Resisting Water Infiltration from Cladding Attachment Penetrations in Wall Assemblies

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AIR INFILTRATION IS an ever-growing concern for buildings, and it is the focus of new codes and regulations in each code cycle. Water, which was previously a priority, seems to now be forgotten until it is too late. The water-resistant barrier (WRB) is very frequently the same product as the air barrier, and sometimes the same as the thermal barrier. These barriers are the final layer of defense before unwanted water or air enters the building, and they are intended to be continuous. The problem is that they are not designed to be the final aesthetic, ultraviolet light–durable covering for the building. When cladding is attached to the building after the WRB is installed, numerous holes are punched through the once-continuous barrier. The question is how to ensure that these penetrations remain watertight, safeguarding that water does not make its way through the wall assembly and into the finished structure.

The current testing of air and water barrier performance varies by material. Self-adhered membranes and fluid-applied membranes are typically tested for nail sealability per Section 8.9 of ASTM D1970, *Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection*.[1] This standard tests the ability of a membrane to resist waterhead after the membrane is applied to plywood and penetrated by a roofing nail.

There is disagreement in the industry about the effectiveness of the ASTM D1970 test method in predicting the in-service success of WRBs tested to this standard. Common construction practices typically use either wood screws or self-tapping screws to secure cladding to the structure. These screws behave very differently from nails when going through a membrane. As a result, industry associations such as the Air Barrier Association of America and the Fenestration & Glazing Industry Alliance are working to develop better standards to test this property. Insulated sheathing used as an air and weather barrier and mechanically fastened WRBs currently do not have any material-only test requirements for nail or fastener sealability. However, these two types of materials are tested for water penetration as full systems per their ICC Evaluation Service (ICC-ES) code acceptance criteria. This testing includes the recommended fasteners used to attach the WRB and as well as other penetrations in the wall assembly.

Building codes require all air barriers to be tested for air leakage as part of an assembly per ASTM E2357, *Standard Test Method for Determining Air Leakage Rate of Air Barrier Assemblies*.[2] This test method specifies exact designs of the wall assembly to be tested, including penetrations, a window opening, and brick ties. The assembly is tested for air leakage per ASTM E283, *Standard Test Method for Determining Rate of Air Leakage through Exterior Windows, Skylights, Curtain Walls, and Doors under Specified Pressure Differences across the Specimen*,[3] both before and after wind pressure conditioning to ensure the system leakage is less than the maximum amount allowed. The *International Building Code* (IBC)[4] includes no requirement for testing additional types of penetrations such as the large fasteners usually required to attach cladding.

The IBC includes additional requirements for WRBs. The code acceptance criteria for WRBs often require an assembly similar to the ASTM E2357[2] penetrated assembly to be tested for water infiltration per ASTM E331, *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference*.[5] The exact pressures and length of the testing, along with the type of wall assembly to be tested, vary by material.

As suppliers of materials with a shorter history make performance claims about air and water resistance, questions arise about the watertight performance of those materials after the entire facade is complete. The question then becomes how to test for these products' in-service properties.

One of the products that is the subject of such questions is foil-faced polyisocyanurate (ISO) insulation, which can be used as an air, water, and thermal barrier when the joints of the insulation boards are sealed. ICC-ES AC71, *Acceptance Criteria for Foam Plastic Sheathing Panels Used as Water-Resistive Barriers*,[6] is designed to address many of these questions. It requires wall assemblies similar to those found in ASTM E2357[2] to be tested for water penetration per ASTM E331[5] for two hours at a differential pressure of 6.24 lb/ft^2 (300 Pa). This requirement is the same as the IBC requirements for exceptions to the use of a WRB. Even with this standardized testing for water infiltration, there are questions about what happens when the foil

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face of the insulation is punctured when cladding is later installed—there is concern that water can migrate through to the interior side of the insulation and subsequently into the building.

This article details a study that was performed to determine how foil-faced ISO insulation performs after cladding attachments, specifically rain screen attachments, are installed onto the face. Previous assembly and project-specific testing of WRBs with fastener penetrations has shown that sealing at the point of penetration of the air barrier provides the greatest chance of success. We predicted that it would be the same for these systems. Unfortunately, it is often easiest to seal fasteners after they have been installed instead of before. To minimize the potential of workmanship errors, the potential sealing solutions included in the study were selected to balance the predicted likelihood of success with the ease of installation in the field.

Several potential solutions were evaluated using a wall assembly test methodology. These tests examined different variables, such as girt system type, orientations of the attachments, and ways to seal the penetrations using different types of fluid and self-adhered flashing. Because of the large number of included variables, the study was divided into two phases. A statistical test design was used to limit the number of experiments for small-scale testing in phase I. Phase I testing focused only on pressurized water leakage through small-scale samples to quickly evaluate the critical pass/fail probability of each variable combination. This was done because water infiltration was chosen as the main criterion for passing the final evaluation. The results of phase I were used to develop a probability-of-leaks model to predict results for the full range of variables, which then helped to refine the plan for larger-scale testing in phase II. The second phase of the testing included additional stresses on the wall assembly to better predict long-term performance of the sealing solution in actual construction. This study design allowed us to quickly understand which solutions would likely work best for implementation in the field.

EXPERIMENTAL STRATEGY

The objective of the experiments was to find the most effective way to flash girts installed over foil-faced ISO insulation boards. One of the most representative ways to test wall assemblies to predict in-field performance for water infiltration is to use pressurized water leakage testing per ASTM E331.[5] In theory, this process is straightforward: walls are built with the different girt and sealing configurations, pressurized water leakage testing is conducted, and then the flashing configurations that did not show water leaks are selected for use. However, there were so many variables in this scenario that it was not possible to allot all the time and resources necessary to test each combination. To reduce the number of full-scale tests, an experimental strategy was created and implemented. Three key challenges and strategies to mitigate them were identified. The experimental strategy is explained as follows.

Challenge #1: Large Number of Experiments

It was ideal to keep the study as broad as possible because construction practices and materials vary widely across regions and building types. Consider the following questions:

- What is the most effective way to flash a hat channel girt? What if the hat channel is applied upside down? What about a Z channel or other proprietary rainscreen systems?
- What is the most effective way to flash a girt in the horizontal orientation? Or in the vertical orientation?
- Which flashing works better: fluid applied or self-adhered?
- Should the fluid-applied flashing be wet or should it be allowed to cure before installing the girt?
- Will the flashing recommendations change with insulation board thickness?

It was resource prohibitive to study every variable combination individually, so the variables were prioritized and factor levels for each variable were combined. (Variables or factors of the study are the characteristics that differentiate the treatments from one another, such as the insulation thickness or girt type in this experiment. The factor levels, or simply levels, are the different treatments of the factor such as the three different insulation thicknesses being studied.[7]) For example, "hat down" girt (the hat channel applied with the long continuous side against the sheathing) was eliminated because it is essentially the same as a Z-girt at the point of contact with the insulation (**Fig. 1**). Hence, it was reasoned that the recommendations for Z-girts will also be watertight for hat down girts.

Similarly, levels of each variable were scrutinized to minimize the total number that would need to be tested while still including those that would have the greatest impact. A list of final primary variables and their factor levels are as follows:

1. ISO insulation thickness: 0.625 in. (15.9 mm), 1.55 in. (39.4 mm), 3 in. (76.2 mm)
2. Girt type: hat, Z, proprietary horizontal attachment system with large openings predrilled for fasteners, proprietary vertical attachment system with large predrilled openings for fasteners
3. Girt orientation: horizontal, vertical
4. Flashing material: no flashing, silicone fluid-applied flashing, water-based acrylic flashing, self-adhered flashing with a polyolefin top sheet, STPE (silyl-terminated polyether) fluid-applied flashing
5. Flashing on edge: no material, top only, all ("Top only" includes only the top edge of a horizontal girt. "All" includes both top and bottom edges. This definition is only for horizontal girts because there is no physical significance of top/bottom for vertical girts. Whereas there could be differences between top- and bottom-edge sealing in horizontal girts, there is no expected difference between left- and right-edge sealing of a vertical girt.)
6. Flashing on fasteners: no material, top only, all
7. Flashing in between (girt and ISO): no material, wet material, cured material

All flashing material used for the testing passes ASTM D1970[1] as defined in AAMA 714-19 (for fluid-applied materials)[8] and AAMA 711-13 (for self-adhered materials).[9] The testing was completed prior to the introduction of the new fastener sealability test method in AAMA 711-20.[10] Variables 5, 6, and 7 in the previous list define where the flashing material is applied on the girt (**Fig. 2**).

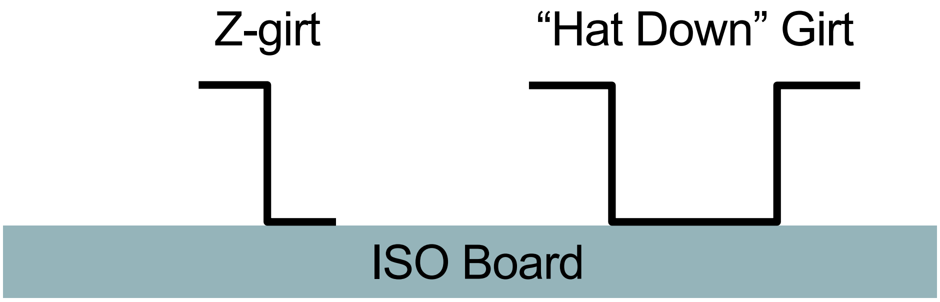
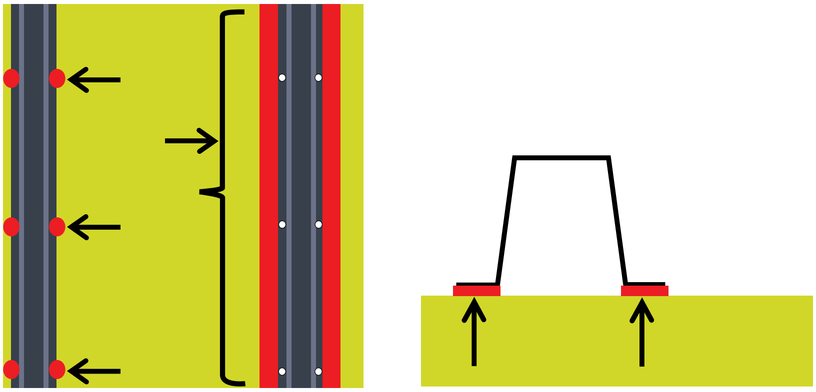


Figure 1. *Z-girt and "hat down" girt connect to the sheathing in the same way. Note: ISO = polyisocyanurate.*



Flashing on fasteners Flashing on edge Flashing in between

Figure 2. *Flashing locations "on fasteners," "on edge," and "in between" shown by arrows.*

A simple calculation shows that a full factorial experimental design would require 3240 test combinations.[11] It was not feasible to test that many combinations, let alone with any replication. Therefore, an experiment was designed to minimize the number of test combinations. The final experiment design with 36 test combinations allowed investigators to study the main effect of each primary variable. The designed experiment was a complex split-plot design consisting of many categorical factors and restricted design space. A split-plot design is used when some of the variables are difficult to change such that the study cannot be completely randomized.[11] For this study, it was difficult to change the insulation board thickness within the same board; therefore a split-plot design was an appropriate choice.

Challenge #2: Resource-Intensive Study

Standard ASTM E331[5] tests are highly resource intensive, as they require building and testing large walls (typically 8 × 8 ft [2.4 × 2.4 m]) along with the use of large-scale test equipment. To counteract this challenge, the study was conducted in two phases. In the first phase, screening tests were conducted on small walls (3 × 3 ft [0.9 × 0.9 m]). Only a subset of variable combinations was then carried forward to phase II, where the full test protocol was tested on larger walls (8 × 8 ft) with replication of each solution. This approach allowed for efficient implementation of the study.

Challenge #3: Inferring and Communicating Results

We hypothesized that without statistical analysis, it would be very difficult to infer and communicate results. Statistical models make it easy to communicate results quantitatively. Statistical analysis also allowed multiple team members to make informed decisions about which combinations were carried forward from phase I to phase II.

Table 1 summarizes the three challenges and the ideas for how to counteract each one.

PHASE I EXPERIMENT METHODS: SCREENING TESTS ON SMALL WALLS

A small-scale pressurized water infiltration test based on ASTM E331[5] was used in phase I testing of 3 × 3 ft (0.9 × 0.9 m) walls. Each wall was able to fit three test conditions. Because the final experiment design had 36 test combinations, there were a total of 12 small walls. Each condition was replicated at least three times, with five replicates for most variables tested. Refer to **Table A1** in the **Appendix** for the full set of variable combinations tested. Only one variation of the fluid-applied, water-based acrylic flashing (Type A) was included in phase I.

Walls were built using 4 in. (100 mm), 18-gauge (1.2 mm) steel studs spaced approximately 9 in. (230 mm) on center with ISO insulating sheathing attached directly to the studs. Templates were built to ensure alignment between the girt location on the sheathing and the steel stud frame. Girts were attached with the flashing applied as per the defined test combinations. All flashing was allowed to cure for two weeks at standard laboratory conditions before being tested. **Figure 3** shows the step-by-step process of building the small-scale walls.

After the flashing cured, the wall was transferred into a small chamber equipped with a vacuum pump and spray head. Water was sprayed on the entire wall under the pull of vacuum pressure. Water was sprayed at a rate of 5.0 US gal/$\text{ft}^2 \cdot \text{hr}$ (3.4 L/$\text{m}^2 \cdot \text{min}$) per the standard. It was sprayed for two hours under a negative pressure of 6.24 lb/ft^2 (300 Pa) per ICC-ES AC71.[6] The vacuum pressure was then increased to 15 lb/ft^2 (720 Pa) for an additional 15 minutes, which is similar to the testing done on many window systems. While the higher vacuum pressure is greater than what is tested for most WRBs, it is in line with the pressures required of windows being tested to the same standard. If fasteners did not leak during the entire protocol, they were recorded as a pass.

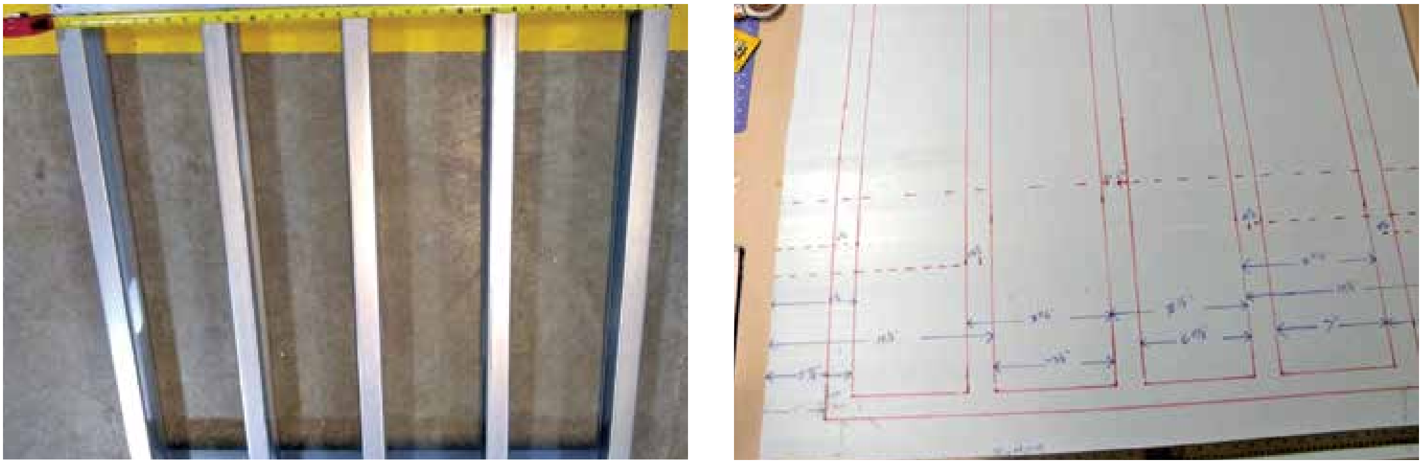
The backside of the walls was examined throughout the testing, and leaks were recorded. To make it easier to identify leaks at the source, the water was infused with red dye and small pieces of paper were attached underneath every penetration between the steel stud frame and ISO insulation—a piece of paper marked with the colored water indicated a leak. In the absence of the paper, a leak might go undetected at the source or the source might be misidentified. For example, water can run down between the stud and the sheathing until it shows at another spot below the actual location of the leak. The indicator paper guarded against such instances. The test chamber, spray nozzle, and paper arrangement are shown in **Fig. 4**.

Two data points were recorded for analysis during the first phase of testing: one was a binary response for water leaks (yes/no) and the second response was a proportion of penetrations of that configuration that leaked (percent leaks). The data were entered into JMP Pro 14.2.0 software for further analysis. The binary response was used to predict the water penetration through a specific combination of variables. The percent leak response was used to identify the most important variables (and consequently the least important variables).

The percent leaks response was analyzed using an ordinary least-squares technique.[12]

Table 1. *Experiment strategy formed by counteracting ideas to the challenges*

Challenge	Counteracting idea
Large number of experiments	Prioritize variables and combine levels Statistically designed experiments
Resource-intensive study	Two-phase testing
Inferring and communicating results	Use statistical models to infer and communicate results



(a) *Make steel stud frame*

(b) *Make templates for placement of girts*

(c) *Make wall with insulation sheathing*

(d) *Attach girts and flashing as per test plan*

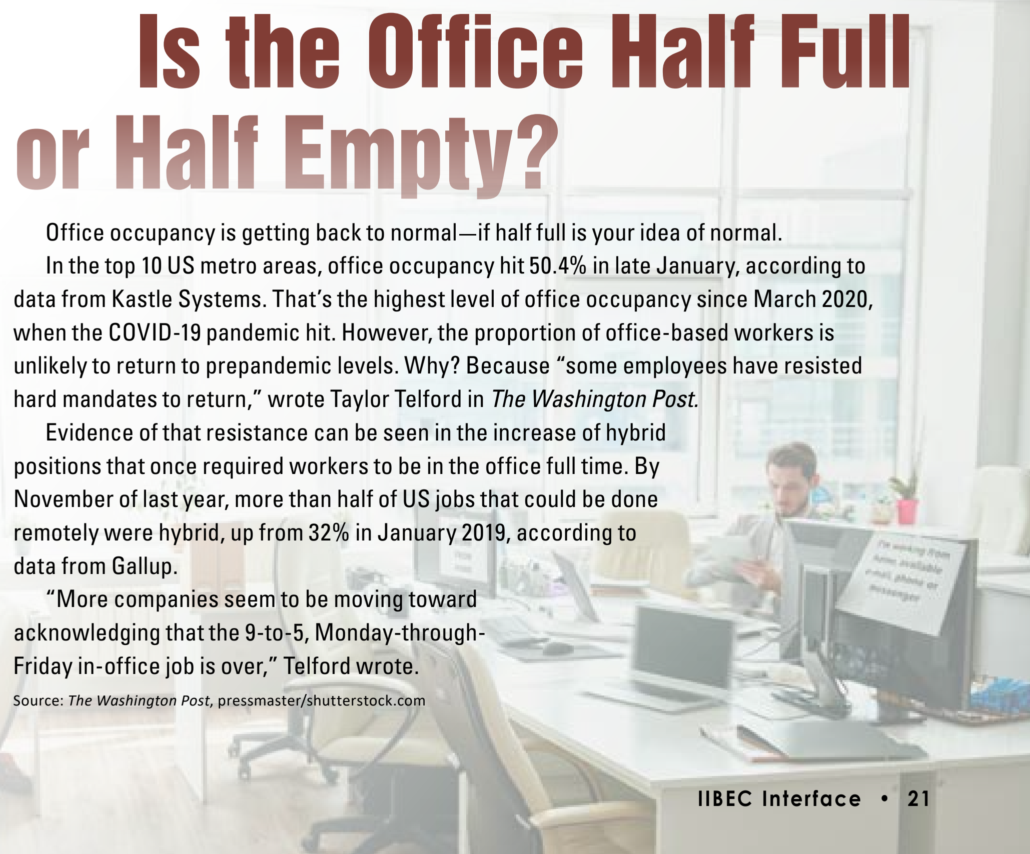
Figure 3. *Step-by-step process to make a wall.*

The *P* value from the hypothesis testing of each variable is shown in **Fig. 5**. The null hypothesis for such a test states that the factor is not important. Hence, wherever there was a low *P* value, the null hypothesis could safely be rejected. For example, it was found that the location where the flashing was applied and the flashing material itself were important factors.

The binary response for leaks (yes/no) was analyzed using a ridge regression model[13] along with the "leave-one-out" validation method. The output of this analysis was a probability-of-leaks model. The misclassification rates are 0.09 for the training data set and 0 for the validation data set. This indicates that the model is a decent model for prediction purposes. A lower probability of leaks (leaks = yes) is desirable. When the probability of this response (leaks = yes) is less than 0.5, the selected combination of variables is considered likely not to leak in future testing.

An interactive graphical model was created using this information. The model allowed the various combinations to be predicted for leaks

Special interest



Is the Office Half Full or Half Empty?

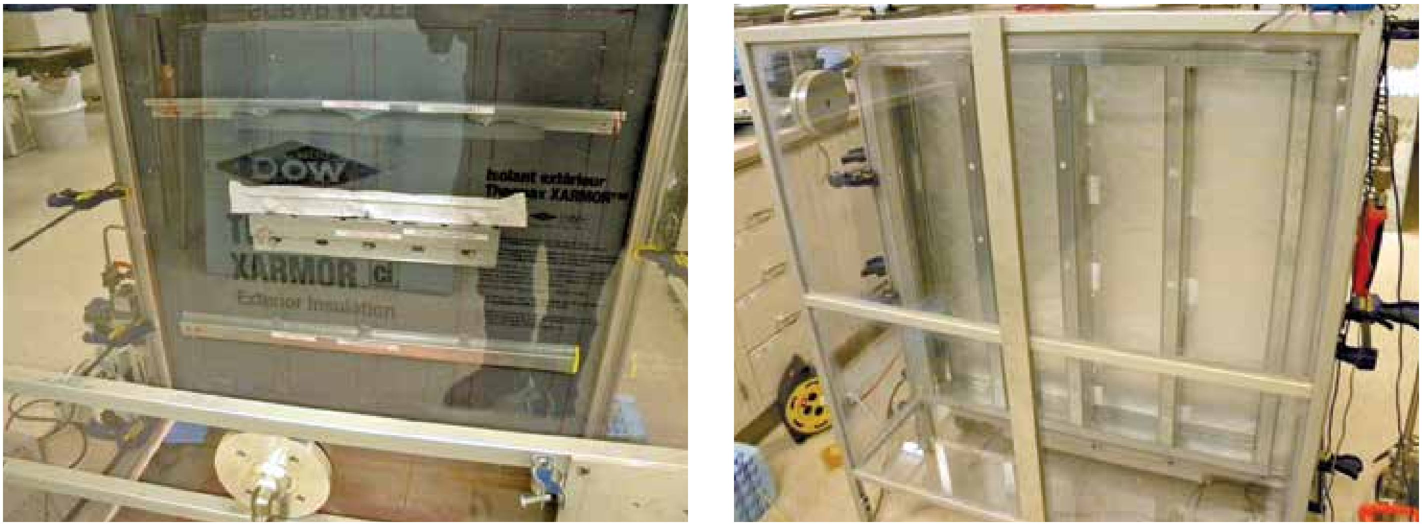
Office occupancy is getting back to normal—if half full is your idea of normal.

In the top 10 US metro areas, office occupancy hit 50.4% in late January, according to data from Kastle Systems. That's the highest level of office occupancy since March 2020, when the COVID-19 pandemic hit. However, the proportion of office-based workers is unlikely to return to prepandemic levels. Why? Because "some employees have resisted hard mandates to return," wrote Taylor Telford in *The Washington Post.*

Evidence of that resistance can be seen in the increase of hybrid positions that once required workers to be in the office full time. By November of last year, more than half of US jobs that could be done remotely were hybrid, up from 32% in January 2019, according to data from Gallup.

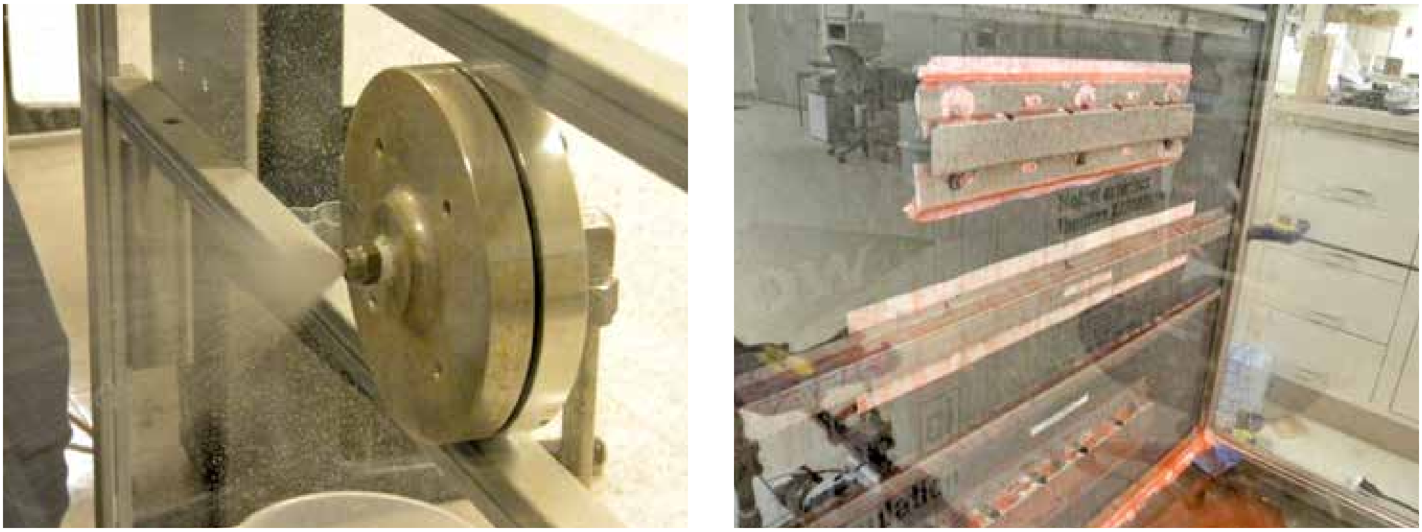
"More companies seem to be moving toward acknowledging that the 9-to-5, Monday-through-Friday in-office job is over," Telford wrote.

Source: *The Washington Post*, pressmaster/shutterstock.com



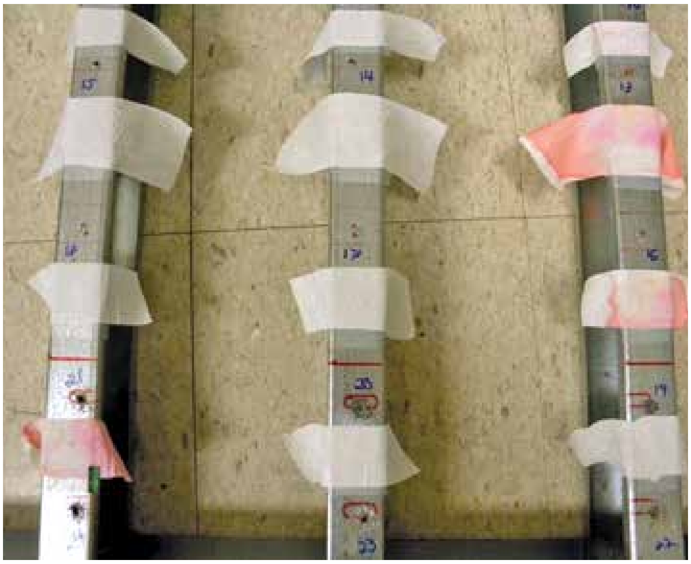
(a) *Wall inside test frame: front view*

(b) *Wall inside test frame: back view*



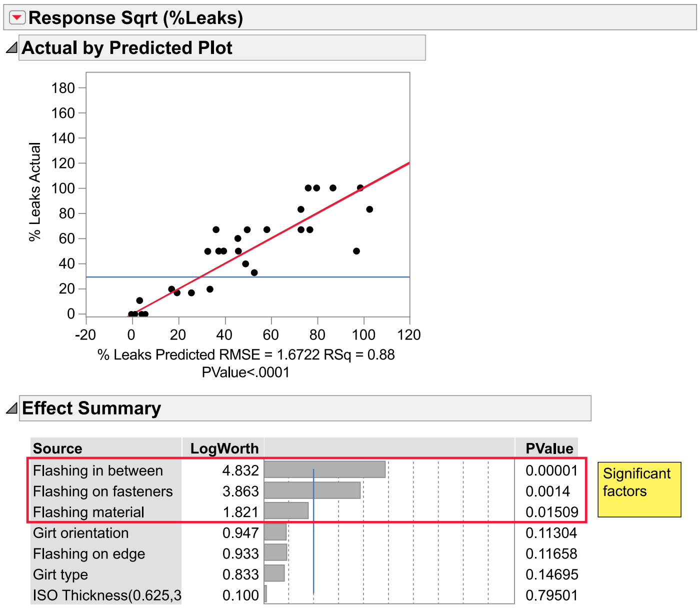
(c) *Close-up of spray nozzle inside the test chamber*

(d) *Wall being tested with colored water*



(e) *Post-test photo of paper pieces that help in accurate leak detection*

Figure 4. *Test setup and paper detectors.*



Response Sqrt (%Leaks)

Actual by Predicted Plot

% Leaks Predicted RMSE = 1.6722 RSq = 0.88 PValue<.0001

Effect Summary

Source	LogWorth	PValue
Flashing in between	4.832	0.00001
Flashing on fasteners	3.863	0.0014
Flashing material	1.821	0.01509
Girt orientation	0.947	0.11304
Flashing on edge	0.933	0.11658
Girt type	0.833	0.14695
ISO Thickness(0.625,3	0.100	0.79501

Significant factors

Figure 5. *Least-squares model for percent leaks and hypothesis test for each of the model variables.*

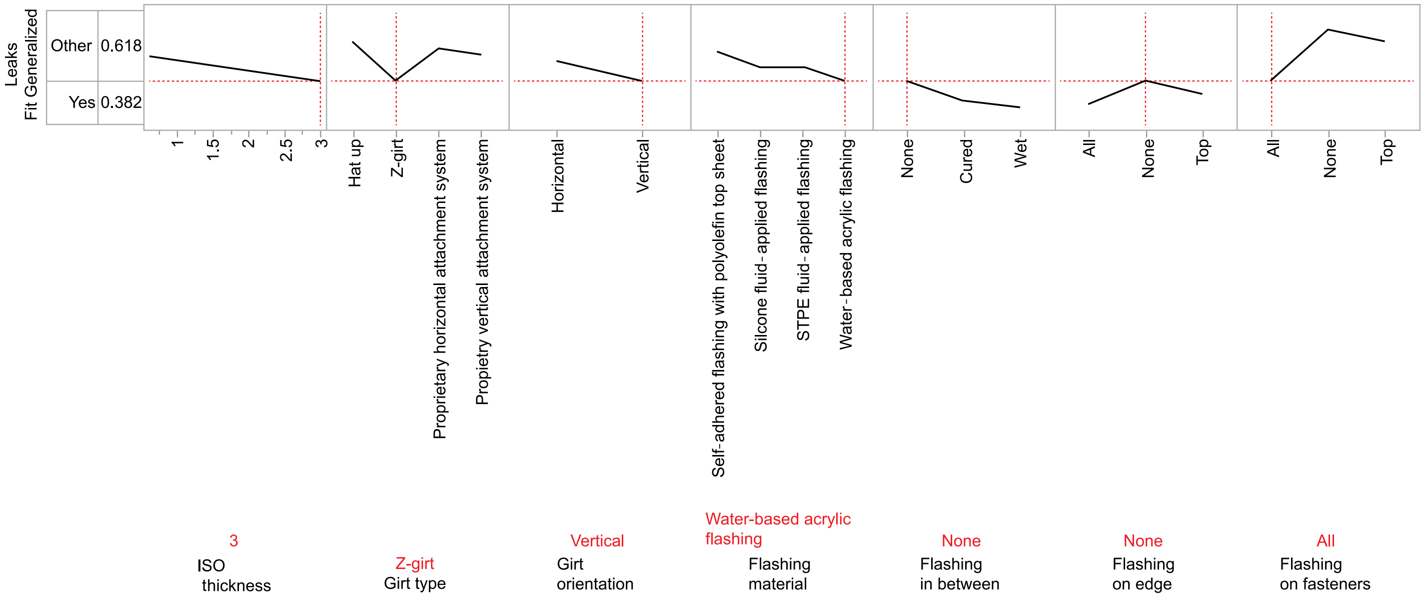


Figure 6. *Interactive profiler to predict the probability of leaks based on various input variable selections.*

by changing the input levels of each variable. **Figure 6** shows the output of a specific set of variables. This scenario shows the prediction that a vertical Z-girt with a water-based acrylic flashing applied only on the fasteners is most likely not going to leak (the probability of "leaks = yes" is 0.38, which is less than 0.5). The interactive profiler was used to predict the effectiveness of multiple combinations. The most promising combinations based on the model, along with additional evaluation based on probability of applicator acceptance and repeatability of the technique between multiple systems, were taken to phase II for full-scale wall assembly testing.

PHASE I RESULTS

All variables from the study were analyzed using the interactive profiler tool. Based on the phase I results, the following factors were found to have the largest impact on percent leaks compared with other factors: flashing being in between the girt and ISO insulation, flashing being on the fasteners, and the type of flashing material used. Girt orientation did not seem to have a strong impact; however, there was a trend of reduced leaks for girts in the vertical direction. The phase I results also showed that the thickness of the insulation had no effect on the results of the configuration. Therefore, this variable was excluded in phase II testing.

Based on previous testing, current field recommendations for various systems, and common assumptions about the performance of self-adhered membranes and fastener sealability, we expected that the self-adhered flashing would be one of the best solutions for sealing behind the fasteners in this wall assembly. However, there were multiple water leaks for this solution in phase I. Therefore, we did not include self-adhered membranes in the phase II test combinations.

PHASE II EXPERIMENTAL METHODS: VALIDATION TESTING WITH FULL-SCALE WALLS

To determine which solutions would be tested in phase II, we used data from the predicted leak probability model, and we also considered both the ease of installation in the field and the desire to have a single recommendation for all types of cladding attachments. As such, we anticipated that some of the configurations tested in phase II would likely fail. We concluded that this expectation was necessary given the ease-of-use and consistency-of-recommendation requirements for the project. This approach would also help to further validate the model.

Two additional variables were added to phase II testing based on the results of phase I. First, a second water-based acrylic fluid-applied flashing material was added (referred to as Type B). The goal was to see whether the performances of Type B and Type A would be similar because of their similar base chemistry or if there would be a difference in performance between the types based on their property differences: Type A passes crack bridging testing, whereas Type B does not.

Second, we had concerns about the ability to get a watertight seal using the proprietary horizontal and vertical cladding attachment systems chosen for the study, as no solutions passed phase I. Therefore, a new technique of wet-dipping the threads and shanks of the screws into the fluid-applied silicone flashing before installing the fastener through the girt/foam sheathing was added for that system. The other tested combinations that were tested in phase II are summarized in **Table A2** of the Appendix.

Once the new set of variable sets was identified for further evaluation, two 8 × 8 ft (2.4 × 2.4 m) walls were assembled. ISO insulating sheathing with a 4.0 mil (0.1 mm) embossed foil facer was secured to 6 in. (150 mm), 18-gauge 1.2 mm) steel studs at 16 in. (410 mm) on center using standard fasteners recommended by the insulation manufacturer. Due to the number of additional fasteners going into the assembly, the fastening pattern of the insulation fasteners was reduced to the perimeter of the boards only. No exterior gypsum was installed between the insulation and the studs. The joints in the insulation boards were sealed using a silicone fluid-applied flashing. Each wall was assembled such that five fasteners were installed for each configuration to determine repeatability of the solution. A solution that would be implemented in the field to help ensure risks of water infiltration through the fasteners needed to achieve a 100% passing rate.

The walls were tested to a full testing protocol like that used for evaluation of some air barriers and WRBs, with additional testing for better assurance of long-term robustness. The overall series of tests is similar to those proposed in AAMA 504, *Voluntary Laboratory Test Method to Qualify Fenestration Installation Procedures*,[14] for testing the installation of window assemblies. The same wall assembly is tested through the entire protocol. This helps determine whether any of the stresses such as wind pressure conditioning cause

Figure 7. *Wall shown in the test setup. Various girts are attached with different flashing configurations. A spray rack is in front of the wall.*

Figure 8. *Side view of the wall during test. Water is seen coming out of various nozzles on the spray rack.*

the assembly to become more porous to air or, more importantly for this study, water. It is not uncommon for wall assemblies that pass the current code limits for air infiltration to have issues with water leakage when tested to this protocol.

The test protocol followed for this study is as follows:

- Conduct air infiltration testing per ASTM E283[3] up to 6.24 lb/ft^2 (300 Pa) pressure differential, with special focus on the code compliance level of 1.57 lb/ft^2 (75 Pa).
- Conduct water infiltration testing per ASTM E331[5] under negative pressure ramping up to 6.24 lb/ft^2, where the wall assembly is held for two hours; then increase the pressure at three additional levels up to 15 lb/ft^2 (720 Pa), with the assembly being held at each of the intermittent and maximum pressures for 15 minutes each.
- Conduct wind pressure conditioning per ASTM E2357.
- Repeat air infiltration testing per ASTM E283.
- Repeat water infiltration testing per ASTM E331.
- Conduct thermal cycling per ASTM E2264-05 (2013), *Standard Practice for Determining the Effects of Temperature Cycling on Fenestration Products* Method A, Level 2.[14]
- Repeat air infiltration testing per ASTM E283.
- Repeat water infiltration testing per ASTM E331.
- Perform forensic evaluation of assemblies.

The pass/fail criterion used for this testing was an air leakage rate less than 0.04 cfm/ft^2 (0.2 L/s·m^2) at a pressure differential of 1.57 lb/ft^2 (75 Pa) and no water observed on the interior side of the wall assembly at any point during the water infiltration testing. The wall assembly was inspected for water leakage after each round of water testing and the conditions were documented. **Figures 7** and **8** show the wall assemblies installed in the testing chamber.

Once the complete test protocol was finished, the wall assemblies were put under negative pressure and sprayed using dyed water. The wall assemblies were then taken apart and further examined for evidence of water infiltration through the fastener onto the backside of the sheathing.

PHASE II RESULTS

During phase II, most of the fasteners that leaked during the testing did so early during the first round of water penetration testing, often during the two hours of water spray with 6.24 lb/ft^2 (300 Pa) negative pressure on the assembly. A few additional fasteners leaked during the second round, with all but one of them leaking at differential pressure equal to or greater than 12.5

Table 2. *Passing results–girt/flashing configuration*

Girt	Flashing	Application
Hat	Silicone fluid-applied flashing	Flashing in between—wet material and flashing on fasteners
	Water-based acrylic flashing A	Flashing in between—cured material and flashing on fasteners
Z-horizontal	Water-based acrylic flashing A Water-based acrylic flashing B	Flashing in between—cured material and flashing on fasteners
Z-vertical	Water-based acrylic flashing A	Flashing in between—cured material and flashing on fasteners
	Silicone fluid-applied flashing	Flashing in between—wet or cured material and flashing on fasteners
Proprietary vertical attachment system	Silicone fluid-applied flashing	Wet-dipped screws
Proprietary horizontal attachment system	Silicone fluid-applied flashing	Wet-dipped screws
	Water-based acrylic flashing A	Flashing in between—cured material and flashing on fasteners

lb/ft^2 (600 Pa). Two fasteners leaked for the first time during the final round of water penetration testing after thermal cycling.

While all of the flashing materials tested in phase II successfully passed the nail penetration testing currently required by AAMA 714,[8] which is based on ASTM D1970,[1] they did not all perform the same. The two water-based acrylic flashing materials exhibited different results when tested under the same conditions. Type A was more likely to pass water penetration testing throughout the entire protocol than Type B. In fact, Type A performed more similarly to the silicone fluid-applied flashing.

The phase II test results identified a common solution for the standard hat channel and Z-girt systems regardless of orientation: use of a Type A water-based acrylic flashing that is cured in between the girt and the sheathing and sealing the fastener heads. This successful result was predicted by the model. Given the study size limitations and current construction practices, phase II did not include the Type A flashing installed wet in between the girt and sheathing. However, the predictive model shows wet flashing in this location always has a lower probability of leaks than cured flashing. This solution could be fully tested in a large-scale assembly to provide additional flexibility in construction operations.

Phase II testing also provided a successful result for the proprietary attachment system. **Table 2** presents all of the girt/flashing/application combinations that showed zero water leakage throughout the entire test protocol from phase II.

There were a few surprising results during phase II testing that were not predicted by the model:

- The biggest surprise was the use of silicone fluid-applied flashing applied wet between the girt and the sheathing with additional flashing on the fastener heads on hat channels. The model predicted that this solution would likely fail. It was included in phase II because the model showed this treatment was likely to be successful for Z-girts and there was a desire to have a consistent solution for the treatment of all systems. This method of sealing the hat channel girts was successful.
- Despite predicted success on the horizontal Z-girt system, this application of silicone fluid-applied flashing applied wet between the girt and the sheathing with additional flashing on the fastener heads was not 100% successful for all fasteners, as there was a late water leak on one fastener at 12.5 lb/ft^2 (600 Pa) negative pressure after thermal cycling. Although this solution did not pass the full criteria for this study, it would likely be acceptable for most building types.
- Like all models, this model has some uncertainty around its predictions. When the model predicts probability lower than 0.5 but close to it, there is still potential for the solution to leak. For example, the model predicted success of only treating the fasteners on the Z-girts in a vertical orientation. The probability of leaks in the model was 0.42. This configuration was included in phase II because of its simplicity, but it leaked during testing.

STUDY LIMITATIONS AND FUTURE WORK

While this study included a large number of conditions and scenarios, it was not comprehensive of all variables found in exterior wall construction. Additional testing is required to continue assessing the impact of additional variables such as different sizes of self-driven screws and different facers of the ISO boards. The current study also did not address the impact of the weight of the cladding on the girts and rotation of the fasteners during both installation and service. It also did not evaluate the impact of thinner-gauge or smaller steel studs. These variables could allow for more movement of the fasteners and the entire wall assembly.

It would also be interesting to investigate whether these same fastener sealing solutions provide a watertight solution for attaching girts to wall assemblies where the insulation is a different layer from the air and water barrier, such as is found in a more traditional wall assembly with gypsum being installed to the steel stud followed by a WRB and the insulation. Additionally, this work could be repeated on wood-based structures. Finally, there is a need to evaluate the wet-dipped screw option for other systems and other types of fluid-applied flashings given its ease of use in the field.

CONCLUSION

The use of statistical design greatly reduced the test effort required for this study, and building a validated predictive model for leaks improved the quality of the results. The probability-of-leakage model allowed the team to evaluate

> The water-resistant barrier is very frequently the same product as the air barrier, and sometimes the same as the thermal barrier. These barriers are the final layer of defense before unwanted water or air enters the building, and they are intended to be continuous. The problem is that they are not designed to be the final aesthetic, ultraviolet light–durable covering for the building.

several variables, compare expected results, and evaluate key candidates for a second phase of more robust testing. Learnings from each phase of the testing were included in the next round of testing to continually improve the proposed solutions and quickly reach final field recommendations.

The study found the following factors significantly affect leak resistance:

- Location of flashing. The testing affirmed the hypothesis that sealing at the point of penetration is important to keep water out of the full assembly. Specifically, it was more beneficial to apply the flashing on the fasteners and in between the girt and ISO insulating sheathing. Wet-set flashing performed better than cured-set flashing in between the girt and ISO insulating sheathing.
- Flashing material. Fluid-applied flashing performed better than self-adhered flashing. The performance of the fluid-applied flashing solutions tested also varied. The difference in performance between the two water-based acrylic flashing materials included in the study indicates that performance cannot be assumed based on the base chemistry of the material alone. None of the tested materials had known self-healing properties, but all are able to pass the roofing nail water-penetration test.

The statistical model suggested that girt orientation did not have a strong impact on leaks. However, all vertical girts had fewer leaks than horizontal ones; there is a trend toward fewer leaks on vertical girts. Additionally, the thickness of the ISO insulation did not have any effect on leaks.

This study has provided data-based flashing recommendations to end users of ISO insulation as to how best to install cladding attachments over the insulation boards to prevent future water penetration.

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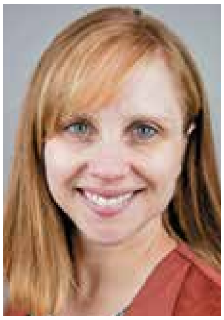

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