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No. 0611-BSc
Rev: July, 2011

Self-sealing and Self-healing of Air Barriers and Water-Resistive Barriers

The terms *self-sealing* and *self-healing* are sometimes used to describe materials used in roofing and waterproofing. They are also used to describe sheet goods, coatings, membranes, self-adhered flashings (SAFs) or self-adhered membranes (SAMs), and other materials used in wall assemblies as air barriers and/or water-resistive barriers (WRBs). The terms relate to the ability of a material to remain air tight and water tight at fastener penetrations. Ironically, these terms are not standard, nor do they represent measured properties of materials. In fact the American Society of Testing and Materials (ASTM) [1] definitions of terms used in construction do not include any reference to *self-sealing* or *self-healing*. The definitions below found on the internet seem to provide a fair characterization of what is meant or intended by *self-sealing* and *self-healing* materials.

Definitions

Self-sealing – "Capable of sealing itself, as or after being pierced"[1]

Self-healing – "Self-healing materials are a class of smart material that have the structurally incorporated ability to repair damage caused by mechanical usage over time"[2]

Let's look next at what basis is used in testing of materials to define them as *self-sealing* (there are no tests for *self-healing* that we could find in relation to construction materials, although similar tests to what is described below might be applicable).

Air Barrier Industry Standard Test

Although ASTM has no definitions for *self-sealing* and *self-healing*, at least one ASTM test method, D 1970 [2], refers to *self sealability,* or, "….the ability of the underlayment sheet to seal around a roofing nail and prevent standing water from leaking through to the underside of the sheet [membrane]."[3] In this test a nail is driven through the membrane material and penetrates plywood sheathing with the nail head flush with the surface of the membrane material. Then the nail is tapped from the underside to raise it ¼ inch from the surface. Next a 5 inch column of water (correlates to 101 mph wind speed) is placed over the nail penetration and sealed at the base around its circumference, and a container is placed beneath to collect water that penetrates. The sample is placed for 3 days in a cold temperature (40 ± 5° F) environment, after which the container underneath, the nail shank, underside of the plywood, and space between the sheet membrane and plywood, are examined. Evidence of water at any of these locations constitutes a *failure*. The standard provides an industry recognized assessment of water penetration resistance at a fastener penetration through a membrane under a water column. It has been used within the air barrier industry (Air Barrier Association of America [ABAA]) [3] as a basis for determining *self-sealing* of an air barrier material. Many air barrier and WRB materials meet the criteria to pass, including StoGuard® materials. The standard can be applied to gypsum sheathing and liquid applied air barriers (as presented in Figure 1), and different fastener types not specifically covered within the standard with relatively minor modifications, while still producing reliable results.

WRB Industry Standard Test

Another water column test that has been used to evaluate *self-sealing* is American Association of Textile Chemists and Colorists Hydrostatic Pressure Test AATCC 127 [4] modified method. In this test a 21.6 inch head of water (correlates to 210 mph wind speed) is placed over a fastener penetration driven through sheathing with the fastener head not quite flush with the surface, and the sample is examined for evidence of water penetration at the underside of the fastener penetration. This modified test method has been incorporated into International Code Council Evaluation Service Acceptance Criteria 212 (ICC ES AC 212) [5] and E 2570 [6], which require a water-resistive coating to prevent water penetration to the underside for 5 hours. The acceptance criteria does not require fastener penetrations to be evaluated, but the test method can be easily modified to include fastener penetrations as depicted in Figure 1.

Test results of water column with thin film fluid applied membrane applied to glass mat gypsum sheathing

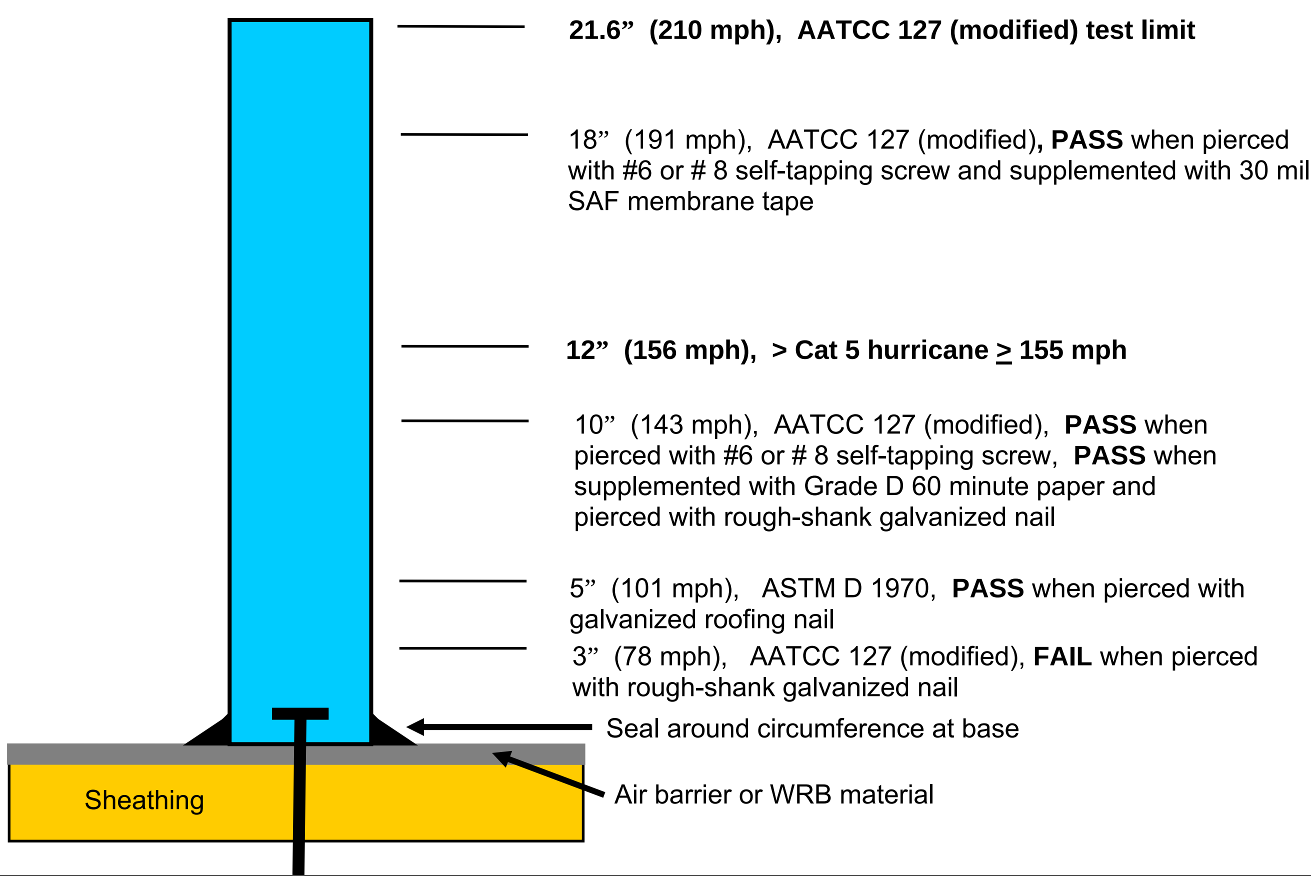


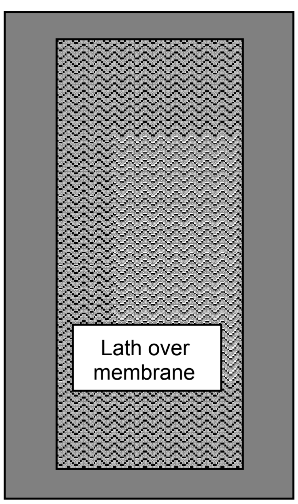
Figure 1. ASTM D 1970 [2] and AATCC 127 [4] modified test are both water column tests. The D 1970 [2] standard requires testing with a 5 inch head of water, while the AATCC 127 modified test [4] method requires testing with a 21.6 inch head of water, though without a fastener penetration. Modifications of these tests with graduated levels of water can be used to evaluate water penetration through air barriers or WRBs with various types of fasteners and sheathing types. Screw fasteners perform best, while a rough-shank galvanized nail consistently has the worst results, regardless of membrane type. Supplementing the fluid applied membrane with a 60 minute building paper or SAM tape also improves performance.

Assembly Tests

Several tests, E 283 [7] and E 2357 [8] go beyond material testing and measure air leakage through an *assembly* of air barrier materials. In doing so, they encompass fastener penetrations, at least those that exist at the plane of the air barrier or those that are installed and can be sealed at the time the air barrier is being installed. The tests typically do not encompass *post-applied* fastener penetrations, for example, fasteners used to attach siding, metal lath, and fixtures attached to the structure after the air barrier has been installed. E 2357 [8] takes into account cyclic loading with 2000 cycles of positive and negative pressure to verify the durability of the connections and fastener penetrations under pressures, including wind gust loads, that can be encountered in service. Again, many air barrier material assemblies meet the allowable air leakage criteria of 0.04 cfm/ft^2 (0.2 L/s·m^2) typically specified by building codes and industry standards. None of these methods, however, take into account any direct measurement of *self-sealing* or *self-healing* characteristics of materials at fastener penetrations, nor do they address water leakage.

In order to gain more insight into how different materials perform with respect to water leakage and *post-applied* fasteners, E 331 [9], a test intended to determine water leakage through windows and curtain walls, was used to evaluate water leakage through *post-applied* fastener penetrations (Figure 2) and several membrane materials. To some extent the test provides a more realistic evaluation than water column testing, since the panel size encompasses multiple fastener penetrations, which is more likely to capture installation variability that can occur in the real world. The test applies a uniform static pressure to a panel of 2.86 psf (correlates to 33 mph wind speed) for a period of 15 minutes with a standard flow rate of water from spray nozzles directed at the panel. Both pressure and period of exposure can be increased, depending on specification requirements, or the desired exposure severity that one seeks in the test. In this particular case test pressures started at relatively low levels, and were ramped up to increasingly more severe levels that exceeded hurricane force winds.

Test Panel



Summary test results of water spray with incremental pressure increase applied to panel with metal lath over Air Barriers and/or WRBs

	Pressure						
mph	14.9	24.7	49.3	66.4	76.5	117	150
psf	0.57	1.57	6.24	12.00	15.00	35.00	57.6
in/H2O	0.11	0.3	1.2	2.3	2.9	6.7	11.1
WRB							
#15 Felt	√	√	√	√	1	2	2
60 min. Felt	√	√	√	1	1	2	NT
Thin Film Fl Applied	√	√	√	√	1	2	2
40 mil SAM	√	√	√	√	1	1	2

Notes:
√ = no leaks detected at back plane (back of studs) of specimen
1 = leak at lath fastener
2 = leak at 2nd lath fastener
NT = not tested
All tests pressure levels done in succession. 150 mph pressure level tested for less than 5 minutes, all other levels tested for 15 minutes.
Membrane air barrier or WRB over sheathing surface. Metal lath attached at 7 inches oc (26 penetrations) with #8 pan head screws into 16 inch oc metal studs. Panel edges sealed.

Figure 2. ASTM E 331 [9] test with increasing severity of exposure (test pressure) gives the opportunity to evaluate multiple fastener penetrations and a better replication of field installation. The test in this case was done without the benefit of a cladding (stucco, brick, adhered masonry veneer [manufactured stone], siding) over the assembly.

Results of Tests and Discussion

A summary of results for each of these tests is shown in Figure 1 (water column tests) and Figure 2 (E 331 test) [9] using several air barrier and/or WRB materials commonly used in construction. Based on these results many materials used in wall assemblies as air barriers and/or WRBs would seem to meet the definition of self-sealing at relatively high levels of exposure. For example, the fluid applied membrane, when pierced with a screw fastener, withstands an exposure comparable to a 143 mph wind based on water column testing. When a supplemental membrane, 60 minute felt, is applied over the fluid applied material, the same pressure level is withstood when pierced with a rough-shank galvanized nail, the worst case fastener penetration. All membranes in the water spray testing demonstrated performance up to the 49 mph level and only 1 or 2 fasteners leaked at the higher levels.

However, discoveries made during tests and inspection of samples after tests led to some other findings. The absence of water on the back side of an assembly or test specimen does not necessarily mean that water has not penetrated the plane of the membrane. In the case of the AATCC 127 [4] modified test, water can be seen along edges of specimens or percolating up through an adjacent hole in the membrane material (Photo 1), without detecting any water penetration on the back side of the specimen. In the case of the E 331 [10] test, evaluation of specimens after testing showed minor water stains at virtually all fastener penetrations, though only one or at most two leaks were noticed along the back side of the specimens during tests. Thus, some degree of leakage past the plane of the membrane occurs through fastener penetrations during the tests, and leakage may not be immediately evident on the back side of test specimens.

Photo 1. The photo depicts water column testing (the base of two columns are visible) and the presence of water percolating up through the sheathing material during the test (red circle) despite the fact that there was no evidence of water penetration on the back side of the specimens at fastener penetrations. This leads to the conclusion that water by-passed the membrane and traveled within the core of the sheathing.

In addition variability introduced during field installation of fasteners can create conditions that are not taken into account in lab tests. For example, if the fastener is not installed straight and true, or if it spins too long in the course of tapping, it can tear the membrane. This is true for ALL membrane products, fluid applied, SAMs, and other sheet goods. Nails would tend to be better than screws in this respect because they do not cut the membrane, they simply "bend" it inward and the membrane stays in contact with the shank. On the other hand, if the nail is a deformed or rough-shank nail, it has irregularities along the shank that make the nail hole larger than the diameter of the shank and hence, more vulnerable to water penetration because of the larger hole produced by the nail penetration. In some circumstances the shank of a fastener will be in tight enough contact with the membrane and sheathing core to prevent water penetration to the extent that water leakage is not observed. Sometimes this is called "friction fit" or "friction-seal" of the fastener penetration and as long as pressures are not too severe no leakage or very limited leakage will occur at the fastener location.

Some materials like SAMs claim to be self-healing in that they "flow" around and seal against the fastener penetration. In reality the sticky material (often asphaltic) may not be that flowable. With heat it remains sticky and tends to bond to the fastener, but if the fastener is not installed exactly right, it will not seal onto the shank. Roofing tar and pitch may flow enough to do this at relatively low temperatures, but the asphaltic material on a peel-and-stick is much less likely to do this consistently. In fact, a 40 mil SAM performed no better than #15 felt and no better than a thin film fluid applied membrane in the E 331 [9] test.

Best Practices and Recommendations

So, how does one address the potential for water intrusion through fastener penetrations, particularly with claddings like siding, stucco, and adhered masonry veneer, where thousands of fasteners can be used to attach the siding or metal lath through the air barrier and/or WRB?

First and foremost, keep water outside of walls by following fundamentally sound design and construction practices. This includes overhangs to minimize wall exposure to driving rain, metal coping over parapets or projections, pan flashing beneath windows, doors and other through wall penetrations that can become sources of leaks into walls, and proper sealing techniques at wall terminations and accessory (stucco) butt joint terminations. Sto Tech Hotline Nos. 0403-BSc [10] and 0603-BSc [11] provide basic guidance on these aspects of wall design.

In wet climate zones where there is increased threat of wind-driven rain entering a wall assembly, added precautions can be taken such as employing a rainscreen wall design where a cavity or space is created – Sto DrainScreen™ -- to decouple incidental water that intrudes through the cladding from the underlying membrane (and fastener penetration points). The addition of a code prescribed WRB sheet material (paper or felt WRB) in combination with a fluid applied waterproof air barrier will also help to some extent in that the layer of sheet material creates yet another obstacle against water getting to the fastener penetration plane. For claddings like stucco the added WRB sheet is required over wood-based sheathing by the International Building Code (IBC) [12] and International Residential Code (IRC) [13]. Industry trade associations such as the Northwest Wall and Ceiling Bureau (NWCB) [14] and Masonry Veneer Manufacturers Association (MVMA) [15] require the two layers of WRB, regardless of sheathing type – addressing both wood and gypsum-based sheathings.

Also important is that fasteners engage with studs as opposed to missing the stud entirely, not only for the obvious reason of structural attachment of the cladding, but also because it will *self-seal* that much better when drawn into a support with no *spin-out*. Supplemental fasteners, sometimes used incorrectly to attach accessories between studs like control joints in stucco (required to be wire tied between studs), should not be used in this manner. Errant fasteners that do not go through studs spin and create a larger opening and a loose connection (particularly in gypsum-based sheathing) that is vulnerable to water penetration. These fasteners should be removed and holes sealed, both as an air barrier quality control measure for air tightness of the building envelope, and as a means of preventing water intrusion. The use of powder or power actuated fasteners is a more obvious issue which can cause damage to sheathing and the air barrier/WRB and should be avoided.

In summary, while lab tests demonstrate the ability of properly installed fasteners to seal to some extent where they penetrate air barriers and/or WRBs, penetrations can become sources of water intrusion, depending on many variables – type fastener, angle at which fastener is driven, and the amount of water and pressure at the fastener penetration - regardless of membrane type and any claim that may be made about *self-sealing* or *self-healing* characteristics. To avoid leakage at fastener penetrations, follow basic principles of design and construction:

- Keep water out of walls by following fundamentally sound design and construction practice that minimizes wall exposure to rainfall (overhangs) and prevents water from getting past the cladding into walls (copings, flashing, and sealing techniques).
- Use fluid applied waterproof air barriers that are fully and independently qualified as water-resistive barriers – StoGuard® – to diminish the risk of water penetration through fasteners. Liquid applied air barriers inherently provide more protection than loose sheet air barriers, since they seal sheathing fasteners and joints.
- Supplement the fluid applied air barrier with a code prescribed sheet WRB to provide another barrier against water penetration over wood and gypsum sheathings, particularly with claddings such as stucco and adhered masonry veneer over metal lath (note, this is required by building codes for stucco over wood-based sheathing and industry standards for stucco and adhered masonry veneer over both wood and gypsum sheathings).
- Follow the rainscreen principle of wall design, particularly in wet climate zones, that incorporates a drainage and drying *cavity* – Sto DrainScreen™.
- Make sure fasteners engage with studs to avoid spin-out and enlarging the fastener hole.
- Seal errant fasteners that do not engage with studs by removing them and filling holes with air tight/water tight material. Do not fasten any wall accessory components such as stucco control joints between studs through sheathing.
- Avoid fastening techniques that damage sheathing, air barrier or WRB, such as power actuated fastening.

One must also bear in mind that a small amount of water getting into a wall, just like a small amount of air leakage through walls is not necessarily a source of material degradation within walls. Many wall assemblies can tolerate moisture as a function of time and temperature (seasonal change), material properties, and the overall configuration and components of the wall assembly. Chronic and repetitive water leakage, however, is often what causes performance issues, and this chronic and repetitive leakage is most often associated with design details at cladding terminations and not any particular shortcoming of materials that make up the wall assembly. "As much as 90 percent of all water intrusion problems occur within 1 percent of the total exterior building surface area. The 1 percent of the structure's façade contains the terminations and transition detailing that all too frequently lead to envelope failures."[4] A comprehensive design strategy using proven materials, proper design detailing and design verification, and proper execution of work are the three ingredients necessary for high performing building enclosures that are dry and air tight.

Footnotes

1. http://www.yourdictionary.com/self-sealing
2. http://en.wikipedia.org/wiki/Self-healing_material
3. *Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used As Step Roofing Underlayment for Ice Dam Protection,* ASTM D 1970-01, American Society of Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, p. 4, www.astm.org
4. *Waterproofing the Building Envelope,* Kubal, Michael, T. (New York, 1993), p.4.

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[1] American Society of Testing and Materials (ASTM), 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, www.astm.org

[2] *Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used As Step Roofing Underlayment for Ice Dam Protection,* ASTMD 1970-08, American Society of Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, www.astm.org

[3] Air Barrier Association of America, 1600 Boston-Providence Highway, Walpole, MA 02081, www.airbarrier.org

[4] *AATCC Test Method 127 – 2008, Water Resistance: Hydrostatic Pressure Test,* American Association of Textile Chemists and Colorists, PO Box 12215, Research Triangle Park, NC, 27709, www.aatcc.org

[5] *Acceptance Criteria for Water-Resistive Coatings Used as Water-Resistive Barriers over Exterior Sheathing,* ICC ES AC 212, International Code Council Evaluation Service, 5360 Workman Mill Road, Whittier, CA 90601, www.icc-es.org

[6] *Test Methods for Evaluating Water-Resistive Barrier (WRB)Coatings used under Exterior Insulation and Finish Systems (EIFS) or EIFS with Drainage,* American Society of Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, www.astm.org

[7] *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen,* ASTM E 283-04, American Society of Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, www.astm.org

[8] *Standard Test Methods for Evaluating Water-Resistive Barrier (WRB) Coatings Used Under Exterior Insulation and Finish Systems (EIFS) or EIFS with Drainage,* ASTM E 2357-05, American Society of Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, www.astm.org

[9] *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference,* ASTM E 331-00(2009), American Society of Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, www.astm.org

[10] *Critical Detail Checklist for Wall Assemblies,* Tech Hotline No. 0403-BSc, Sto Corp., 3800 Camp Creek Parkway, Building 1400, Suite 120, Atlanta, GA 30331, www.stocorp.com

[11] *Moisture Control Principles for Design and Construction of Wall Assemblies,* Tech Hotline No. 0603-BSc, Sto Corp., 3800 Camp Creek Parkway, Building 1400, Suite 120, Atlanta, GA 30331, www.stocorp.com

[12] *International Building Code*, IBC-2009, International Code Council (ICC), 500 New Jersey Avenue, NW, 6th Floor, Washington, DC, 20001, www.iccsafe.org

[13] *International Residential Code,* IRC-2009, International Code Council (ICC), 500 New Jersey Avenue, NW, 6th Floor, Washington, DC, 20001, www.iccsafe.org

[14] Northwest Wall and Ceiling Bureau (NWCB), 1032-A NE 65th Street, Seattle, WA 98115, www.nwcb.org

[15] Masonry Veneer Manufacturers Association (MVMA), 750 National Press Building, 529 14th Street, NW, Washington, DC, 20045, www.masonryveneer.org