The Art of Water Testing

by Francesco J. Spagna, PE

All photos courtesy Simpson Gumpertz & Heger

"YOU'RE RUNNING YOUR WATER TEST TOO LONG—WHY ARE YOU GOING FOR MORE THAN 15 MINUTES?" "YOU'RE APPLYING TOO MUCH WATER—ARE YOU SUPPOSED TO BE REPLICATING AN 'ACTUAL' RAINSTORM? BECAUSE THIS FLOW RATE IS MORE THAN ANYTHING THE BUILDING EVER EXPERIENCES." THESE CRITIQUES FROM OBSERVERS OF WATER LEAKAGE INVESTIGATIONS RAISE BROADER ISSUES ABOUT HOW WE ASSESS AND FIX LEAKY BUILDINGS.

This author was part of a team charged to find the cause of leakage at a typical mid-rise commercial building in New England. The leak had been a source of aggravation to the building owner, architect, contractor, occupants, and facilities staff from the day the building opened. After prolonged, significant rainstorms, substantial leakage persisted from the ends of low-sloped glazing rafters into occupied space. Despite past investigation, its source remained unknown.

Seven stories of curtain wall rose above the low-sloped glazing. A spray rack, calibrated in accordance with industry standards, was used for this project (Figure 1). The equipment consisted of copper pipes with nozzles spaced in a grid to deliver a uniform spray to the test area. The vertical curtain wall was water-tested above the leakage area for approximately three hours without replicating the leaks.

The architect and contractor representatives advised this test went on for too long and applied too much water; they said the source of the leakage was likely elsewhere. It was the very end of the day, and the investigating team left the site with the intention of continuing testing the next day. However, 20 minutes later, the facilities staff called to report the leakage in this area was active.

Fact-finding

Part of the investigation involved reviewing shop drawings and removing the brake metal installed between the curtain wall and low-sloped glazing. Beneath the brake metal, pre-formed silicone sheeting created a gutter between the base of the curtain wall and perimeter of the low-sloped glazing (Figure 2, page 54). The silicone sheeting then terminated at a metal gutter at the glazing's base.

The brake metal was intended to be the first line of defense in stopping water from entering the building between the curtain wall and sloped glazing, while the underlying sheet was the second. The silicone sheet was unsupported between sloped glazing rafters and, as a result, sagged between them. This created numerous troughs that held as much as 76 mm (3 in.) of water at the end of the testing (Figure 3, page 56). Since the system was already primed and most of the water in the troughs remained overnight, the leakage was replicated

Figure 1

This photo shows a water test at the intersection of sloped glazing and seven-story curtain wall. The spray rack consists of copper pipes with nozzles in a uniform grid pattern.

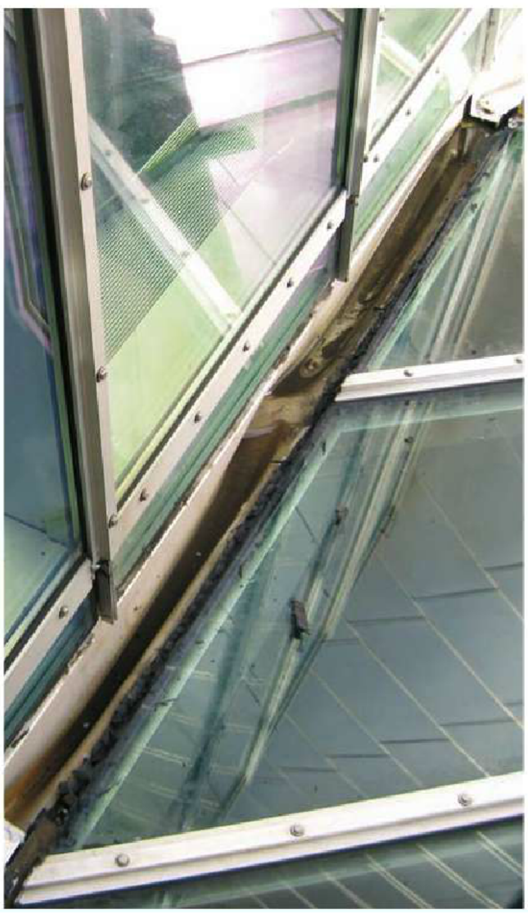
[Misinterpreting standards can lead to mistakes during building investigations. Had claims of 'excessive' testing been accepted, the owner's problem would never have been solved.]

quickly (approximately 30 minutes) when testing commenced on the second day.

The water had to follow a convoluted path measuring more than 15 m (50 ft) from the point of entry into the silicone sheet gutter to the point of leakage into the building. Leakage occurred only after all the troughs in the silicone sheet upstream of the point of leakage into the building had filled. Replicating this leakage required a substantial volume of water and hours of testing with a spray rack.

Using only one spray rack for a relatively short duration (*e.g.* 15 minutes) could never replicate the amount of water the test area would experience during a heavy rainstorm. For starters, the rack does not account for the seven-story fetch of curtain wall rising above the sloped glazing and delivers water to the same area tested. In other words, the water flow rate of the standard spray rack was not intended to replicate the rate of rainfall; rather, it delivered a consistent, reproducible flow rate that produced a uniform film of water over the test area.

Figure 2



The removal of the brake metal at the base of the curtain wall revealed a silicone sheet gutter.

Aligning test purpose with test procedure

Misinterpreting test standards can lead to mistakes during building leakage investigations; it might also mean erroneous remedial work based on those results. Had the claims of excessive testing been accepted in this particular case, the owner's problem would never have been solved.

Incorrectly founded opinions on water testing often stem from a misunderstanding of the intent of ASTM E 1105, *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.* When investigating building leakage, industry professionals and contractors often refer to this standard without fully grasping its intent.

ASTM E 1105 is intended to evaluate a fenestration product for resistance to water penetration with respect to specified performance criteria. However, its basic procedures can be modified and used in building leakage investigations if properly structured for the task at hand.

ASTM E 2128, *Standard Guide for Evaluating Water Leakage of Building Walls,* describes "methods for determining and evaluating causes of water leakage of exterior walls." Though the standard was first published in 2001, many investigators are still not familiar with the procedures it describes. This, along with misapplication of E 1105, inevitably leads to points of contention among investigators typically with respect to:

- testing duration;
- volume of water applied to the envelope components;
- spray rack flow rate; and
- spray rack's general intention.

Duration of testing

Some claim water tests should not be run for more than 15 minutes because that is the duration noted in ASTM E 1105. The notion of a maximum time of 15 minutes likely stems from language included in Procedures A and B, which describe the testing of a window product to predetermined performance criteria under a uniform static (*i.e.* A) or cyclic (*i.e.* B) pressure with an accompanying water spray for 15 minutes.

However, neither Procedure A nor B states that 15 minutes is the maximum test duration. Procedure B further describes that 15 minutes is the minimum duration of water spray with pressure. Regardless, these procedures were not written with the intention of replicating known building leakage. ASTM E 1105, and it predecessors E 331 and E 547, were created to evaluate standalone fenestration products—not wall systems composed of assemblies of wall components.

Applying arbitrary test duration (whether 15 minutes or another length of time) during an investigation risks obtaining false results. There is no foundation for claims that running a water test for more than 15 minutes is excessive and in violation of E 1105.

ASTM E 2128 recognizes that several factors influence the time it takes to replicate known leakage. These include:

- wall construction;
- length of leakage paths;
- absorption of materials; and
- potential internal storage capacity of components being tested.

Relatively thin, non-absorptive cladding components (*e.g.* curtain walls, windows, or metal panels) typically require shorter testing duration to replicate leakage than thicker, more absorptive systems (*e.g.* multi-wythe masonry or curtain walls with long leakage paths).

This author's experience in the aforementioned investigation illustrates a case in which testing required a relatively long duration to replicate leakage due to the internal storage capacity of the silicone sheet gutter that spanned between the curtain wall and sloped glazing and the substantial length of the leakage path. It was only through shop drawing review, wall component disassembly, experience with similar building types, and patience that known leakage could be replicated. There is art behind the science of water testing.

Discussing spray rack flow rate and volume of applied water

Both ASTM E 1105 and E 2128 refer to a testing apparatus that delivers a water flow rate of approximately 3.4 L/m^2/min (5 gal/sf/hour) to the test area. A spray rack set at this rate using standard, commercially available nozzles, and placed about 0.3 m (1 ft) in front of the test area produces a consistent film of water (Figure 4, page 57).

Due to obstructions encountered in field investigations, it may not always be possible to position the testing apparatus at the desired distance from the area in question—for example,

Figure 3

A spray rack set up on the exterior of this window delivers a consistent film of water over the test area.

the front rail of a suspended scaffolding can obstruct spray racks. Wind may also influence the amount of water reaching the test area. In these cases, judgment should be exercised to increase the flow to the test apparatus for achieving the desired uniform film on the test area.

Note 3 to Paragraph 6.2.4 of ASTM E 1105 states:

> the National Weather Service Technical Paper No. 40 records that in the contiguous 48 United States, the greatest rainfall for a 1 hour period is less than 5 inches [*i.e.* 127 mm]. The rate of 5 U.S. gal/sq ft/hr specified in this test method corresponds to a rainfall of 8 in./h [*i.e.* 203 mm/h].

While the note suggests a meaningful correlation between the flow rate of the testing apparatus and the rate of rainfall, this is not the case. As stated earlier in this article, replicating actual rainfall amount is not the purpose of the water spray application rate. The testing apparatus is strictly a tool to deliver a consistent film to the test area.

The logic behind uniform coverage is to evaluate all components of the tested assembly. The right combination of wind and rain can wet every part of the wall and fenestration (in the absence of certain architectural features), and therefore should be assessed.

The argument of excessive water volume typically ignores certain key factors that need to be considered during a field investigation. After a substantial amount of time spraying a test area, if there is no leakage, then either the source is simply not within the area receiving the spray or the initial methods are insufficient.

An example of the latter would be water-testing a window for two hours without a differential pressure and not observing leakage, then testing with an applied differential pressure and replicating known leakage within minutes. This simply means the window only leaks during rainstorms with coinciding wind.

Water testing with an applied differential pressure

On another recent leakage investigation of a four-year-old building, an observer suggested the team test windows only under differential pressure consistent with the ratings of the product when they were created. This would mean testing to 15 percent of the design wind pressure, and reducing this pressure by one-third, in accordance with American Architectural Manufacturers Association (AAMA) 502-08, *Voluntary Specification for Field Testing of Newly Installed Fenestration Products.*

However, testing solely at the rated pressure differential would not be appropriate. The task was to replicate known leakage, and not certify that the windows were performing to their originally specified rating.

The assembly was first tested without differential pressure—no leakage was observed. Weather conditions under which the facility staff reported window leakage were researched. When the windows were tested at differential pressures approximating these reported wind speeds (*i.e.* a two-minute duration), the leak was recreated. These pressures were well below the window's rated capacity.

Issues often arise as to the one-third reduction in the 'rated' pressure differential compared to the originally tested levels. While this author knows of no quantitative justification for the test pressure reduction recommended by AAMA 502, such debate is beyond this article's scope. Nevertheless, the concept of lowering pressure when testing windows in the field versus the controlled environment of a laboratory makes sense.

Not with standing the controversy over the magnitude of reduction, it is almost always appropriate to first test fenestration without a differential pressure to help establish the principal contributors of leakage and the relative contribution of various components. (Zero-pressure testing can be applied uniformly to all wall components, while pressure differential testing cannot within most budgets.)

Further, when testing with differential pressure, gaskets and weatherseals can close up and create a tighter seal to exclude water penetration (and reduce air infiltration), especially in the case of outward-opening operable vents. As a result, some windows that do not leak under differential air pressure will do so under a zero air pressure differential.

After testing at zero pressure, it is sometimes necessary to test at increased intervals of differential pressures to fully understand the test specimen's behavior at different exposures. Using this process, one can often determine the threshold of wind-driven rain that results in leakage.

Recommendations

When investigating building envelope components for leakage, investigators should keep in mind several points. Failure to do so could lead to misleading results when trying to diagnose building leakage and identify the sources.

ASTM E 2128, not E 1105, is the more appropriate standard to reference when investigating known leakage. The test procedures in the latter are useful and are incorporated in the former, but they alone do not fully address the needs of a building leakage investigation. It is important not to rely on preconceived notions of test duration when diagnosing building leakage. Instead, one should use judgment based on experience with testing similar building types and knowledge of the construction of the components being tested. Arbitrary test duration can be irrelevant when the goal is to replicate known leakage.

Note 3 to ASTM E 1105 relates to the flow rate of the testing apparatus to a rate of rainfall. It is misleading and should be eliminated, as it has been in E 331 and E 547. The intent of the water-testing apparatus is to produce a consistent film of water over the test area, not to replicate any particular rain event.

Figure 4

A close-up of the troughs in the silicone sheet between rafters, which held as much as 76 mm (3 in.) of water.

When investigating known leakage, weather data should be researched to approximate the wind speeds and pressures under which the fenestration leaked. The other option is to establish a range of test pressures spanning the plausible actual exposure events. When testing with differential pressure, one should begin at zero, and then move to increased intervals to fully understand the behavior of the test specimen at different exposures. **CS**

ADDITIONAL **INFORMATION**

Author

Francesco J. Spagna, PE, is a senior project manager at national engineering firm Simpson Gumpertz & Heger (SGH). He is experienced in the performance of building envelope investigations, condition assessments, construction litigation support, design of building envelope repairs and subsequent construction administration, and peer reviews of building envelope designs. Spagna has been involved in the investigation and remedial design of curtain walls, windows, roofing, claddings, masonry structures, and plaza and below-grade waterproofing. He can be reached at fjspagna@sgh.com.

Abstract

"You're running your water test too long—why are you going for more than 15 minutes?" "You're applying too much water—are you supposed to be replicating an 'actual' rainstorm, because this flow rate is more than anything the building ever experiences." These critiques from observers of water leakage investigations raises broader issues about how we assess and fix leaky buildings. The article explores the misunderstandings surrounding ASTM tests related to leaks and fenestration.

MasterFormat No.

08 01 40–Operation and Maintenance of Entrances, Storefronts, and Curtain Walls

08 01 50–Operation and Maintenance of Windows

UniFormat No.

B2010.40–Fabricated Exterior Wall Assemblies

B2020–Exterior Windows

Key Words

Division 08

ASTM

Curtain walls

Leakage

Spray rack

Water testing

Windows