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Wind Load Design Specs and Air Barrier Performance Levels

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Abstract

This intermediate/advanced-level presentation will outline the important characteristics for air barrier assembly performance by addressing:

- Review of desired wind load design specs by project type
- Methodology of ASTM 1677 vs. ASTM 2357 as assembly tests
- Understanding how assembly airtightness impacts emerging energy code compliance
- Examples of how installation details can impact the performance level for a given air barrier system

Speaker

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Wind Load Design Specs and Air Barrier Performance Levels

ABSTRACT

Building envelope airtightness is an essential requirement for a building's performance. Recent energy codes have recognized the importance of air leakage control, and continuous air barriers have become mandatory code requirements for the building envelope (ASHRAE 90.1 2010/2013, IECC 2009/2012, and others). While this is an important first step, simple inclusion of an air barrier requirement does not guarantee air barrier performance under field application conditions. Air barrier systems must be properly installed, meet the building envelope structural performance (structural integrity) requirements under wind pressure loads, and maintain their performance over time.

There are two accepted performance levels for commercial air barrier systems, determined by the wind pressure load design parameters for the building envelope:

- ASTM E1677, *Standard Specification for Air Barrier Material or System for Low-Rise Framed Building Walls.* This test measures structural integrity of air barriers for envelope design specifications of up to 105-km/h (65-mph) equivalent wind pressure loads.
- ASTM 2357, *Standard Test Method for Determining Air Leakage of Air Barrier Assemblies.* This test measures structural performance of air barriers for buildings designed to withstand wind pressure loads higher than 65 mph.

This paper describes the air barrier performance requirements for the desired wind load design specifications. The performance level is not determined by the type of air barrier material, but by the installation details. Examples of how these details can impact the performance level for a given air barrier system will be provided, with special emphasis on mechanically fastened air barriers.

Note that the terminologies "structural performance" and "structural integrity" are used in standards ASTM E2357 and ASTM E1677, respectively, to describe the ability of air barriers to resist pressure loads. For example, ASTM E1677 defines "structural integrity" as "the ability of the air barrier to maintain air leakage performance after exposure to elevated positive and negative pressure."

AIR LEAKAGE AND ENERGY CODES

Air leakage can impact many aspects of building performance: energy efficiency, durability/moisture management, and indoor air quality. The impact of air leakage on moisture management and indoor air quality is more difficult to quantify than its impact on building energy use. It is for this reason that air leakage control is mandated through energy codes.

There are three code compliance options for air leakage control: air barrier materials, assemblies, and whole-building testing. Different codes provide one, two, or all three compliance options. For example, the model energy code for commercial buildings, ASHRAE 90.1-2013, provides two compliance options: air barrier materials or assemblies. Energy and sustainability standards, as well as government agencies, require whole-building testing. These include: U.S. Army Corps of Engineers (USACE), the first to mandate whole-building testing; General Services Administration (GSA); Naval Facilities Engineering Command (NAVFAC); United States Air Force (USAF); IECC-2012; ASHRAE 189.1 2009; and International Green Construction (IgCC) 2012.

AIR BARRIER MATERIALS

The first step in air leakage control and the most common strategy for code enforcement is the design and specification of a continuous air barrier. Air barrier materials are materials that can resist airflow. Air infiltration resistance is an intrinsic material property that defines the amount of air that passes through a material under a specified pressure difference. Any material with an air permeance less than 0.02 L/(s • m^2) @ 75 Pa pressure differential (0.004 cfm/sf @ 0.3 in. wc or 1.56 psf pressure differential), when tested in accordance with ASTM E2178, *Standard Test Method for Air Permeance of Building Materials*, qualifies as an air barrier. Even though many common building products are air barrier materials (e.g., metal sheets, glass, oriented strand board [OSB], and gypsum board), a continuous air barrier requires many compatible components to achieve a continuous plane of airtightness. In practice, most air barrier materials are specifically designed membranes effectively integrated into a continuous air barrier system.

Common air barrier materials include mechanically fastened sheets (i.e., building wraps), fluid-applied membranes, and self-adhered membranes. The choice depends on many factors, such as the substrate, desired performance level, installed cost, personal preference, local practices, and regional availability.

For example, in framed construction where air barriers are applied over exterior sheathing, building wraps are the most cost-effective and could provide either ASTM E1677 or ASTM E2357 performance levels, depending on installation details. For masonry or concrete backup walls, fluid-applied membranes are the common choice. Self-adhered membranes can be used with either substrate, but most are vapor-impermeable and their use should be limited to specific climates and wall design options. For example, vapor-impermeable membranes should not be used on the cold-in-winter side of the insulation. Some self-adhered membranes are vapor-permeable but require primers for proper adhesion to common substrates, resulting in lower water vapor permeance for the installed system.

In the case of vapor-impermeable air barriers, the membrane plays a dual role: air and vapor control. While air barriers could be installed anywhere in the building envelope, vapor retarder location and its use is climate- and design-specific. For example, vapor retarders are required by code only in cold climates and must be installed at the warm-in-winter side of the envelope. In warm-humid climates, a vapor retarder could generally be acceptable on the outside of the envelope (where the air barrier is generally installed) if the design options include drying pathways—e.g., if all materials to the inboard of the vapor barrier are vapor-permeable to allow drying to the inside. An exulation system (i.e., exterior insulation only, with no insulation in the stud cavity) is an example of wall design that can use vapor-impermeable air barriers in any climate. The impact of air barriers' vapor permeance on moisture management has been discussed elsewhere[5,6], and it is beyond the scope of this paper. However, building physics must always be considered when an unintended vapor retarder is used in a wall assembly. The optimum vapor permeance will depend on the building envelope design and climate zone and must be assessed for each project.

There are four essential performance requirements for air barriers: 1) air infiltration resistance, 2) continuity, 3) structural integrity, and 4) durability. These requirements have been described in the literature,[1-4] and additional references can be found at the Air Barrier Association of America (ABAA) website (http://www.airbarrier.org). Another critical property for air barriers is vapor permeability that could impact moisture management, as discussed above; however, there are no clear requirements for air barriers' vapor permeance, leaving this decision to the building envelope designer.

Air infiltration resistance is an inherent material property for air barrier materials. The air barrier requirements listed above depend not only on material properties, but also on the performance of the installed system determined by the integration of air barrier components into a continuous plane of airtightness, as well as its durability under use conditions. In addition to the primary air barrier membrane, an air barrier system includes installation and continuity accessories, such as primers, mechanical fasteners, seam tapes, flashing, adhesives, and sealants.

This paper mainly focuses on the structural integrity requirement, which is the ability of an air barrier system to withstand wind loads after construction is complete. There are two accepted performance levels based on building envelope design parameters with regard to wind loads and wind-driven rain. To establish the performance level of an installed air barrier system, air barrier wall assemblies must be tested in accordance with the respective ASTM standards.

	ASTM E1677-11	**ASTM 2357 -11**
Number of test Specimen and configuration	One specimen 2.4 x 2.4-m (8 x 8-ft walls): 1 - opaque wall (Usually wood-based sheathing over wood framing)	Test two of the three specimens below (2.4 x 2.4-m walls): 1 - opaque Wall 2 – wall with penetrations 3 – wall/foundation Interface (Usually exterior gypsum sheathing and metal framing)
Conditions for air leakage testing	Five Test Pressures: 75 Pa (1.56 psf, 25 mph), two pressures below 75 Pa, and two pressures above 75 Pa. Air leakage results are reported at 75Pa. ***(Positive & negative pressures)***	Seven Test Pressures: ± 25 Pa (0.56 psf, 15 mph) ± 50 Pa (1.04 psf, 20 mph) ± 75 Pa (1.56 psf, 25 mph) ± 100 Pa (2.09 psf, 30 mph) ± 150 Pa (3.24 psf, 35 mph) ± 250 Pa (5.23 psf, 45 mph) ± 300 Pa (6.24 psf, 50 mph) ***(Positive & negative pressures)***
Pressure loading schedule	Sustained loads up to ± 500 Pa (10.4 psf, 65 mph) ***(Positive & negative pressures)***	1 - Sustained, ± 600Pa (12.5 psf, 71 mph) 2 - Cyclic, ± 800 Pa (16.7 psf, 82 mph) 3 - Gust, ± 1200 (25 psf, 100 mph) ***(Positive & negative pressures)***
Water resistance (ASTM E331)	Required for **Type I** air barriers (which can also perform as water-resistive barriers [WRBs]); no water penetration shall occur at 27 Pa (0.11 in. H_2O) pressure difference (approximately **15 mph** wind-driven rain) during a 15-min. test period	Water resistance testing is not required for ASTM E2357; air barrier assemblies designed for high wind loads should have water infiltration resistance at equivalent wind driven rain of *above* 15 mph, if they are to also perform as WRBs

Figure 1 – Summary comparison between ASTM E1677 and ASTM E2357 wall assembly testing.

INSTALLED AIR BARRIER PERFORMANCE AND WALL ASSEMBLY TESTING

Use of air barrier materials is a mandatory requirement for air leakage control, but this is not sufficient for ensuring an airtight building envelope. Testing of air barrier wall assemblies is important for demonstrating performance of installed air barriers on a practical scale, for developing robust installation guidelines, and for establishing the performance level for different installation options.

As mentioned, ASTM E1677-11 applies to air barrier performance levels for building envelope design requiring up to 105-km/h (65-mph) equivalent wind pressure loads, and up to 24-km/h (15-mph) equivalent wind-driven rainwater infiltration resistance. This level is generally adequate for buildings of up to five stories, but higher performance is typically required on some low-rise buildings such as medical facilities and military buildings. ASTM E2357-11, on the other hand, applies to air barrier performance levels for building envelope design wind pressure loads beyond this; such a performance level is generally necessary for buildings taller than five stories.

Both test methods are performed on 2.4- x 2.4-m (8- x 8-ft) wall assemblies. ASTM E1677 requires testing of a single opaque wall assembly (i.e., no penetrations except for the fasteners), while ASTM E2357 involves two specimens—an opaque wall, and a penetrated wall that includes standard penetrations such as window openings, external junction boxes, and galvanized duct.

Both test methods require pressurization and depressurization testing, but use different wind pressure loads and schedules. The major differences between the two test methods are summarized in *Figure 1* and consist of the test pressures, structural (wind) loading schedule, and requirement for water infiltration resistance testing.

As shown, ASTM E1677 requires five test pressures:

- ± 75-Pa pressure differential (1.56 psf, 25 mph)
- Two pressures below 75 Pa
- Two pressures above 75 Pa

The structural wind-loading schedule includes sustained loads of up to ±500 Pa (10.4 psf, 65 mph). This standard requires testing for water infiltration resistance per ASTM E331, *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference.* Air barriers or air retarders (as they are referred to in ASTM E331) are classified as either Type I or Type II. Type I air barriers, which can also perform as water-resistive barriers (WRBs), must exhibit no water penetration when tested at 27 Pa (11-in. water pressure difference)—the equivalent wind speed of approximately 24 km/h (15 mph)—during a 15-minute test period. Type II air barriers are not required to be tested in accordance with ASTM E331.

ASTM E2357 requires a minimum of seven test pressures, from ±25 Pa (0.56 psf, 15 mph) to ±300 Pa (6.24 psf, 50 mph). The structural wind-loading schedule includes sustained, cyclic, and gust winds up to ±160-km/h (100-mph) equivalent wind speed. This standard does not require ASTM E331 testing for water infiltration resistance, which is a significant limitation since many air barriers are commonly required to also perform the WRB function and are exposed to loads above those produced by 105-km/h (65-mph) winds.

Air leakage results are reported at 75 Pa for both methods. Current codes require the average air leakage rate for air barrier assemblies not to exceed 0.2 L/(s•m^2) @ 75 Pa pressure differential (0.04 cfm/sf under a pressure differential of 0.3 in. w.g. or 1.57 psf) when tested in accordance with ASTM E2357 or ASTM E1677.

ASTM E2357 is a more stringent test method than ASTM E1677, and it is used for air barrier wall assemblies intended for high-performance buildings designed for over 65-mph equivalent wind pressure loads. The air barrier design for these conditions is based on the assumption that the air barrier will take the full wind loads, that it will experience repeated cycling of high positive and negative pressure during its service life (e.g., thousands of cycles), and that it will see two severe storms in the first 15 years in service.

Since a continuous air barrier experiences both positive and negative pressures during its use, it is important that wall assemblies be tested under both positive and negative pressures. The negative load (suction) is typically the most severe, as it tries to pull the air barrier off the wall. Different air barrier types have varying susceptibility to negative pressures.

For fluid-applied air barriers, wind loads are transferred to the substrate underneath. When the substrate is masonry or concrete, a fully adhered fluid-applied air barrier has excellent structural performance under suction, as the pressure it typically takes to separate it from the substrate far exceeds the actual pressure it must withstand. However, for framed wall construction, the structural performance of fully adhered fluid-applied air barriers under negative wind loads depends on how well the sheathing is fastened to the building structure. When the exterior sheathing is not installed to withstand the design wind loads, this could reduce the air barrier system's structural performance. In this case, the typical mode of failure for fluid-applied air barriers is the sheathing pulling over the fasteners.

In comparison, when building wraps are installed over exterior sheathing, the air barrier membrane is supporting the entire load. Consequently, this type of air barrier is more susceptible to wind loads. The suction forces are transferred through the air barrier membrane to the mechanical fasteners, and then back to the structural supports (i.e., steel or wood studs). As a result, for a mechanically fastened air barrier, the wind load performance is determined by the type of fasteners and the fastener schedule.

The photos in *Figure 2* show an example of high-pressure performance testing of commercial building wraps and exemplify the extreme forces experienced by the air barrier wall assemblies under negative pressure loads. The steel studs actually buckle under the pressure differentials used for high-performance testing (beyond ASTM E2357 requirements) of building wraps (left

Figure 2 – High-pressure testing of wall assemblies with mechanically fastened air barrier systems. Source: DuPont testing at ATI.

Washer Size	Fastener Spacing	Allowable Pressure*	
2" Metal	12"	90 psf	188 mph
	18"	60 psf	153 mph
2" Plastic	12"	70 psf	165 mph
	18"	45 psf	133 mph
1.25" Metal	12"	60 psf	153 mph
	18"	40 psf	125 mph

*Values represent maximum allowable pressures. A factor of safety may need to be applied for certain cladding systems.
Source: DuPont™ Tyvek® Weather Barrier Commercial Installation Guidelines, Version 4

Figure 3 – Washer size and fastener spacing for screws on 16-in.-on-center (oc) steel studs.

photo), but a properly fastened building wrap withstands this pressure and maintains the system's structural integrity (right photo). These pictures demonstrate the importance of proper fastening of building wraps to withstand high-suction loads and maintain the air barrier structural integrity during use. A common mistake with building wrap installation is use of staples for fastening the building wrap into the exterior sheathing (a practice often employed for WRBs in residential construction), rather than employing recommended screws with washers to fasten the membrane into the structural members (wood or steel studs).

Building wrap manufacturers usually provide guidelines on the type of fasteners and the fastening schedule recommended for meeting the desired performance level. *Figure 3* provides an example of fastening type and schedule guidelines and the maximum allowable wind loads.

Alternate fasteners are also allowed, when applicable. Examples include standard brick tie base plates and metal plates, metal channels, horizontal z-girts, and wood furring strips mounted vertically. They can be used in conjunction with the manufacturer-recommended fasteners to meet and/or satisfy the desired design performance.

In addition to fastener selection and spacing, other installation details are critical when designing for a specific performance level. Some building wrap manufacturers provide different installation details for ASTM E1677 and ASTM E2357. These include details on sealing of penetrations, transitions, and interfaces. For example, no additional fastener sealing is necessary for building envelope design requiring up to 105-km/h (65-mph) equivalent wind loads (i.e., ASTM E1677), when recommended fasteners and schedules are used. However, if higher structural performance is desired (i.e., ASTM E2357), self-adhered flashing must be used under the fasteners.

Figure 4 shows examples of alternate fasteners, as well as the use of self-adhered flashing under the fasteners for ASTM E2357 performance level. Some manufacturers claim self-sealing of fluid-applied air barrier membranes; however, no fluid-applied membrane is truly self-sealing, and the same recommendations for fastener treatment are recommended for fluid-applied membranes.

Among the most critical details determining the air barrier structural performance level are window and door integration into the continuous system. Most manufacturers provide step-by-step window installation guidelines. Changes in the provider's detailing and sequencing could change the performance level (i.e., ASTM E1677 or ASTM E2357). *Figures 5* and *6* show examples of specific details for achieving the desired wind load design specifications.

The detail in *Figure 5* shows how the rough window openings are treated with self-adhered flashing for the high-performance level required by ASTM E2357. For example, when the building has non-flanged, storefront, and/or curtain wall windows, the air barrier membrane is typically cut flush with the edge or the rough opening. Then, the self-adhered flashing is installed to protect the rough opening and provide a positive termination of the air barrier membrane. The photos show examples

Figure 4 – Alternate fastening and additional detailing for high wind loads (ASTM E2357).

of high-performance flashing for nonflanged and/or curtain wall windows that may be bumped out from the wall plane.

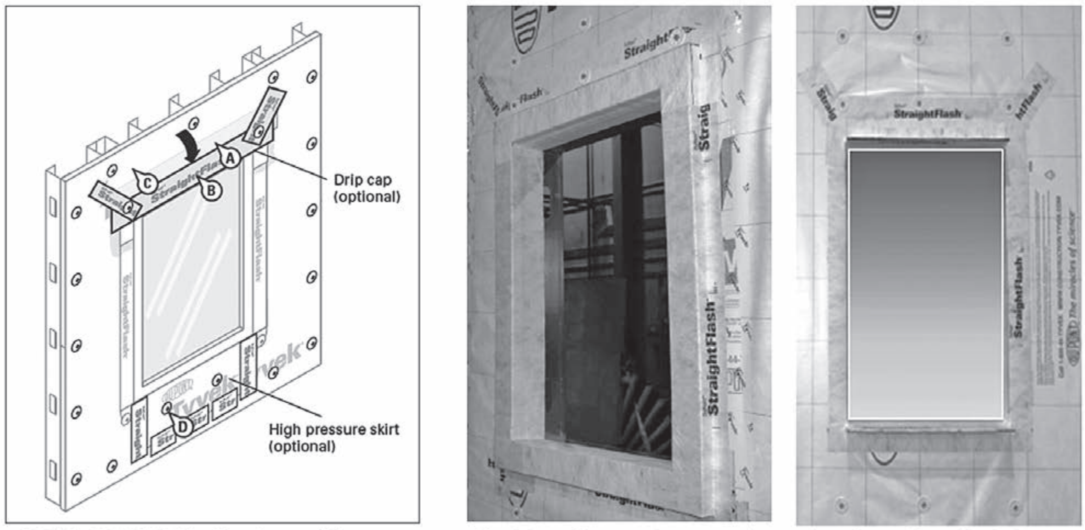
Figure 6 shows an example of window flashing for ASTM E1677 performance level. The picture captures the alternate head detail, which is generally allowed for buildings with building envelope design requirements not exceeding ASTM E1677. After the air and water barrier is wrapped into the window rough opening, a top hat is created with sealant to divert water away from the window opening (if the air barrier is also intended to serve as the WRB). WRB cut pieces are then installed by (I) wrapping in and around the studs at the jamb and the head and stapling to the inside framing to secure at the area marked "A." The next steps include: (II A) apply a continuous sealant bead along jambs and head, B) install flanged window, C) install jamb flashing, and D) install head flashing.

The recommended installation guidelines are based on many wall assembly tests, and changing the installation details in the field could affect the performance level for the installed air barrier assembly. Engaging the air barrier manufacturers in early design stages is critical in understanding the installation details requirement and the optimal installation sequence to achieve the desired performance level. Additionally, it helps avoid unnecessary delays during the construction phase.

The difference between the two performance levels for air barriers is not always understood by industry professionals and installers, and is not clearly stated by codes. For example, the American Society of Heating, Refrigerating, and Air-conditioning Engineers's (ASHRAE's) 90.1-2013, *Energy Standard for Buildings Except Low-rise Residential Buildings*, Section 5.4.3.1.3.b, defines code-compliant air barrier assemblies as:

> Assemblies of materials and components (sealants, tapes, etc.) that have an average air leakage not to exceed 0.04 cfm/sf under a pressure differential of 0.3 in. w.g. (1.57 psf) when tested in accordance with ASTME 2357, ASTM E1677.

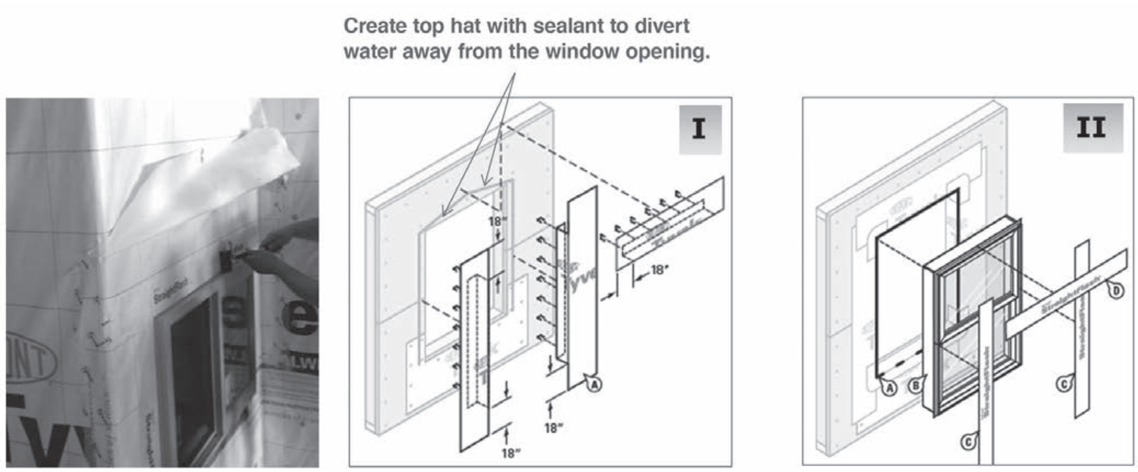
As evident from this paper, performance levels for ASTM E1677 and ASTM E2357 are not equivalent; nevertheless, ASHRAE 90.1-2013 provides the two options as equals. It is surprising that there is confusion in the industry, and the potential impact of



ASTM E2357: SA flashing is used for wrapping the rough opening.
(A) Flip down the head flap and adhere 4-in. SA flashing over diagonal seams,
(B) tape along the top of the window with 4-in. SA flashing,
(C) install remaining fasteners at head per the recommended spacing, and
(D) install fasteners at appropriate spacing.

Flashing of bumped-out, nonflanged, and curtain wall windows: window rough openings are treated with self-adhered flashing for higher performance level required by ASTM E2357 (Source: DuPont laboratory test facility in Richmond, VA).

Figure 5 – Example of window flashing details for ASTM E2357 performance level.



ASTM E1677: The air and water barrier is wrapped into the opening.

A) Install the WRB cut pieces by wrapping in and around the studs at the jamb and head. Staple the membrane to the inside of the framing to secure.

A) Apply a continuous sealant bead along jambs and head with skip seal along sill to allow drainage.
B) Install flanged windows.
C) Install jamb flashing.
D) Install head flashing.

Figure 6 – Examples of window flashing details for ASTM E1677 performance level.

changes to the manufacturer's installation guidelines is not always appreciated.

Fortunately, in order to apply consistent standards across the industry, ABAA recently introduced an evaluation process for air barriers. The association lists, on its website (www.airbarrier.org), the air barriers that have been evaluated and demonstrated to meet ASTM E2357 performance level. The ABAA evaluation process is discussed in the next section.

ABAA-EVALUATED AIR BARRIER ASSEMBLIES

Even though some codes include air barrier assembly as a compliance option, in practice, the default compliance path for air leakage control has been through air barrier materials. For many years, practitioners relied on air barrier material properties, while the performance of installed air barriers was largely untested. Testing air barrier assemblies can provide information on performance of installed air barriers, but because it wasn't required, very few manufacturers have performed these tests.

The ABAA is a trade organization representing the air barrier industry, with a mission of developing a professional air barrier specialty trade and industry dedicated to the installation of effective air barrier systems in buildings. Even though ABAA was founded in 2001, it was not until 2009 that ABAA introduced an evaluation process to establish performance of installed air barriers.

Air barrier manufacturers were required to submit third-party test reports for materials and assembly testing for ABAA evaluation. In addition to materials testing, ABAA required manufacturers to demonstrate that air barrier assemblies do not exceed 0.04 cfm/ft^2 @ 0.3 in. wc or 1.56 psf pressure differential [0.2 L/(s • m^2) @ 75 Pa], when tested in accordance with ASTM E2357, *Standard Test Method for Determining Air Leakage of Air Barrier Assemblies.* In order to be listed on the ABAA website as an air barrier, the manufacturers were required to complete the evaluation process for air barrier materials and air barrier assemblies and demonstrate compliance with current standards.

The website currently lists all air barrier materials and their manufacturers that have completed the evaluation process. Even though the importance of air barrier assembly testing was recognized and documented by some[7] before the ABAA initiative, the ABAA evaluation process was critical in implementing a uniform performance requirement across the industry for installed air barriers. ABAA's website also lists the vapor permeance of air barrier membranes to provide building envelope professionals with the necessary tools for moisture-managed envelope design.

CURRENT LIMITATIONS OF AIR BARRIER ASSEMBLY TESTING

Figure 7 shows a flowchart of current wall assembly testing, and it gives a side-by-side comparison between ASTM E1677 and ASTM E2357 test methods. For both methods, the wall assemblies (one wall for ASTM E1677 and two walls for ASTM E2357) are submitted to the initial air leakage test using the test pressures specified in *Figure 1,* and the initial air leakage is reported at 75 Pa. Following the initial test, the walls are submitted through the structural wind loads schedule and then retested for air leakage. The "final" assembly air leakage is reported at 75 Pa.

There are two major differences between ASTM E2357 and E1677.

- ASTM E2357 requires testing at higher wind loads; and for this reason, it is more appropriate for high-performance commercial buildings. This is also the reason the ABAA evaluation process selected the ASTM E2357 test for demonstrating assembly performance.
- ASTM E1677 requires testing of water penetration following the wind loads, to measure how the wind loads have impacted the water penetration resistance of the wall assembly. This is a significant advantage, especially when the air barriers must also perform as WRBs. Unfortunately, ASTM E2357 does not require water penetration testing.

Both tests are limited in predicting the longterm durability of air and water barrier systems under use conditions. A summary of two important parameters that need to be incorporated in air barrier wall assembly testing is provided below.

Thermal Cycling

Both tests measure the structural integrity of air barrier assemblies under wind loads, but are usually performed on freshly installed air barrier assemblies, providing a false sense of security that what passes today will pass tomorrow—or five, 10, and 20 years from now. This testing does not provide information on the durability of multiple interfaces as a result of temperature variations experienced by above-grade exterior walls during field service applications. ASTM E2357 standard acknowledges the importance of such factors but does not require integrating these variables into the testing.

For the air barrier system to be effective, it must reduce air flow.

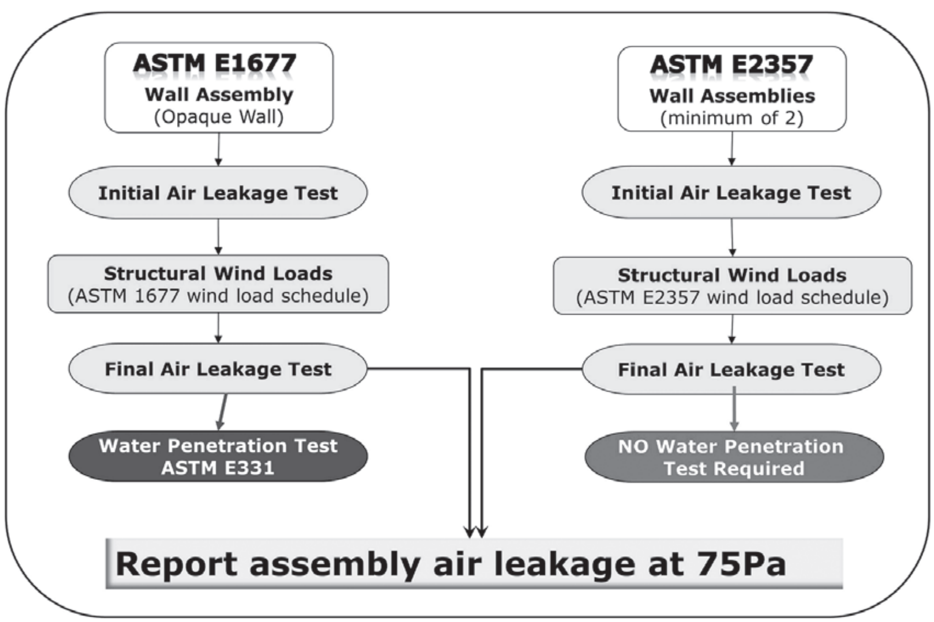
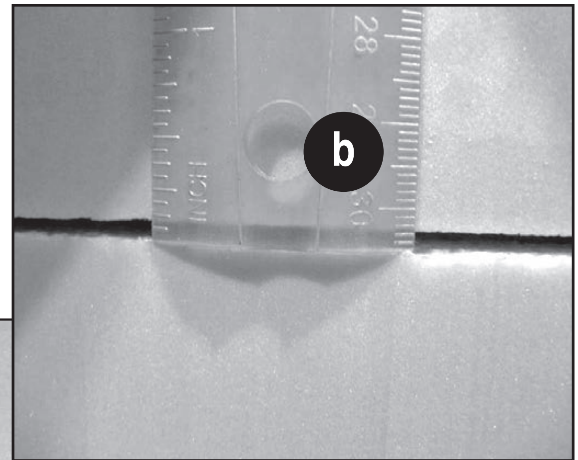


Figure 7 – Flowchart with main steps in wall assembly testing. Side-by-side comparison of ASTM E1677 and ASTM E2357.



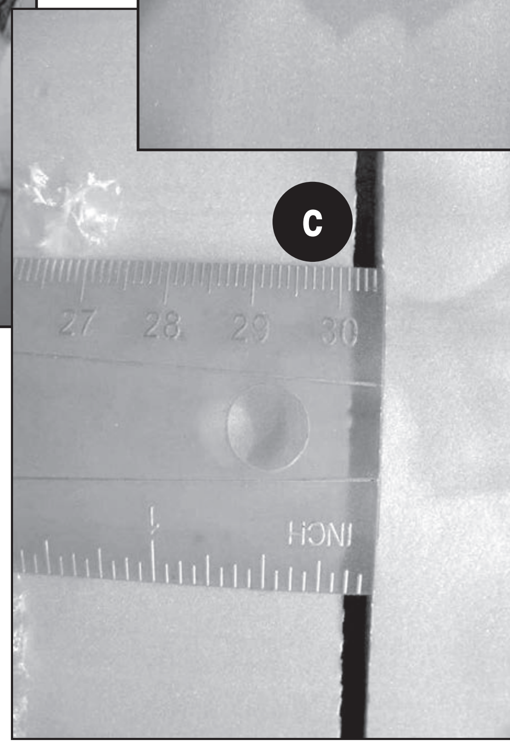


Figure 8 – Loss of air barrier continuity as a result of differential thermal expansion (a). Gaps in XPS board insulation subjected to thermal cycling (b, c).

> This resistance to air flow can only be achieved by maintaining continuity (no breaks or tears). Continuity of joints must be maintained by overlapping, sealing with weatherable adhesive tapes, or caulkings/gaskets. Caulked joints must accommodate dimensional changes in framing members without loss of seal integrity. Such dimensional changes can be induced by lumber drying and settling thermal movement and structural movement. NOTE X1.1—Test Method E1424 may be utilized to determine the effect of temperature on air barrier assembly.

Differential expansion and contraction of assembly components that form the plane of airtightness (e.g., substrates, framing members, tapes, etc.) could affect the continuity during use conditions. Air barrier foam products are especially vulnerable to temperature effects due to large dimensional changes experienced during use, which could significantly impact adhesion to substrates, integrity of taped joints, etc., and therefore compromise the continuity of air barriers over time. Foam insulation products have standard thermal stability requirements (ASTM D2126), but this is a product test, not an assembly test. Foam insulation can expand and contract within accepted limits (up to 2%) and still perform properly as thermal insulation. It is the difference between expansion coefficients of multiple materials that interface in order to form the continuous plane of airtightness that could compromise the durability and continuity.

Figure 8 shows a field example of loss of continuity at joints for taped foam insulation board, which could be the result of differential thermal expansion between foam and tape (a). The photos on the right show gaps which developed in both horizontal (b) and vertical (c) seams in extruded polystyrene (XPS) foam boards subjected to thermal cycling during laboratory testing.

In fact, in some states, taped insulation is not allowed as an air barrier:

> Taped rigid insulation is not allowed as an air barrier in Wisconsin. When some types of insulation boards get colder by 70°F, they can shrink ¼ in. on all sides. The tape cannot adequately perform under such circumstances. (Air Barrier Update, International Masonry Institute Technology Brief, January 2004.)

Foam insulation is not the only type of air barrier material susceptible to loss of continuity under field application conditions. Some fluid-applied air barrier membranes are also susceptible. ASTM C1305, *Standard Test Method for Crack Bridging Ability of Liquid-Applied Waterproofing Membrane*, is an excellent test to better understand the durability of a fluid-applied membrane under field application conditions. The test is intended to determine the ability of the membrane to bridge a crack that may form in a substrate over time as a result of dimensional changes induced by settling due to thermal and/or structural movement.

One cycle of the test is performed by separating two CMUs to 1/8 in. apart at a rate of 1/8 in./hr., followed by closing the gap at the same rate. The test is performed at -15°F. In order to pass the test, the membrane must complete a minimum of 10 cycles. *Figure 9* shows examples of different fluid-applied air barrier products submitted through this testing. Some membranes passed, while others failed during the first cycle. All four membranes in this test are listed at the ABAA website and have passed the "as-installed" air barrier assembly testing per ASTM E2357.

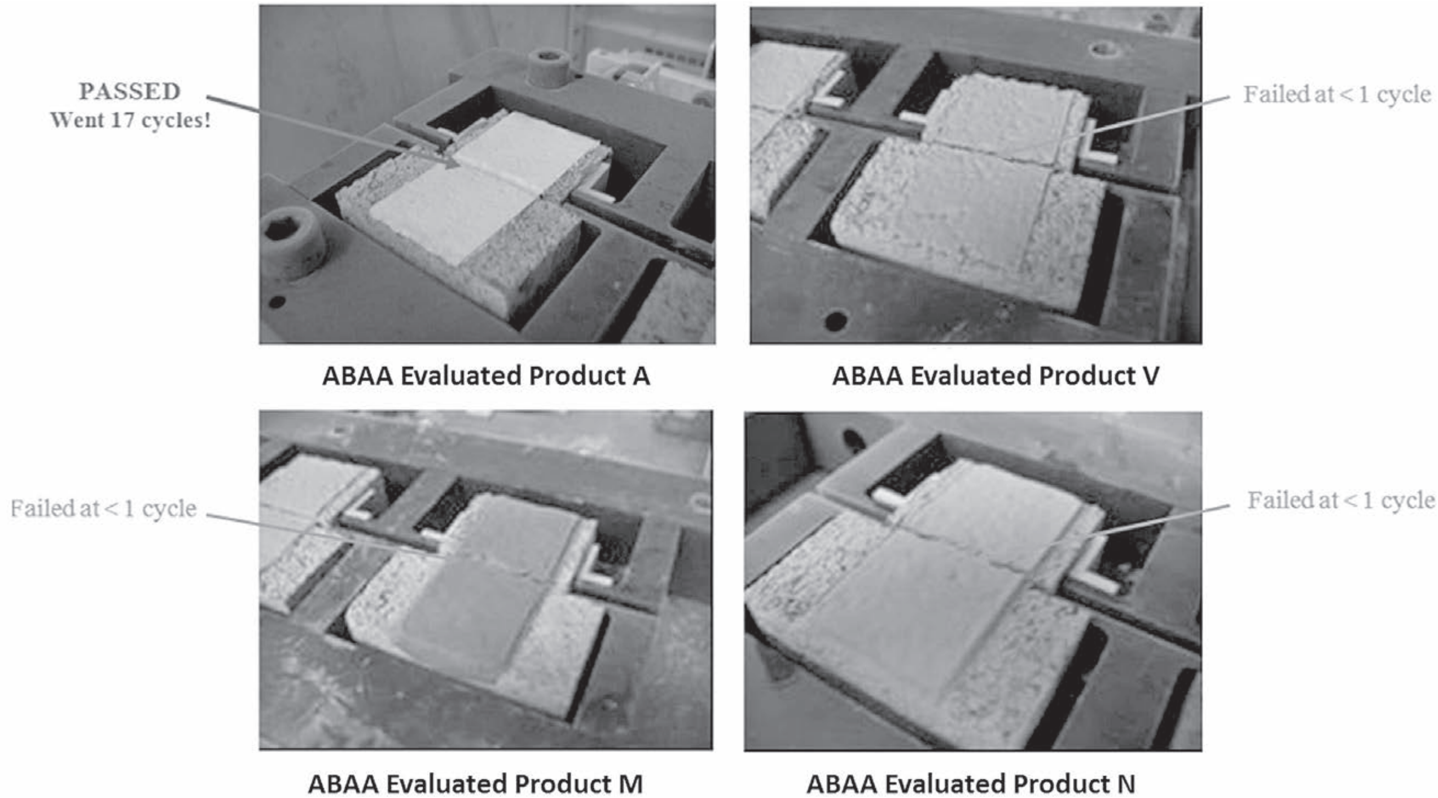


Figure 9 – Side-by-side comparison of crack bridging performance of a number of fluid-applied air barrier membranes. The pictures show the membranes at full extension. Graphics by Jason Martin, PE, DuPont Building Innovations.

Water penetration testing

Most air barrier systems installed to the exterior of the building enclosure also perform the function of WRBs, protecting against rainwater intrusion. Water leakage is generally tested using ASTM E331, but the test is performed at ambient temperatures on newly assembled test walls. However, the wind pressure and temperature fluctuations experienced by the wall assembly during field applications could impact the continuity of air and water barrier systems and impact water penetration resistance. Very few manufacturers integrate ASTM E2357 air infiltration resistance testing of installed wall assemblies with ASTM E331 water infiltration resistance. ABAA evaluation does not require water penetration testing.

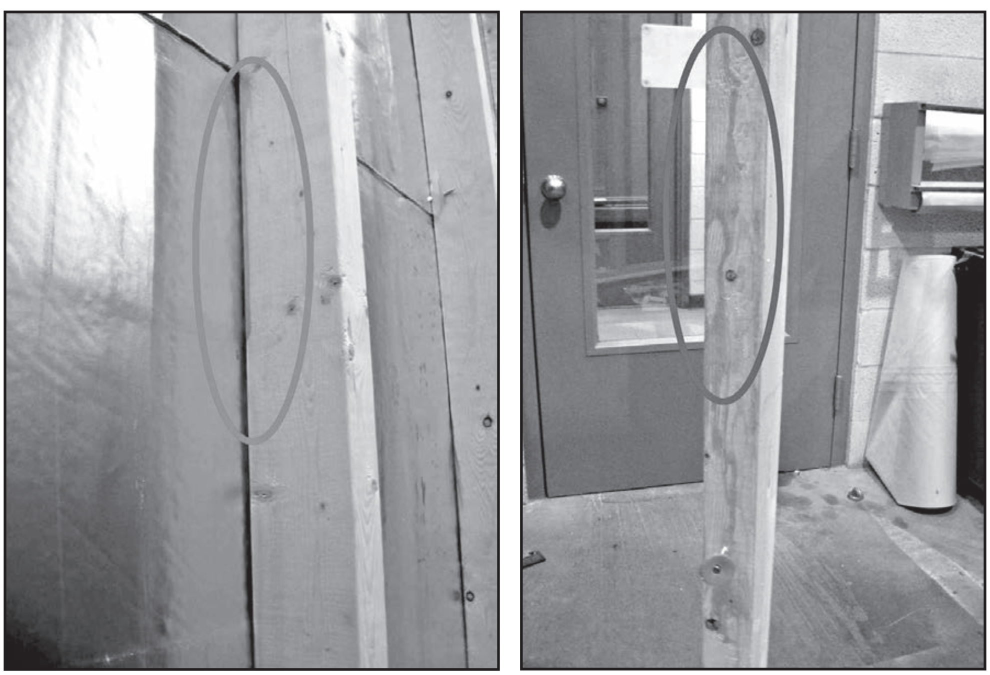


Figure 10 – Water intrusion at foam sheathing joints following laboratory wall assembly testing per ASTM E2357 integrated with thermal cycling.

Figure 10 shows water intrusion at foam sheathing joints following laboratory wall assembly testing per ASTM E2357 integrated with thermal cycling. Note the traces of stained water on the studs, clearly showing water entry at failed taped sheathing joints. In addition to the differential expansion and contraction of air barrier assembly components, taping of joints generally leads to reverse shingling, which could further contribute to water penetration.

The examples discussed above demonstrate the limitations of current air barrier assembly testing. The flowchart in *Figure 11* shows a more advanced testing of air and water barriers achieved by integrating the air barrier assembly testing with thermal cycling and water penetration testing.

The black-shaded boxes in *Figure 11* show the current industry standards for testing of air barrier assemblies per ASTM

E2357, which has been adopted by the ABAA evaluation process. The current method includes air leakage testing before and after structural wind loads (initial and final air leakage), and the test ends with the "final air leakage," which is reported at 75Pa.

The gray-shaded boxes show the additional testing which integrates ASTM E2357 air leakage testing of wall assemblies with thermal cycling and water penetration resistance. While water leakage is not required by ASTM E2357, performing a water leakage test after the wall assemblies have been submitted through the structural wind-loading schedule is very important if the air barrier must also perform as the WRB. The water leakage test per ASTM E331 (described inside the gray-shaded water leakage test box) is performed after structural wind loads and before thermal cycling, to evaluate the impact of wind structural loads on water infiltration.

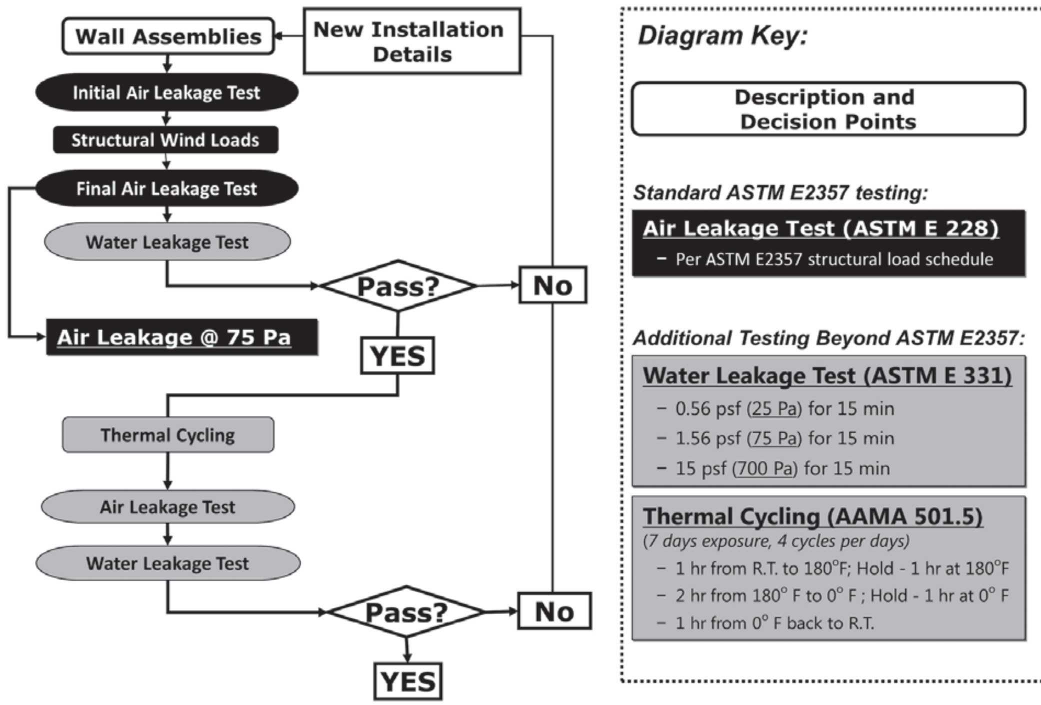


Figure 11 – Integration of water penetration and thermal cycling with ASTM E2357 wall assembly testing.

After completing the above testing, the wall assemblies are submitted through thermal cycling per AAMA 501.5 (under conditions described inside the green-shaded thermal cycling box), in order to test the impact of temperature fluctuations on the long-term durability and continuity of air and water barrier assemblies. This includes retesting the wall assemblies for both air leakage and water infiltration.

Integration of rigorous structural integrity testing of air barrier wall assemblies with thermal cycling and water infiltration resistance will provide confidence in the long-term durability of these systems.

CONCLUSIONS

Building energy codes mandate a continuous air barrier for leakage control. The air barrier system must withstand the conditions a building is exposed to during its use. There are two acceptable performance levels for air barrier wall assemblies—ASTM E1677 and ASTM E2357—that are determined by the wind pressure load design parameters for the building envelope.

Current test methods are effective in measuring performance of newly installed air barrier assemblies under pressure differentials experienced by above-grade exterior walls and represent a huge step forward from relying solely on materials properties. However, current standards do not provide information about the long-term performance under field use conditions experienced by the buildings, which include seasonal and daily temperature variations. Air barrier system performance is only as good as the weakest link, and differential expansion and contraction of multicomponent air barrier systems can compromise its continuity over time.

Another major limitation of ASTM E2357 is the lack of water infiltration resistance requirement. Very few manufacturers integrate ASTM E2357 air infiltration testing with ASTM E331 water infiltration resistance of installed wall assemblies.

Integration of rigorous structural integrity testing of air barrier wall assemblies with thermal cycling and water infiltration resistance will provide valuable information on the long-term durability of these systems.

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