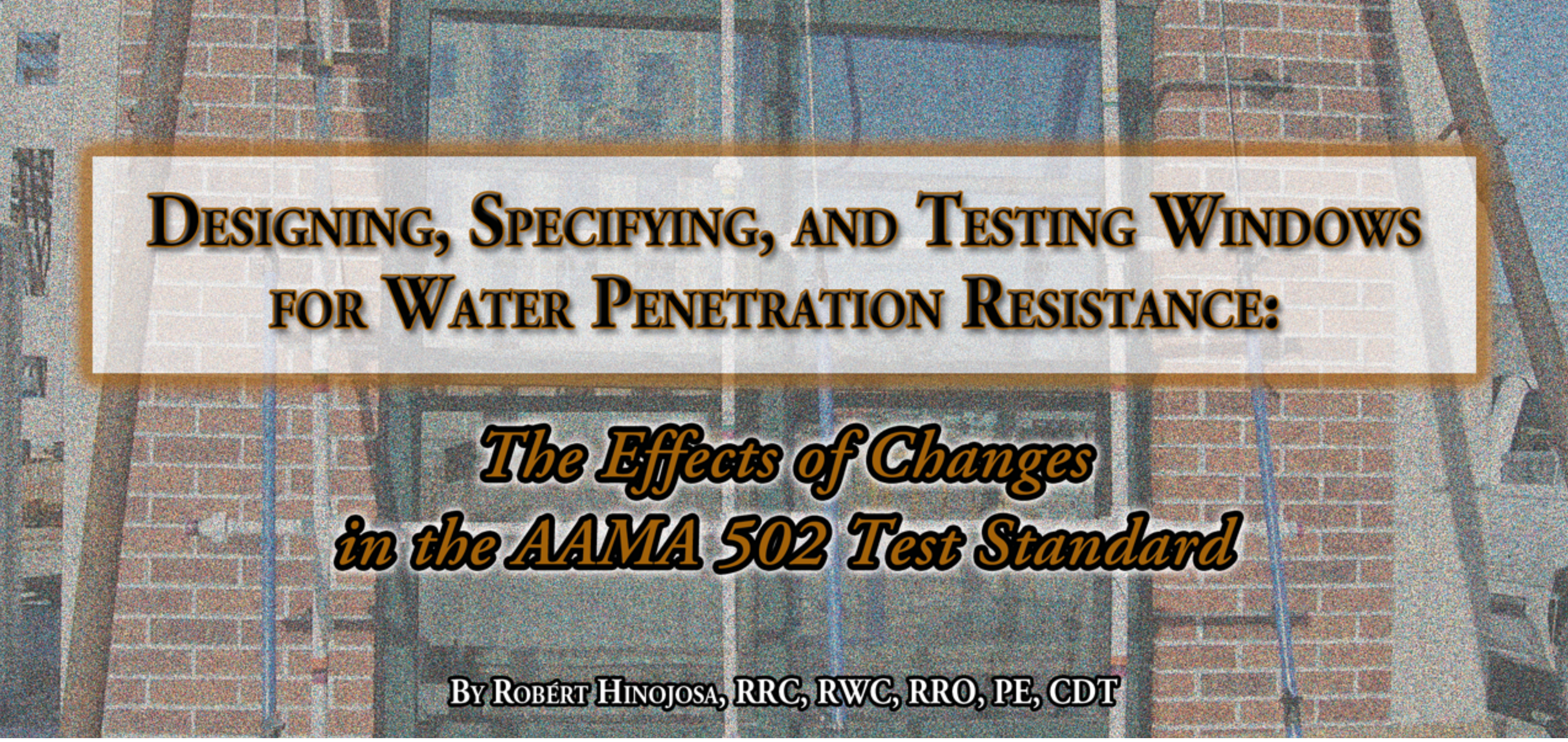


Designing, Specifying, and Testing Windows for Water Penetration Resistance:

The Effects of Changes in the AAMA 502 Test Standard

By Robért Hinojosa, RRC, RWC, RRO, PE, CDT

INTRODUCTION

Uncontrolled water penetration through the building façade, exterior walls, and especially fenestrations (windows) results in billions of dollars of damage in the construction industry every year. Water penetration is of the utmost concern to building owners, the contractors and subcontractors who construct the buildings, the architect or engineer responsible for designing and specifying the window products, and the manufacturers of the products. Manufacturers perform extensive "controlled" lab tests in which windows are subjected to structural loads, including wind force, as well as water penetration tests using nationally recognized test procedures.

Based on these test results, window and door units are assigned a performance rating by their respective industry organizations, such as the American Architectural Manufacturers Association (AAMA) and the National Wood Window and Door Association (NWWDA). However, field water penetration tests must also be conducted to test the performance once the products are installed in buildings. The industry standards for field water penetration tests have certain restrictions that must be understood by the design professional to ensure that the window products installed within the exterior walls of a building meet the appropriate required code and industry standard water penetration pressure. Recent changes in the test standard should be carefully reviewed to guarantee that the appropriate windows are designed, selected, installed, and properly tested in the field to resist water infiltration and avoid water damage to buildings.

WINDOW DESIGN

Selection of window units for residential and commercial buildings begins with calculations by the project's structural engineer or architect to estimate the design force or pressure imposed by the wind. The formulae used to perform these calculations are found in ASCE 7, Minimum Design Loads for Buildings and Other Structures. Chapter 6, Wind Loads, contains the methodology and formulae to estimate the wind-induced design pressure at three zones on the roof and two zones on the perimeter walls of the proposed building. The applicable version of ASCE 7 and the wind speed to be applied at specific projects are generally found in the building code adopted by the local governing authority.

As an example, many cities have adopted the International Building Code (IBC) and the International Residential Code (IRC) for one- and two-family dwellings. A city may also adopt local amendments to selected sections of the model codes. The city of Houston, for example, has stipulated that structural design shall be based on ASCE 7-02, and the wind speed to be used in the calculations shall be 110 mph (three-second gust). Other physical factors, such as building dimensions, topography, and the proximity of surrounding structures, are factored into the calculations to estimate the effective wind forces that will impact the subject building.

These structural design loads are reported as positive and negative loads and are commonly expressed in pounds per square foot (psf). The positive load generally occurs on the windward side of the building and corresponds to the force of the wind pushing against the walls, windows, and doors. The negative load occurs at the leeward side of the building, where a vacuum is created at the downwind side by the wind blowing past the building. The negative load exerts a force that effectively attempts to pull the cladding, windows, and doors off the building. It is not uncommon for the value of the negative load to be different from the value of the positive load. In any case, the absolute value of the greatest wind-induced load, known as the design pressure, should form the basis for most structural designs, water penetration requirements and, ultimately, window selections.

WINDOW SELECTION

The computed wind forces must be considered when selecting windows. Selecting windows with a performance rating equal to or greater than a building's highest positive or negative design pressure as calculated using ASCE 7 ensures that the window unit will resist the calculated wind forces and associated water penetration requirements. When selecting a window, it is important for the design professional to understand the different performance classes and performance requirements and what information they provide. Windows are classified into five performance classes: R – Residential, LC – Light Commercial; C – Commercial; HC

Product Performance Class	Minimum Performance Grade	Minimum Design Pressure, Pa (psf)	Minimum Structural Test Pressure, Pa (psf)	Minimum Water Resistance Test Pressure, Pa (psf)
Windows and doors				
R	15	720 (15.0)	1080 (22.5)	140 (2.90)
LC	25	1200 (25.0)	1800 (37.5)	180 (3.75)
C	30	1440 (30.0)	2160 (45.0)	220 (4.50)
HC	40	1920 (40.0)	2880 (60.0)	290 (6.00)
AW	40	1920 (40.0)	2880 (60.0)	390 (8.00)
Unit skylights and roof windows				
R	15	720 (15.0)	1440 (30.0)	140 (2.90)
C	30	1440 (30.0)	2880 (60.0)	220 (4.50)
HC	40	1920 (40.0)	3840 (80.0)	290 (6.00)

TABLE 1 GATEWAY REQUIREMENTS

Table 1 – Gateway requirements from AAMA/WDMA/CSA 101/I.S.2/A440-05, Standard Specification for Windows, Doors, and Unit Skylights.

– Heavy Commercial; and AW – Architectural Windows. Each performance class has minimum gateway performance requirements that the fenestration product must achieve to be designated with a performance class (*Table 1*). After the performance class, the window designation will have a performance grade that is expressed as the numeric equivalent to the design pressure in psf to which the specimen has been tested. For example, a window with a designation of HC50 would be a heavy commercial window with a performance grade of 50 psf. This performance grade also equates to a water-resistance test pressure that must be considered when selecting a proper window. Typically, AAMA equates the water-resistance test pressure to 15% of the design pressure (varies between 15% and 20%, based on the window unit's performance class). As such, the performance grade of the window designation should be reviewed when selecting the proper window for a project design load and water penetration requirements.

WATER PENETRATION TESTING

In my experience, the single biggest claim of "failure" for a window is with regard to water infiltration. Leaking windows on a new or existing building are major factors in construction litigation today. Industry-standard tests exist for resistance to water penetration by windows. Field testing is performed in accordance with ASTM E1105, "Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference," and/or AAMA 502. However, it should be noted that AAMA 502 refers to ASTM E1105 for the actual field procedure and test apparatus requirements. The difference is that AAMA 502 describes the manufacturer's requirements for field test specimens, sampling, and reports to be used in verifying the water penetration resistance of windows.

ASTM E1105 is a test standard intended primarily for determining the resistance to water penetration through windows for compliance with specified performance criteria. To perform ASTM E1105 water testing, a chamber is typically made and attached to the interior or exterior wall that borders the frame of the specimen (*Photos 1* and *2*). A mechanical blower is then used to exhaust air from the chamber if installed on the interior or supplying air to the chamber if installed on the exterior at a rate required

Photo 1 – An interior-mounted pressure chamber on a large, triple-mulled window assembly on a project in Houston, TX.

Photo 2 – A pressure chamber mounted directly to the precast concrete panel at a window mock-up for testing on a project in New Orleans, LA.

Photo 3 – Water spray from a spray rack is applied from the exterior at a prescribed pressure and distance from the wall as stipulated in ASTM E1105.

to maintain the specified pressure difference across the specimen. Simultaneously, water is sprayed onto the outdoor face of the specimen at a rate required by the test standard, and the specimen is observed for water penetration (*Photo 3*). The water-spray rack should be built to deliver water uniformly against the exterior surface of the test specimen at a minimum rate of 3.4 L/m^2•min (5.0 U.S. gal/ft^2•hr). This rate corresponds to a rainfall of 20.3 cm (8.0 in)/hr. The water spray rack should have nozzles spaced on a uniform grid located a uniform distance from the test specimen and should be adjustable to provide the specified quantity of water in such a manner as to wet all of the test specimen uniformly and to wet those areas vulnerable to water penetration (*Photos 4* and *5*).

ASTM E1105 describes two different test procedures. Procedure A is a test under uniform static air-pressure difference. This test procedure requires applying the specified static air-pressure difference while applying the water spray at the specified rate for a continuous 15 minutes. Procedure B is a test of cyclic, static air-pressure difference. This test procedure requires applying the specified static air-pressure difference while applying the water spray at the specified rate for a five-minute duration cycle (unless otherwise specified by the project requirements). After the five-minute cycle, while maintaining the water spray, reduce the air-pressure difference to zero for a period of not less than one minute. This five-minute to one-minute cycle should be repeated a minimum of three times for a total pressure application of no less than 15 minutes. The number of cycles can be greater, however, if required by the product specifications. The window product performance class typically dictates which procedure should be utilized on a particular window

Photo 4 – A water spray is constructed to test windows on a slight radius on a high-rise building in Houston, TX. Part of the window assembly extends past the edge of the balcony, so swing-stage equipment was utilized to support portions of the water-spray rack during the testing.

Photo 5 – The spray rack is placed to test a mock-up on a project in New Orleans, LA. The spray rack is placed on the test specimen so that the nozzles spray the water in such a manner as to wet the entire test specimen uniformly.

> "If no window manufacturer will guarantee or provide a warranty that its products will withstand water penetration equal to the ratings in which they are tested in the lab and certified for their performance rating, how will this affect the windows that we design, specify, and install in our buildings?

specimen.

AAMA 502 refers to ASTM E1105, described above, for the test procedure, but as previously mentioned, AAMA 502 further defines the testing in the field. Although many people are familiar with AAMA 502, they are unfamiliar with the recent changes. Previously, AAMA 502-02 was titled "Voluntary Specification for Field Testing of Windows and Sliding Glass Doors." The new AAMA 502-08 is titled "Voluntary Specification for Field Testing of Newly Installed Fenestration Products." The biggest difference between these two is that the AAMA 502 can no longer be used for windows that have been installed for more than six months. It is only to be used during construction, prior to an issuance of the building occupancy permit, but no later than six months after installation of the fenestration products. One of the main reasons for this change is to discover corrections that need to be made during the construction process in order to minimize financial impact on the responsible parties. After the products have been installed for six months, the AAMA 502 test standard now references AAMA 511-08, "Voluntary Guideline for Forensic Water Penetration Testing of Fenestration Products."

AAMA 502 also now differs with regard to its test methods. Previously, AAMA 502-02 described two different test methods. Test Method A was conducted to test the fenestration product within the confines of the perimeter of the main frame (*Figure 2*). This test method only tests the operable elements (sash, vents, panels) and fixed glazing components under the specified pressure for water penetration. Test Method B was conducted to test the fenestration product, inclusive of the joint between the fenestration product and the rough opening. With this test method, the chamber is installed to the wall construction in such a manner as to create the pressure differential across the entire fenestration product (including the subframe/receptor and/or sill pan) and the perimeter seals (*Figure 3*). Now, AAMA 502-08 describes only one test method. The test method described above as Test Method B is the only test description in the new AAMA 502 standard. As such, *Figure 3* from AAMA 502-02 is the only figure in AAMA 502-08 that shows the test chamber. This change suggests that the AAMA 502 standard will now always test the entire assembly – including the window itself and the installation of that window – for water penetration.

As mentioned above, ASTM E1105 describes two different test procedures. AAMA 502 designates which test procedures should be performed in the field, based on the performance class of the window. This has changed in the latest version of AAMA 502 and should be understood to ensure the proper test procedures are being performed in the field.

AAMA 502-02 previously stipulated Procedure B (cyclic, static test pressure) for residential (R), light commercial (LC), and commercial (C) performance-class fenestrations; Procedure A (uniform static test pressure) for architectural (AW) class products; and both Procedures A and B for heavy commercial (HC) class products. AAMA 502-08 now stipulates Procedure B for all performance classes except for AW win-

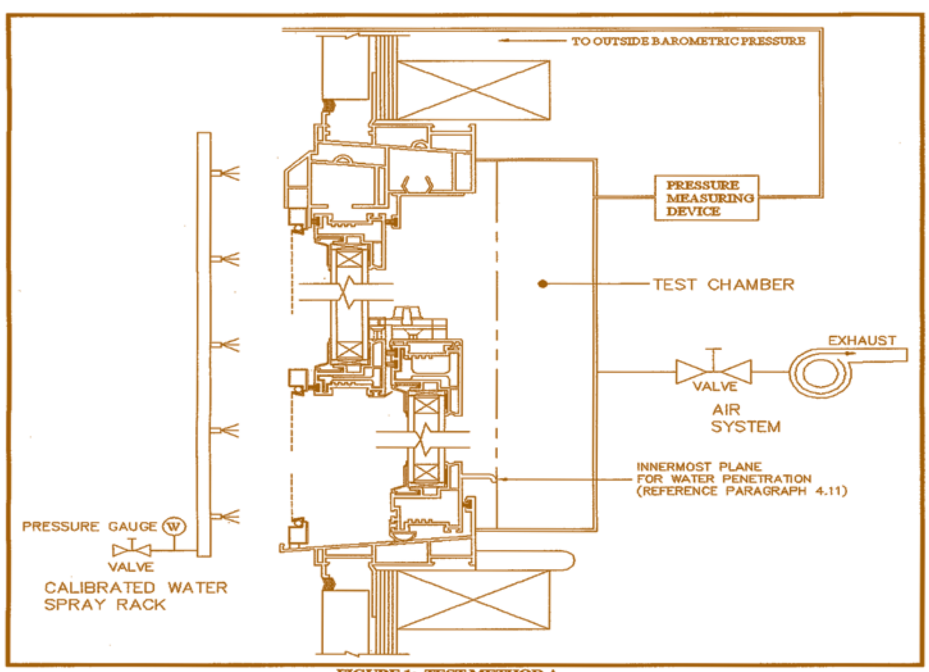


FIGURE 1: TEST METHOD A

Figure 2 – Figure 1 from AAMA 502-02, Test Method A.

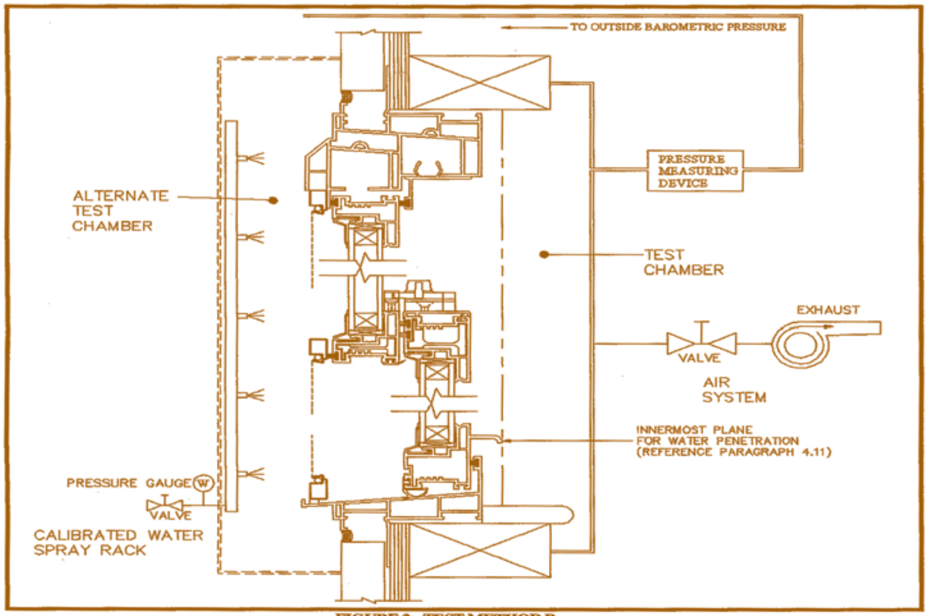


FIGURE 3: TEST METHOD B

Figure 3 – Figure 3 from AAMA 502-02, Test Method B.

dows, which shall be tested using Procedure A. AAMA 502-08 goes further to state that Procedure A shall consist of a single 15-minute test as described in ASTM E1105, and that Procedure B will consist of four cycles consisting of five minutes with pressure applied and one minute with the pressure released. This is above the minimum described in ASTM E1105 and should be understood when performing field tests.

Perhaps the greatest difference with regard to the changes in AAMA 502, and the one that potentially affects the selection of window products, is the change regarding the water-penetration resistance pressures to be tested in the field. Both AAMA 502-02 and AAMA 502-08 state that the water penetration resistance testing in the field shall be conducted at a pressure equal to two-thirds of the tested and rated laboratory performance test pressure. For example, an HC 50 window is a heavy commercial window with a performance grade of 50 psf. The laboratory performance test pressure with respect to water penetration resistance is 15% of the performance grade, or 7.5 psf. However, using the AAMA 502 reduction, the appropriate field test pressure for the window is 2/3 x 7.5 psf, or 5.0 psf.

Previously, AAMA 502-02 included a note after discussing the two-thirds reduction that stated, "The specifier is permitted to increase the field water penetration resistance test pressure to the value specified for the project." This allowed the design professional or specifier to require that the field testing of the installed window was equal to the lab test or 15% of the design pressure calculated by the architect or structural engineer of record. In this author's opinion, any window installed in a building that could not meet the water penetration resistance equal to 15% of the calculated design pressure would be unacceptable for that building. Many architects or engineers are in the practice of writing in their specifications that there be no reduction in the field test pressures. Now, AAMA 502-08 includes a note stating:

> The field installation conditions also influence the product performance. Products tested in the laboratory are perfectly plumb, level, and square in a precision opening. Field test specimens, although installed within acceptable industry tolerances, are rarely perfectly plumb, level, and square. Shipping, handling, acts of subsequent trades, aging, and other environmental conditions all may have an adverse effect upon the performance of the installed specimen. A one-third reduction of the test pressure for field testing is specified as a reasonable adjustment for the differences between a laboratory test environment and a field test environment.

Another section of AAMA 502-08, Specifier Note 4, states:

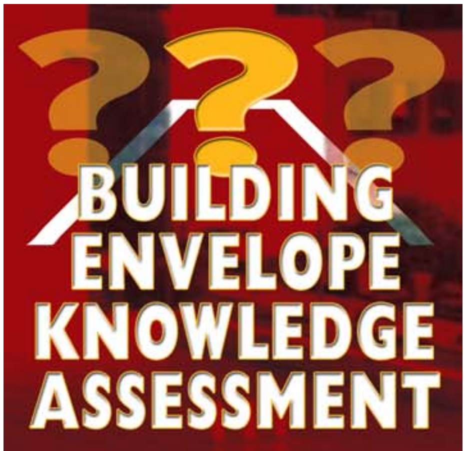
> When selecting static water test pressure to be tested at the job site, in no case shall the specified test

BUILDING ENVELOPE KNOWLEDGE ASSESSMENT

Test your knowledge of building envelope consulting with the following questions developed by Donald E. Bush, Sr., RRC, FRCI, PE, chairman of RCI's RRC Examination Development Subcommittee.

1. **How does a curtain wall or window system design allow for the thermal movement of materials of different thermal expansion coefficients?**
2. **Describe how to wet-glaze failed, shrunken, and dry-glazing gaskets at a window unit.**
3. **What purpose do end dams serve in a glass curtain-wall system ?**
4. **What are the most common causes of adhesive failure at a sealant joint?**
5. **A new low-slope roof system is being installed with a one-quarter in/ft roof slope. The roof slopes north to south and south to north to a drain valley that equally divides the area to be drained. The drain valley is dead level and has two drains, one at each end. A cricket with a one-half in/ft slope is to be installed between the drains. The cricket will be 60 ft long and 30 ft wide. What will the slope-to-drain be at the drain lanes of the cricket?**
6. **How many board feet of insulation are required to build a one-half in/ft tapered cricket that is 60 ft long and 30 ft wide for the roof described in question #5? (Assume a minimum insulation thickness of zero.)**

Answers on page 12



Answers to questions from page 11:

1. **Properly designed sealant joints and the right sealant will accommodate the movement.**
2. **Cut dry gasket to form a 90-degree angle between window glass and metal. Solvent wipe glass and metal to clean substrate. Install silicone sealant with ± 50% movement rating. Tool fillet bead to ensure a complete seal.**
3. **They contain any water within the aluminum channels at the horizontal/vertical intersection and route the water out through the window weep system.**
4. **Improper surface preparation, substrate contamination, and improperly tooled sealant.**
5. $a^2 + b^2 = c^2$

   $15^2 + 30^2 = 1125$

   $\sqrt{1125} = 33.54$ **ft = length of drain lane**

   $\frac{1}{4} \times 15 = 3.75$

   $\frac{3.75}{33.5} = \frac{1}{8.9} =$ **slope along drain lanes**
6. **(Total area of cricket) (Average insulation thickness) = Cubic feet of insulation**

   (Cubic feet) (12) = Board feet of insulation

   900 x .625 x 12 = 6750 BF

REFERENCES:

Questions 1-4 – *SWRI Waterproofing Manual*

Question 5 – *NRCA Energy Manual* and basic geometry

Question 6 – *NRCA Energy Manual*

pressure exceed two-thirds of the tested or rated laboratory performance.

In discussing new AAMA 502 requirements for field testing and performance requirements and ratings with numerous window manufacturers, this author has not found any window manufacturer who will state, claim, certify, or warrant that any of its products will withstand water penetration in the field at the same test pressure that the product is tested in the lab.

This poses a significant concern with regard to designing, specifying, and testing of windows. Industry standards for window manufacturers dictate that:

1. Windows must withstand water resistance of no less than 15% of the window products' performance ratings,
2. The performance rating is equivalent to the design pressure calculated for a building from code requirements, and
3. Building codes establish minimum requirements for design, construction, and quality of materials, etc.

If no window manufacturer will guarantee or provide a warranty that its products will withstand water penetration equal to the ratings in which they are tested in the lab and certified for their performance ratings, how will this affect the windows that we design, specify, and install in our buildings? Even if we, as design professionals, specify windows that are equal to the design pressures calculated for a building by the new AAMA 502-08 test standard, it is safe to assume that water infiltration could potentially result under "typical" conditions based on standard building codes.

CONCLUSION

Uncontrolled water penetration in a building exterior – especially windows – is a significant issue that we face in construction today. The basis of much construction litigation deals with damage resulting from leaking windows. Architects and/or engineers of record for projects responsible for design and specification of window products need to understand the industry test standards that are utilized by manufacturers with regard to their ratings and guarantees for water penetration resistance. It is the responsibility of the design professional to specify systems that, at a minimum, meet the code requirements for the building. That being said, is it prudent or necessary to specify a window product that is rated higher than the calculated building code requirements to ensure that the guaranteed and warranted water penetration resistance of the product meets accepted industry standards and building code calculated pressures? Interpretation of the code, the industry standard water penetration tests, associated reductions with regard to field water testing, and ultimately, the specification of the product, are the decisions of the architect or engineer of record. However, having a complete understanding of window ratings and test standards will help the design professional make the proper decisions when designing, specifying, and stipulating water penetration testing requirements for windows in buildings. Let's hope they don't leak.

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