (240 Pa)	6.84 L/s (14.49 ft^3/min)
7.5 psf (360 Pa)	8.38 L/s (17.76 ft^3/min)
10 psf (480 Pa)	9.68 L/s (20.51 ft^3/min)
12.5 psf (600 Pa)	10.8 L/s (22.88 ft^3/min)

8.12 Calibration shall be performed as required by the party commissioning the test.

9. Test Procedure

9.1 With the membrane assembly specimen constructed in the bottom chamber and covered with the removable top chamber, the test procedure comprises of measuring the extraneous leakage of the bottom chamber and air intrusion of the test specimen.

9.2 Ensure that the top chamber is tightly fixed to the bottom chamber during the test to make sure that no membrane slippage occurs.

NOTE 3—Clamping devices or gaskets may be used for tightening the top chamber to the bottom chamber.

9.3 To measure the extraneous leakage, connect the air system and the airflow measurement system as shown in Fig. 2. With the relief valve closed, measure the extraneous leakage of the bottom chamber at the negative air pressure differences of 75 Pa (1.5 psf), 120 Pa (2.5 psf), 240 Pa (5.01 psf), 360 Pa (7.5 psf), 480 Pa (10 psf), and 600 Pa (12.5 psf).

9.4 Express the measured extraneous leakage of the bottom chamber in terms of flow at standard conditions and plot the relationship between the air flow and pressure difference as per Eq 1 as described in 8.7.

9.5 To measure the air intrusion of the test specimen, connect the air system's pipe network along with control valve to the opening of the top chamber, and connect the airflow measurement system with the control valve to the opening on the bottom chamber as shown in Fig. 3.

9.6 The air intrusion quantification of the test specimen shall be determined by following the below procedure of depressurization technique:

9.6.1 Close the relief valve on the bottom chamber and open the control valve on the airflow measurement system.

9.6.2 Apply a negative pressure of 240 Pa (5 psf) by the adjustment of the control valve on the air system.

9.6.3 As the negative pressure builds and reaches the stabilization, using the data acquisition system record the pressure difference across the specimen (top and bottom chamber) and measure the air intrusion rate through the airflow measurement system.

9.6.4 Allow the negative pressure application for time duration of 5 min, after which stop the pressure application.

9.6.5 Close the control valve on the air flow measurement system to prevent the back flow of air and open the relief valve to neutralize the system.

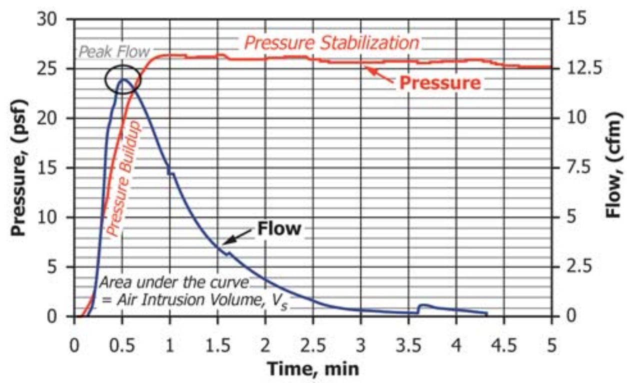

FIG. 4 Example of Measured Data on the Data Acquisition System

9.6.6 Following the procedure from 9.6.1 to 9.6.5 apply negative pressures of 480, 720, 960, 1200 Pa (10, 15, 20, 25 psf) to complete one test cycle. All the negative pressures shall be applied within the range of ±47 Pa (±1 psf). Fig. 4 shows an example of the measured data that should be recorded on the data acquisition system.

9.6.7 Repeat the procedure from 9.6.1 to 9.6.6 one more time for a total of two data sets for a membrane assembly specimen.

9.7 After the completion of each test cycle, the membrane assembly specimen shall be inspected by the party commissioning the test for signs of any failures.

9.8 During the entire testing process, the barometric pressure, temperature, and relative humidity of the air at the test specimen should be recorded.

10. Calculation

10.1 At each applied negative pressure on the membrane assembly specimen, the differential pressure across the specimen causes air intrusion through the airflow measurement system and extraneous leakage depending on the bottom chamber leakiness, as shown in Fig. 5.

10.2 Based on the measured differential pressures in the bottom chamber, extraneous leakage of the bottom chamber shall be calculated from the plotted graph in 9.4 (Eq 1), and the corresponding extraneous air intrusion volume, V_e, shall be calculated.

10.3 Express the air intrusion rate measured through the airflow measurement system at each applied negative pressure in terms of flow at standard conditions. From the measured air intrusion rate, compute the volume of air intruded into the membrane assembly specimen, as shown in Fig. 4, to obtain the air intrusion volume, V_s.

10.4 At each applied negative pressure, express the total volume of air intruding into the membrane assembly specimen (specimen air intrusion), V_{ai} (see Fig. 5), as follows:

$$V_{ai} = V_s + V_e, \text{ L } (\text{ft}^3) \quad (3)$$

10.5 Calculate the air intrusion per linear length, Q_{ai}, as follows:

$$Q_{ai} = V_{ai}/(Fr \times N), \text{ L/m } (\text{ft}^3/\text{ft}) \quad (4)$$

where:

Fr = fastener row spacing, m (ft), and
N = number of full sheets.

11. Report

11.1 The test report shall contain the date of test and report, the name of the author of the report, and the names and addresses of the party commissioning the test.

11.2 The report shall contain a description of the membrane assembly specimen, a description of the method of membrane assembly specimen construction, the name(s) of the manufacturer(s) of all components, and a description of all components.

11.3 The results of the tested membrane assembly specimens shall be reported, with each specimen being properly identified. A separate drawing for each specimen shall not be required if all of the difference between the specimens are noted.

11.4 The following information shall be reported:

11.4.1 List the ambient air temperature, relative humidity, and barometric pressure as measured and recorded during the test.

11.4.2 Extraneous leakage of the bottom chamber must be presented in graphic form. The flow rate shall be established with the power law equation and should be reported.

11.4.3 Tabulation of the applied negative pressures on the test specimen, differential pressures across the test specimen, extraneous air intrusion volume and the total volume of air intrusion into the specimen.

11.4.4 Graphical plots showing relationship between the testing time versus applied pressure, differential pressure across the test specimen and the flow rate.

11.4.5 Graphical plots showing relationship between the testing time versus measured air intrusion volume.

11.4.6 Tabulation of the peak flow rates and total volume of air intrusion into the membrane assembly specimen at each applied negative pressure.

11.5 At the reference pressure of 1200 Pa (25 psf), the air intrusion volume per linear length [L/m (ft^3/ft)] shall be reported as follows:

$$\{10\,\% \times [PF - SF]\} + SF \quad (\text{see Fig. 6}) \quad (5)$$

where:

PF = Peak Flow Rate, and
SF = Stabilized Flow = less than 3 % deviation in the flow rate within 10 s duration.

12. Precision and Bias

12.1 The accuracy required for the determination of the air intrusion is affected by the extraneous leakage of the testing chamber and the appropriate sealing measures, such as in 6.2.1.1, 6.2.1.2, 7.2 and 7.4.

12.2 The repeatability relative standard deviation is determined to be between 5 to 10 %. The reproducibility of this test method is being determined and will be available on or before December 2011.

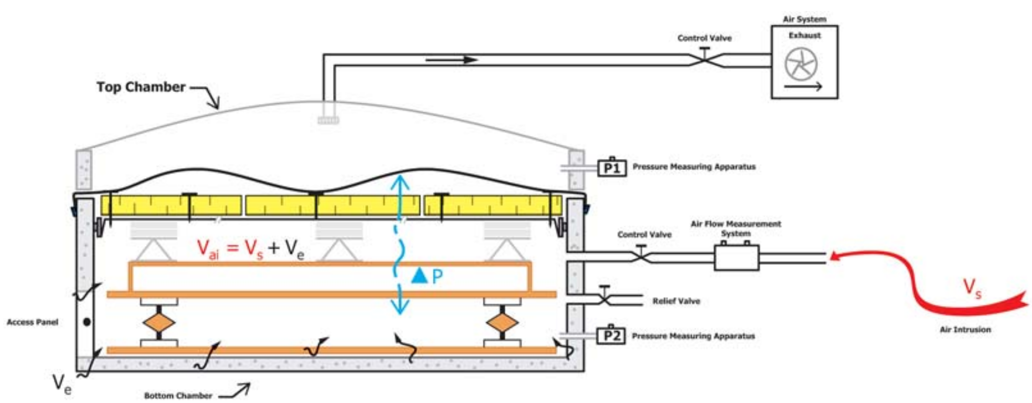

FIG. 5 Determination of Total Air Intrusion into the Membrane Assembly Specimen

13. Keywords

13.1 air; air flow; air intrusion; air leakage; flow; flow meter; laboratory method; membrane; negative pressure; pressure; roof; wind pressure

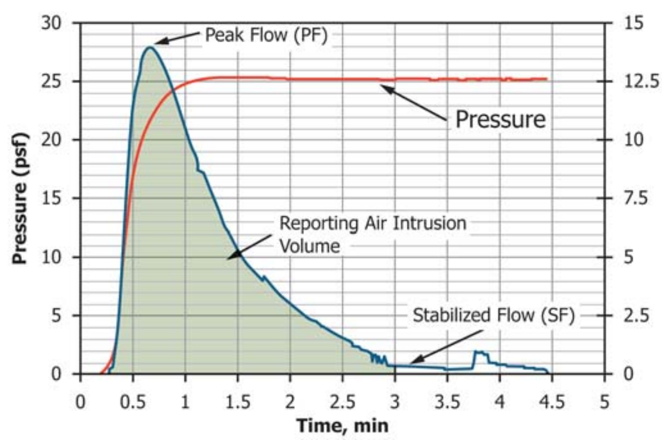

FIG. 6 Reporting Air Intrusion Volume

APPENDIX

(Nonmandatory Information)

X1. GENERAL DISCUSSION

X1.1 Conventional roofs with the water proofing membrane on the top exposed to the weathering and insulation below are one of the common low-sloped membrane roofing assemblies. In these assemblies the membrane can be mechanically attached, fully adhered or partially attached to the substrate.

X1.2 In these roofing assemblies most of the attention has been focused on the performance of individual roof components to maintain the integrity of the waterproofing system. Relatively, very little attention has been given to the overall assembly performance with regards to air movement, which is still misunderstood within the building community. A common misconception is, air movement in roofing assemblies can be characterized by the air leakage that typically occurs in walls and windows. Some of the factors that contribute to this confusion are the existing energy and building code requirements and the current air barrier standards, which are all focused on wall assemblies. Kalinger[3] clearly documented that "ASTM Test Method E2357–05 for Determining Air Leakage of Air Barrier Assemblies" contains three references to roofs in contrast to forty-five references to walls. He also states that "roofs are not simply horizontal walls, and it is inappropriate to generalize information and requirements relating to wall performance to low-slope roof assemblies."

[3] Kalinger, P., "The Roof as an Air Barrier," Proceedings of the RCI 23rd International Convention & Trade Show, February 28–March 4, 2008, Phoenix, AZ.

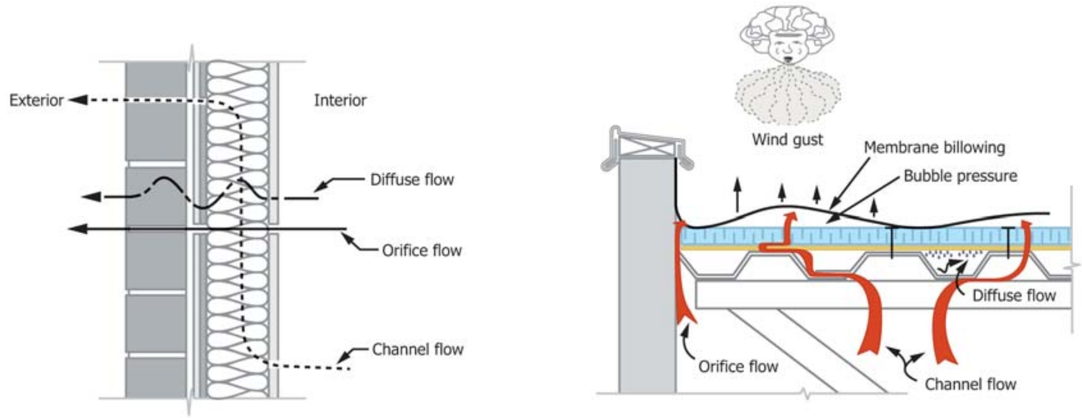

FIG. X1.1 Concept of Air Leakage (Brick Cladding Wall) versus Air Intrusion (Mechanically Attached Roofing System)

X1.3 For airflow to occur across a building component, there must exist two prerequisites, one is the pressure difference between two locations, and the other is a continuous flow path or openings connecting the locations. In the building envelope, air movement can be described by the following terms (Molleti et al)[4]:

X1.3.1 *Air Leakage*—When air enters or leaves from one environmental condition to the other environmental condition through the building envelope assembly such as walls and windows, it is termed as "Air Leakage."

[4] Molleti, S., Baskaran, B. A., Ko, K. P., and Beaulieu, P., "Air leakage vs. air intrusion in low-sloped roofing assemblies," Proceeding of the 12th Canadian Conference on Building Science and Technology, Montréal, Quebec, May 2009, pp. 567–578.

X1.3.2 *Air Intrusion*—When conditioned indoor air enters into a building envelope assembly but cannot escape to the exterior environment, as is the case for mechanically attached roofs, it is termed "Air Intrusion."

X1.4 Cautions regarding air intrusion are not new. There are existing technical notes and manuals, which identify the impact of air intrusion on roof wind uplift resistance and condensation within the roof assembly. However, very little information is available regarding how sensitive are the roofing assemblies to air intrusion. This test method evaluates the role of different roofing components in providing resistance to air intrusion into the assembly.

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(5) Molleti, S., Baskaran, B. A., Ko, K. P., and Beaulieu, P., "Air intrusion vs. air leakage—the dilemma for low sloped mechanically attached membrane roofs," Proceedings of the Canadian Symposium on Roofing Technology, Toronto, March 2009, pp. 1–9.

(6) Zarghamee, M. S., "Wind Effects on Single-Ply Roofing Systems," Journal of Structural Engineering, Vol 116 , No. 1, January 1990, pp. 177–187, Paper No. 24277.

(7) Zarghamee, M. S., "Dynamics of Roofing Membranes In Wind," Proceedings of the Roofing Research and Standards Development, Second Volume, American Society for Testing and Materials, San Francisco, CA, June 1990, pp. 152–162.