Industry Response to:

"Wind-Driven Rain Tests of Building Envelope Systems up to Hurricane-Strength Wind-Driven Rain Intensity"

by Dr. David Prevatt, Dr. Daniel Smith, Michael Louis 2020

Florida Building Commission Project #PO150337

by Fenestration Research Team Advisory Group (AG) members representing:

- **Fenestration and Glazing Industry Alliance (FGIA)** – Previously known as American Architectural Manufacturers Association (AAMA)
- **Fenestration Manufacturers Association (FMA)**
- **Window and Door Manufacturers Association (WDMA)**

Submitted August 28, 2020

Attn: Mo Madani, Florida Department of Building and Professional Regulation (DBPR)

Executive Summary

This Industry Response provides the fenestration industry's concerns about opinions and non-fact-based conclusions in the research team's report, *"Wind-Driven Rain Tests of Building Envelope Systems up to Hurricane-Strength Wind-Driven Rain Intensity" (Dr. David Prevatt, Dr. Daniel Smith, Michael Louis 2020.* Report presented July 28, 2020.) **(Florida Building Commission (FBC) Project #PO150337.)**

The research project was funded by the FBC to examine issues related to water penetration through the building envelope of mid- to high-rise structures due to wind-driven rain encountered during tropical storms and hurricanes. An Advisory Group (AG) was formed to aid and inform researchers.

Seven fenestration industry representatives participated in each of the AG's five conference calls held from February 21, 2020 - July 17, 2020. Fenestration AG members represented respected companies which manufacture products used in Florida Commercial and Residential projects. All seven fenestration representatives represent companies with manufacturing facilities in Florida.

The researchers based their latest 2019-2020 research on a previous report (Prevatt 2019) in which water penetration was reported in 15 buildings after Hurricane Irma.

A summary of fenestration industry concerns with the 2020 report for project #PO150337 and its inaccurate assumptions and conclusions include that researchers:

- **Speculated and attributed economic loss from water damage encountered in 7 of 15 buildings examined to fenestration products, without providing forensic data or conducting a root cause analysis to determine the source of water penetration. The data provided was unverified, and from a single source.**
    - Without in-depth forensics and root cause analysis, it is not feasible to speculate on water penetration sources or solutions to mitigate water penetration.
- **Failed to examine buildings that performed well** to understand best practices, in addition to those that reported water penetration following Hurricane Irma.
- **Failed to deliver on numerous aspects of the original scope** approved and funded by the Florida Building Commission, which included a whole building envelope approach, not a focus on only one building component.
- **Arbitrarily and significantly changed the project's scope** without the AG's knowledge or informing the HRAC, the Structural Technical Advisory Committee (TAC) or the Commission.
- **Failed to discuss or to reach consensus with the Advisory Group** on many conclusions in the report by eliminating the required charette.
- **Failed to properly understand fenestration test specifications, procedures, NAFS Performance Classes and Performance Grades,** despite the industry's repeated attempts to educate researchers.
- **Overlooked and minimized the fact that high-performing AW fenestration products have existed since 1993 and perform well in mid- to high-rise building envelopes.** See **Appendix 5** for details on Performance Grades and Performance Classes.
- **Failed to recognize that performance criteria for water penetration has not been established** for tropical storms and hurricanes.
- **Jumped to a conclusion that their research project to create "an idealized fenestration specification" was needed,** despite the lack of essential data on the true source of water penetration.
- **Failed to understand that consensus has not been reached on what hurricane event criteria should be**, or how it should be defined, measured, or quantified.

Our industry believed this research project would have objectively analyzed mid- to high-rise structures and compared the details of buildings and components that performed during Hurricane Irma to those that did not. The fact is, without solid forensic data, it is impossible to determine the source(s) of water penetration resulting from tropical storms or hurricanes.

This industry response includes recommendations for future research for funding consideration by the Florida Building Commission to better understand which building envelopes that have and continue to withstand Florida hurricanes and tropical storms and why they are performing as part of considering future water management options. These recommendations are provided by the fenestration industry in **Appendix 7.**

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Key concerns with the researchers' project and report

1. The U of F report attributes reported leakage resulting from Hurricane Irma to fenestration products without first performing a root-cause analysis to determine the actual source of the leakage.

- The genesis for this study began in August 2018 when Dan Lavrich, a member of the Florida Structural Technical Advisory Committee (TAC), shared reports of water penetration in mid- to-high-rise buildings with the Structural TAC, based on post-storm damage assessments he reportedly conducted as a consultant for an undisclosed client(s) after Hurricane Irma on 15 buildings in Southeast Florida.
- Mr. Lavrich said these buildings experienced water damage because of the storm, and attributed leakage to fenestration products installed in the buildings.
- However, no forensic analysis or any other data was provided to substantiate this claim. The limited data he provided is summarized in a report presented to the Structural TAC in June 2019 (Prevatt 2019.)
- Mr. Lavrich asked the Structural TAC to authorize research into the water penetration resistance of fenestration products during tropical storms and hurricanes.

1.1 - About the Fenestration Water Resistance Work Group (WG) which met in 2019

Following Mr. Lavrich's request, the TAC created the Fenestration Water Resistance Work Group (WG.) The scope of work for the Work Group is:

a) Evaluate the Florida Building Code "the Code" requirements relating to design and testing of exterior envelope and fenestration and determine:
   - Whether the Code requirements should be modified to provide better resistance to water intrusion during high wind events, and/or…
   - Whether installation/maintenance of fenestration as well as the installation of the building envelope in general is suspect and should be better defined and more effectively monitored.

b) Formulate a proposed code change language/recommendation for addressing water leakage due to wind-driven rain.

The Water Resistance WG met three times in February, April, and June 2019 before going dormant after failing to reach agreement or to produce any report. During these meetings, it was revealed that in the 15 buildings Mr. Lavrich examined, water penetration was attributed to the fenestration products based solely on occupant interviews and his own walk-throughs conducted after Hurricane Irma. **No forensic data was provided to indicate the actual source of water penetration.** Nor were the manufacturers of fenestration products contacted to assess any reported concerns or determine if leakage through their products actually occurred. Note that fenestration industry representatives provided verbal comments to the WG which indicated that the type of products (primarily compression sealed products versus sliding or gliding products which present more challenges in managing water penetration) and the higher ratings of the products installed in mid- to high-rise structures performed well during Hurricane Irma.

1.2 - 2019 Florida Water Resistance Work Group produced no conclusions, no report

- **This lack of objective forensic data substantiating the actual source of reported water penetration in the buildings in question halted the work of the Fenestration Water Resistance WG.**
  - The WG produced no final conclusions, nor was any report issued.
  - Without forensic data, it is impossible to determine the origin of water penetration into mid- to high-rise buildings in Florida coastal areas, to evaluate buildings that performed versus those that did not prior to proposing options on how to prevent it in the future. While leakage through the fenestration product is a possibility, other potential sources also need to be considered and evaluated, including fenestration installation joints, exterior wall cladding, penetrations in the building envelope for

utilities, balconies, and expansion joints, installation of any aftermarket products like storm shutters, and the roof.

- **1.3 - How the mid- to high rise building envelope wind-driven rain research project began**

- Citing this lack of forensic data, the Florida Department of Building and Professional Regulation (DBPR) staff recommended to the Structural TAC that the Engineering School of Sustainable Infrastructure and Environment (ESSIE) group at the University of Florida conduct a "feasibility study" to determine if objective data could be obtained that would allow the WG to move forward with their assigned task.
- In November 2019, Acting Florida Building Commission Chair and current Structural TAC Chair James Schock requested research employ a whole-building envelope approach, to be funded by the Commission and conducted by the University of Florida.
- Based on the research scope approved in November 2019, the public was led to believe the project's focus was on a whole-building envelope approach to better understand the attributes of buildings that performed well and withstood Hurricane Irma, as well as those with reported water penetration. After an initial research proposal submitted by Dr. Prevatt garnered substantial objections, including those from the fenestration industry, DBPR staff worked with Dr. Prevatt to create the research scope that was approved by the Structural TAC in November 2019.
- Unfortunately, as pointed out repeatedly, this proposal completely ignored the fundamental need for objective forensic data to determine a root cause analysis of water penetration into mid- to high-rise buildings by wind-driven rain. Instead, it focused on creating the researchers' desire for a specification of an idealized fenestration product that can withstand a Category 3-5 hurricane with no water penetration, resist impact from wind-borne debris without experiencing glass or frame damage, and perform at 100 percent of its rated performance in post-storm conditions.
- This specification for an idealized fenestration system deliberately ignores the costs of manufacturing and installation, instead focusing on what would be possible if, "we could wave a magic wand." Further, it ignores that fenestration manufacturers have provided comments that products did perform during Hurricane Irma.

1.4 - The research team's focus on creating an idealized fenestration specification or system while ignoring the need for foundational forensic testing is flawed for several reasons.

- Without first correctly identifying the source of the reported water penetration, it is impossible to determine which specific areas of the building envelope, including the fenestration, failed during the storm, why they failed, and how they can be improved.
- It also ignores the fact that proper installation and ongoing maintenance are essential to the building envelope, including fenestration product performance. Many issues that lead to water penetration through building envelope components can be triggered by improper installation and/or maintenance.
- It is also impossible to determine the source of water penetration simply by performing post-storm walk-throughs of affected buildings. Water entering a wall runs downhill until it reaches an exit point. Often this exit point is the rough opening containing a fenestration product. Fenestration products are engineered to mitigate water coming from the exterior.
- Water that has already breached the water management plane cannot be mitigated by the fenestration product, and often presents as a "leak" at the opening. This is not a leak in fenestration, but instead, is water that is bypassing the fenestration product's water management system as designed.
- Without properly conducting a thorough forensics analysis, these "leaks" may mistakenly be attributed to the fenestration product, when in fact, the leak stemmed from other causes/sources.
- Products may have been exposed to and potentially affected by numerous storms over their lifetime, and in some cases, structural damage may not be readily visible, without field testing or even disassembling the product(s). This prior damage could result in water pathways that present themselves in subsequent storms. This is yet another reason root cause analysis is required.
- It is also critical to examine buildings that did not report water penetration following Hurricane Irma, to understand the attributes of what enabled them to withstand wind-driven rain. This data can then be

compared/contrasted with the forensic data from buildings that did report water penetration to compare differences and better understand what worked as well as what did not perform.

- **Appendix 1** further describes the research team's failure to use objective data as a basis for their project.

2. Lack of adherence to the scope approved by the Structural TAC, funded by the Florida Building Commission (FBC)

Researchers agreed to the approved scope, yet arbitrarily and unilaterally made significant, fundamental, substantial changes to it without informing the Advisory Group, or Structural TAC.

- **The approved scope mandated a whole-building envelope approach** to more fully understand best practices employed by designers and builders in mitigating water in mid- to high-rise building envelopes, as well as to better understand what may lead to failures.
    - Instead, researchers removed the building envelope focus from the project and solely focused on fenestration.
    - Researchers stated that the change in scope was due to time lost because of the COVID-19 pandemic. However, the project scope was approved in November 2019 — three months before the first AG conference call was held on February 21, 2020.
    - The Advisory Group was assembled before the pandemic, and all meetings had been planned as conference calls. No representatives from the exterior cladding industry or other types of building envelope construction professionals were added to the roster. This sector of the building construction industry would have provided a critically important role and experience to the project.

Researchers failed to deliver on key aspects of the approved scope, including:

- **The approved scope mandated a charrette be held** to create a consensus-based specification "acceptable to condominium owners and code officials as desired performance, as well as to building envelope product manufacturers."
- **No charette was held** to provide an opportunity for the advisory group to propose and refine possible specification options. Researchers cancelled the charette — and the two follow-up meetings planned after it — without discussion with the AG.
- **The final report was not issued by the deadline**, June 19, 2020, to allow ample time for review of the report by others, before the end of the Florida fiscal year.
- Instead, it was haphazardly put together to meet a June 26 meeting where the incomplete and inaccurate report was positioned as the "final report" which the Hurricane Research Advisory Committee (HRAC) and Structural TAC were urged to approve due to the impending end of the FBC's fiscal year.
- **During the June 26 public meeting, no public comments were allowed, which prohibited the public and members of the Advisory Group from expressing concerns with the incomplete and inaccurate research report.**
- Only HRAC or Structural TAC members were able to speak to the report in the June 26 public meeting, shutting out input from Advisory Group members that wanted to express serious concerns with the researchers' approach, failure to achieve the agreed upon approved scope, conclusions based on opinion rather than data or fact, and overall lack of accuracy.

- **Fenestration industry representatives provided information to assist the researchers and the entire advisory group verbally during the five conference calls**, and through email to help everyone gain a better understanding of the role of fenestration products in the building envelope. However, much of the information industry representatives attempted to share with the research team — including comments on inaccuracies and unsubstantiated opinions represented as fact in the research paper and its conclusions — were not included in the final report.
- **Much of the final report was never shared with the Advisory Group before it went public.** The same scenario occurred before the July 28 joint HRAC and Structural TAC meeting. A 27-page draft was shared with the AG members for review and comment on July 21 with the mandate that all comments

must be received by researchers in 24 hours. The fenestration industry responded with over 80 comments by the deadline. The final report then ballooned to 79 pages before being presented to the HRAC and Structural TAC on July 28, with the bulk of that information never shared, discussed with, or agreed to by the Advisory Group.

- **Ideas generated in brainstorming discussion in the five Advisory Group meetings were not rated, ranked, prioritized, or agreed upon by the AG.** The report misleads in stating conclusions, as none were reached by the Advisory Group.

3. Lack of understanding by the project's research team on the proper use of fenestration testing specifications.

- **Researchers assumed that conditions experienced during laboratory water penetration testing are equivalent to the conditions generated during a hurricane. This is not the case.**
    - The research team assumed that testing per ASTM E331 or E547 in the laboratory or ASTM E1105 in the field recreates the actual conditions encountered in a tropical storm or a hurricane. This simply is not true.
    - **Appendix 2** details why this assumption is flawed.
- To inform the research and project team, fenestration representatives provided facts on industry testing specifications, and product performance types and grades. They also communicated the importance of proper building envelope design, as well as the need for proper installation and maintenance of products to help protect Floridians and structures from the elements.
- They also shared details on their years of direct experience with product performance in Florida, including actual forensic investigative experience with buildings and products that have withstood hurricanes and other high-wind conditions.
- Much of the report focused on what researchers described as the creation of a "100 percent leakproof" or "bulletproof" fenestration product that could weather a hurricane without a drop of water penetrating the interior of the home or structure without defining what "leakproof" actually means.
    - Before an aspirational "leakproof" fenestration product could ever be considered, it is first necessary to define and agree upon what constitutes water penetration. That necessary foundation was never completed in this project.
    - **Appendix 3** details the definition of water penetration from the ASTM test standards used for evaluating fenestration products.

4. Guide to the Appendices in this report

- **Appendix 1** details issues with the original data set and information used as the basis for the 2019-2020 research project.
- **Appendix 2** details the differences between conditions created during laboratory testing and conditions experienced during a tropical storm or a hurricane.
- **Appendix 3** details the industry-accepted definition of water penetration through fenestration products.
- **Appendix 4** details the key differences between curtain wall/storefronts and fenestration intended for use in punched openings.
- **Appendix 5** explains different Performance Classes used by the North American Fenestration Specification (NAFS) to rate products for air, water, and structural performance.
- **Appendix 6** explains the role of impact-resistant products as a last line of defense from windborne debris, and not to "hurricane proof" a building.
- **Appendix 7** contains a proposal for further research that could allow the Fenestration Water Resistance Work Group to complete their work.

Closing Summary - Fenestration industry committed to serving Floridians' needs

Windows, doors, and skylights are some of the few building materials seen and enjoyed from both inside and outside the home or commercial building. They play a vital role in helping protect the building and its occupants from the elements, as well as allowing fresh air in or out for ventilation and to provide a means for egress or ingress in the case of operable windows and doors. They are among the most regulated components of the building envelope.

The hundreds of member companies of the collective memberships of the Fenestration and Glazing Industry Alliance (FGIA), Fenestration Manufacturers Association (FMA), and Window and Door Manufacturers Association (WDMA) manufacture millions of products each year in Florida and used in Florida. Our industries provide thousands of jobs for Floridians. We care about the performance of structures in Florida, because many of us and our team members live, work, and raise families in Florida.

Our members provide solutions to meet the needs of residential and commercial structures, building owners and occupants in Florida. Millions of fenestration products have been installed in Florida and perform well.

We are committed to serving our customers and prospective customers well in Florida. We are also dedicated to partnering with architects, builders, contractors, installers and property owners to help them specify the right fenestration products for given applications, as well as how to help them understand how to install and maintain them properly for best performance.

In the spirit of collaboration, the fenestration industry has included future potential research needs for funding consideration by the Florida Building Commission as part of the Appendix.

As innovators, our members are dedicated to continuous improvement and sound data-driven approaches to objective research. We look forward to continuing to partner with the Florida Building Commission, the Hurricane Research Advisory Committee (HRAC), Structural TAC and DBPR staff so we can all better understand what is now working and where there are opportunities for future improvement. That includes our research proposal included in this report to truly take a whole-building envelope approach to root cause analysis backed by sound building science, actual forensics, and representative data.

Sincerely,

Fenestration Industry Mid- to-High Rise Building Envelope Wind-Driven Rain Research Advisory Group members representing the:

- Fenestration and Glazing Industry Alliance (FGIA) previously known as AAMA
- Fenestration Manufacturers Association (FMA)
- Window and Door Manufacturers Association (WDMA)

References

- Lopez, C. R. (2011) *Measurement, Analysis, and Simulation of Wind Driven Rain*. A Dissertation Presented to the Graduate School of The University of Florida
- Prevatt, D.O., Smith, D.J., Louis, M.J. (2020). *Wind-Driven Rain Tests of Building Envelope Systems up to Hurricane-Strength Wind-Driven Rain Intensity*. Florida Building Commission Project # PO150337
- Prevatt, D.O., Pinelli, J. P. (2019) *Water Resistance Performance of Exterior Building Envelope and Fenestration During Minimally High Wind Events in Hurricane Irma*. Florida Building Commission Project #PO108029
- AAMA/WDMA/CSA 101/I.S.2/ A440, North American Fenestration Standard/Specifications for Windows, Doors and Skylights
- ASTM E331-00 (2016), Test Method for Water Penetration of Exterior Windows, Skylights, Doors and Curtain Walls by Uniform Static Air Pressure Difference
- ASTM E547-00 (2016), Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference

Appendix

Appendix 1 – Issues with the 2019 report referenced by the 2020 research

In June 2019, the report, "*Water Resistance Performance of Exterior Building Envelope and Fenestration During Minimally High Wind Events in Hurricane Irma"* was issued (Prevatt 2019.) This report is referenced in the final report that is the subject of this response, and part of it is devoted to a study of the "data" on the water damaged buildings resulting from Hurricane Irma that were the genesis of Dan Lavrich's request for research to the Structural TAC in 2018. The report has several issues. It shows that the current study was built on a questionable foundation, and that the researchers ignored some key conclusions.

In the report, it was claimed that 15 buildings examined after Hurricane Irma experienced economic losses due to water damage. However, the only data provided on these buildings was construction data, number of apartment/condo units, number of stories, Zip Code, and directional orientation of the front face of the building. No other data was shared with the research team, including critical information on the fenestration products and surrounding building envelope. It's also important to note that about 1,100 mid-rise and high-rise buildings were in the path of Hurricane Irma. Due to the small sample size — which was not randomized — it makes it more challenging to glean meaningful information on the root cause of water penetration in buildings from such a small, statistically insignificant sample size of limited data (15 of 1,100 buildings.)

Additionally, the report makes it unclear if all 15 buildings experienced economic losses due to water penetration. Table 3 of the report only shows losses for 7 out of the 15 buildings, implying that 8 of the buildings did not experience water damage. If the buildings experienced water damage, why wasn't the dollar amount of the claim included in the report? If buildings examined didn't experience water damage, why were they included in the report at all? This chart creates more (and important) questions instead of providing answers.

Further, in Section 4.5, the report references promotional videos on the website of a building envelope consulting firm, GCI Consultants (https://www.gciconsultants.com/videos). In these videos, the president of the firm, Paul Beers, hypothesizes on the source of reported water penetration resulting from Hurricane Irma.

These hypotheses include:

- Pre-existing defects in the building envelope that were exacerbated by the storm. This could have resulted from a combination of factors including but not limited to design flaws, faulty installation, lack of maintenance, and/or damage accrued from previous storms.
- Conditions created by the storm exceeded the ratings of fenestration products.
- Fenestrations and/or other components of the building envelope were damaged by the storm. This damage was discreet, resulting in cracks in exterior cladding, compressed weather seals, damage to fenestration products' internal seals, and failed sealant joints in the building envelope.

Mr. Beers also discussed other observations made during his investigations including the presence of an unusual amount of beach sand in the sill cavities of the fenestration systems.

However, **Mr. Beers specifically refrained from making conclusions on the actual source of water penetration,** instead stating, "further testing is needed to determine the source of the leakage." He clearly says the only way to determine the cause of the reportedly unusual amount of leakage experienced during Hurricane Irma, is to conduct a forensic investigation, including water penetration testing, on the fenestration products and to check seals, weather stripping, and framing to determine if and where a failure may have occurred. **The researchers mistakenly characterized these hypotheses as conclusions**.

We're curious why links to videos promoting a business were included in the research report as evidence, especially since they offered no conclusions on the reason(s) for excessive water penetration. In the videos, **Mr. Beers only speculates on what may be occurring and instead emphasizes the need for a true forensic**

investigation. Why then did the research team ignore the need for forensic data to determine the source of water penetration and instead jump to the conclusion that fenestration products were the source?

The type of research mentioned by the GCI videos included in the researcher's report presented July 28 would be helpful to determine the root cause of water penetration and the total context of the building envelope's role in water infiltration. For example, what's the impact of beach sand in fenestration gaskets or in clogged weep holes and how does that impact water penetration?

Also, including a GCI representative on future research project teams would be advisable.
(See **Appendix 7.)**

Appendix 2 – Understanding the difference between laboratory test pressures and actual weather conditions

When a product is tested in the lab, it is exposed to a static differential pressure to simulate actual wind pressure. This pressure is held for 5 minutes on, 1 minute off and repeated for 4 cycles for a total duration of 24 minutes (ASTM E547) or 15 minutes continuously (E331) depending on the standard followed. This uniform, unwavering pressure is used to ensure that water applied to the product will be drawn into all critical joints and seals that need to be wetted to evaluate the product. These water test pressures are lower (15-20 percent of Design Pressure (DP) up 15 pounds per square foot (psf)) than the equivalent peak wind speeds found in a thunderstorm or a hurricane, but the pressures are held for a much longer duration than anything encountered during a thunderstorm or a hurricane.

In addition, the volume of water applied to the product far exceeds the volume of water encountered during a thunderstorm or hurricane. In his U of F dissertation from 2011, Carlos Lopez demonstrated that the wind-driven rain intensity (RWDR) generated during ASTM E331 and E547 testing (RWDR= 509) **exceeds the wind driven rain intensity encountered in a typical Category 3-5 hurricane (RWDR= 95) by more than a factor of 5**. If the equivalent amount of water applied to a fenestration product during one of these tests were released by an actual rainstorm it would be a Biblical event.

These key differences account for two things:
1) Why it is incorrect to directly compare the laboratory water test pressure to the wind pressures encountered during a thunderstorm or hurricane, and more importantly…
2) Why a product tested at a lower water test pressure than what is encountered during a hurricane can perform well and remain leak-free if properly specified, properly installed, and properly maintained.

Appendix 3 – Understanding water penetration

It is common for building leaks to result from improper installation of any number of components in the building envelope, as the AG agreed during their meetings, citing the importance of proper installation as a key factor in building envelope performance.

Fenestration representatives informed the AG on how water penetration is defined in fenestration product testing.

According to well-established and consensus-based performance standards, water leakage is described in 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.* ASTM E331, E547 also have the same definition of water penetration.

The ASTM E1105 reference follows:

- **3.2.3 *water penetration, n***- the penetration of water beyond the plane parallel to the glazing (the vertical plane) intersecting the inner most projection of the test specimen, not including interior trim and

hardware, under specified conditions of air pressure differences across the specimen. For products with non-planer surfaces (domes, vaults, pyramids, etc.) the plane.

- **10.2** - Unless otherwise specified, failure criteria of this test method shall be defined as water penetration in accordance with 3.2.3. Failure also occurs whenever water penetrates through the perimeter frame of the test specimen. Water contained within drained flashing, gutters, and sills is not considered failure.

If the design of a window or a door redirects water to the exterior, water is not penetrating the product. If water moves through the fenestration product and pools on a horizontal member, this is not water penetration since it is not causing damage to unprotected interior surfaces.

The fenestration industry shared these facts several times in Advisory Group meetings. We also offered to provide additional information that explained how water penetration is defined to consumers, property owners, project managers, building envelope engineers, and academia to note what should be included in the research. However, the research team never acted on our offer.

Understanding fenestration water penetration testing requirements including NAFS

The fenestration industry also offered to explain water penetration testing requirements criteria covered by the current AAMA/WDMA/CSA 100/I.S.2/A440 (North American Fenestration Standard (NAFS)) standard and how NAFS is used to specify which product Performance Class is best-suited to a given application.

Accurately understanding current industry specifications, testing procedures and product quality assurance testing is fundamental to understanding what fenestration products are designed and tested to do in terms of their performance.

- **Different code requirements in the Florida Building Code and I-Codes apply to different types of fenestration products.**
- **The Florida Building Code allows products to be rated to Florida TAS requirements. NAFS is not a requirement for all fenestration product ratings for use in Florida.**

Appendix 4 - Understanding the difference between storefront, curtain walls and other fenestration products

Throughout the research paper, authors frequently intermingled the terms and requirements for storefront, and curtain walls. Some curtain walls and storefronts are now factory-built, others may be assembled on the job site. Many curtain walls can be factory-built and taken to the job site for installation to stack single-story units together.

This demonstrated the researchers' lack of understanding of industry product types, terminology and most importantly which products are designed for which construction applications and conditions**.**

It is important to understand the significant differences between these three products: storefronts, curtain walls and fenestration products that are factory-built for punched building openings. This includes a correct understanding of how they are used in the building envelope system and how they are manufactured.

Despite the fenestration industry's numerous offers to help educate the research team on these fundamental and important differences, they failed to truly comprehend the differences in these products, and the codes and standards guiding their specification, testing, installation use and maintenance.

These products are defined as:

- **Curtain Walls:** A non-loading bearing exterior wall cladding that is hung to the exterior of the building, usually spanning from one floor to another. Curtain wall vertical framing members run past the face of floor slabs, and provisions for anchorage are typically made at the vertical framing

members only. In contrast to combination assemblies and composite units, non-residential curtain wall systems often need to meet additional performance requirements for inter-story differential movement, seismic drift, dynamic water infiltration, etc. Operating vents and entrance doors are provided as separate inserts.

- **Storefronts:** Storefront systems are typically designed to accommodate field fabrication and glazing and employ exterior glazing stops at one side only. Storefront employs shallow rectilinear framing profiles (approximately 150 mm [6 inches] or less), which are often made available in "stock lengths." Vertical framing members run between the top of the floor slab and structure above, with provision for anchorage at all perimeter conditions. Operating vents and entrance doors are provided as separate inserts. Storefronts are not to be confused with curtain walls or other fenestration products.

Fenestration products designed for use in punched openings must meet NAFS, as detailed in the building code.

- Windows, doors, and skylights are individually framed units manufactured in a factory and shipped to the jobsite for installation into a prepared rough opening, often referred to as a punched opening. These units are typically not assembled in the field in the same manner as a storefront or curtain wall, although some products can be mulled (joined) together.

There are huge differences between storefronts, curtain walls and other fenestration products.

Because of these inherent differences, building codes look at each of these products and base the specification for their respective use on a number of factors, including from how they are to be installed to the specific design loads they must meet.

Most are tested to either NAFS or TAS for use in Florida. From a water testing performance pressure requirements standpoint, the two are similar, especially for Architectural Window (AW) products.

It is important and essential to understand that today's performance standards and codes do not include requirements for building envelope systems and their components to be "leakproof" during hurricane events.

"Leakproof" is an unrealistic term and can be put in the same category as "bulletproof", "bombproof," or "hurricane-proof." It sets false expectations because it simply is not attainable in terms of building design or product performance. Products may help improve the resistance of a product to certain events, but they are described and rated as impact-resistant, rather than hurricane-proof. That's because they help improve the resistance of a product to a given condition, but they do not claim to absolutely protect against extreme conditions like bombings, hurricanes, etc.

In high-wind events like hurricanes, many factors can contribute to the ingress of water during a storm. For example, improper product specification selecting a product not rated to the code required design pressure for the building height and location, improper building envelope design, poor installation, and lack of maintenance on any number of building components can lead to water penetration.

Appendix 5 - Understanding NAFS, Performance Classes and Performance Grades (PG)

Understanding the different fenestration product Performance Classes and Performance Grades (PG)

- In the pursuit of a specification for an idealized fenestration product, **the research team ignored Performance Classes that are already detailed in the North American Fenestration Specification (NAFS). NAFS is referenced in the current and previous editions of the Florida Building Code as the means to determine the product's design pressure rating.**

- A window, is not just a window. There are many types of windows designed to meet different needs and different performance ratings.
- The four Performance Classes increase in rigor as they progress from R to LC to CW to AW.
- **CW and AW Performance Classes are intended for use in mid-rise and high-rise buildings that will experience heavy use or extreme wind loads.**

The standard formerly known as AAMA/WDMA/CSA 101, I.S.2/A440 is now described as the North American Fenestration Standard, or "NAFS" for short. This standard is established primarily for factory-built fixed and operating fenestration units. Storefront, curtain wall and commercial entrances are covered by other standards and are specifically excluded from this standard.

Some commonly installed NAFS product types and product designations are:

Double & Single Hung	**H**
Horizontal Sliding	**HS**
Casement	**C**
Awning / Hopper / Projected	**AP**
Sliding Door	**SD**
Architectural Terrace Door (side hinged)	**ATD**
Fixed Window	**FW**
Dual-Action Window	**DAW**

The **Performance Class** is established by bundling the five primary performance requirements:

1) Structural strength (expressed through design pressure — for example, wind, dead loads, and any other anticipated loads)
2) Water penetration resistance
3) Air leakage
4) Operating force (where appropriate)
5) Forced-entry resistance (where appropriate).

Bundles fall into four Performance Classes, with progressively more stringent performance levels.

These descriptions represent a general guide to help determine which fenestration Performance Class is likely best suited for a given application:

a) **R —** commonly used in one- and two-family dwellings.
b) **LC —** commonly used in low-rise and mid-rise multi-family dwellings and other buildings where larger sizes and higher loading requirements are expected.
c) **CW —** commonly used in low-rise and mid-rise buildings where larger sizes, higher loading requirements, limits on deflection, and heavy use are expected.
d) **AW —** commonly used in mid-rise and high-rise buildings to meet increased loading requirements and limits on deflection, and in buildings where frequent and extreme use of fenestration products is expected.

Although general suggestions for use are specified in items (a) to (d) (listed above) **product selection, including the proper Performance Class and Performance Grade, should be based on the performance requirements of the project** and not solely on these suggestions.

As desired, people may specify a higher Performance Grade of fenestration product to exceed what applicable local building codes may require. The higher the Performance Grade or "PG" rating of the product, the higher the water testing the product has met.

Nothing prevents someone from installing a higher performance grade fenestration product than building codes require. Fenestration manufacturers offer many product options which exceed building codes.

In moving from R to LC to CW to AW, the required test size increases.

The **Performance Grade** is expressed with PG in front of the design pressure as shown below. All other minimum requirements are tied to the design pressure. Examples below illustrate the NAFS designation for Hung Windows, and an example showing minimum requirements for each Performance Class.

Minimum Requirements
For Hung Windows

Class	Size	Design Pressure	Water	Air Leakeage	Life Cycle
R	40"x 63"	15 psf	2.9 psf	0.3 cfm/ft² @ 25 mph	NO
LC	44"x 75"	25 psf	3.8 psf	0.3 cfm/ft² @ 25 mph	NO
CW	56"x 91"	30 psf	4.5 psf	0.3 cfm/ft² @ 25 mph	NO
AW	60"x 99"	40 psf	8.0 psf	0.3 cfm/ft² @ 50 mph	YES

AW products must comply with AAMA 910 – Life Cycle Testing. R, LC, and CW do not have to comply with AAMA 910. The intent of AAMA 910 is to simulate — through actual performance — 7 years of everyday use. Testing includes:

- 4,000 Operating Cycles of open, close, lock, unlock
- Three thermal cycles from minus 20 degrees to plus 180 degrees
- Misuse test repeated 5 times – excessive force and 100 pounds applied to rack out of square
- After all other testing (above), repeat air, water, and structural tests.

Advantages of specifying AW fenestration products

- **Water testing before and after structural testing** – helps guarantee long-term performance.
- Adds Cycling and Abuse Standards.
- Reduces risk, follows highest industry standard.
- Provides best product for Institutional Projects.
- Recommended in Wind-Borne Debris Regions based on higher water performance levels.

NAFS applies to both operating (opening) and fixed, (products that are fixed in place and do not open) new construction and replacement windows, doors, secondary storm products like storm windows and storm doors (SSPs), tubular daylighting devices (TDDs), roof windows, and unit skylights installed into exterior building envelopes. NAFS establishes material-neutral, minimum, and optional performance requirements for these products.

NAFS establishes criteria for the determination of Performance Class, Performance Grade (PG), and for air leakage, water penetration resistance, and structural performance and other related performance tests for fenestration products.

Performance Class ratings should be viewed as an indication of the level of performance, with the least stringent requirements for the R Performance Class and the most stringent for the AW Performance Class.

Appendix 6 – Understanding the role of impact-resistant products

The research paper mentions homeowner misconceptions with "hurricane-proof" windows. To be clear, **hurricane-proof products do not exist.** Nor do any hurricane-proof performance standards exist because windows contain glass — and glass breaks on impact at a certain point — even with high-performance laminated glass options.

While building codes refer to them as impact-resistant, a consumer may incorrectly construe that as a "hurricane-proof" product. In reality, it is an impact-resistant product — and not a hurricane-proof or hurricane-resistant product. **Impact-resistant products are not designed to be hurricane-proof.**

It's important to understand what impact-resistant products are and are not designed and tested to do.

- In the late 1990s, Florida building codes initiated the requirement for "opening protection" by either an impact-resistant rated window or door, or the installation of an impact-resistant shutter as a means of keeping the building envelope intact as much as possible.
- In a real-world event, impact-resistant glazed products struck by windborne debris may break and require replacement. This is not because the product has failed.
- Instead, it is because **the impact-resistant product is designed to absorb the impact and prevent a breach of the building envelope.**
- Their function is similar to an airbag in a vehicle. In an accident, airbags are deployed to help reduce impact, as a last resort. Impact-resistant products and airbags help reduce the impact from a catastrophic event, but they are not designed to be reused, due to the significant impact caused by the catastrophic impact.

In hurricane-prone regions, codes require installation of impact-resistant exterior windows and doors in buildings to help protect against wind-borne debris from shattering and penetrating non-impact-resistant glass, or to provide impact-resistant shutters or covers over non-impact-resistant windows and doors. Impact-resistant products significantly reduce the potential for catastrophic failure of the building during high-wind events like tropical storms and hurricanes where debris can become missile-like projectiles that can create extensive damage.

Prior to the implementation of impact-resistant requirements for exterior windows and doors, when glass shattered in the window or the door, it often left large unprotected openings that allowed the pressure in buildings to compromise the structural integrity of the roof and walls, often leading to partial or full structural collapse of the roof and walls.

Impact testing requirements for ASTM E1886 and E1996, and TAS 201/203 established a series of criteria for exterior glazed products like windows, doors, curtain walls and storefronts to use laminated glazing that could reduce damage to the building by protecting the opening.

The goal of the impact-resistant performance standard is to prevent the opening from being breached by retaining glazing in the opening after subjecting it to a series of missile tests, and running the product through a cycle test of positive and negative pressures to simulate hurricane conditions. At the conclusion of the test, the glazed product must remain intact in the window frame and not have damage that would allow a three-inch sphere to pass through or a tear greater than five inches in length.

It is not surprising that homeowners or others in the public may not be aware of this and the fact that at the conclusion of the test, the damaged window is not useable and would not prevent water to pass through it. Provided the window remains in place, without a hole or tear that exceeds the fail criteria, by industry standards it is not a fail, because it helps protect the building envelope.

Appendix 7 – Proposed future research for Florida Building Commission funding consideration

The fenestration industry supports objective research that allows the Florida Building Commission to make data-driven decisions that will benefit the residents of Florida. The Florida Fenestration Work Group was formed to aid the Commission in making these decisions.

The scope of work for the Work Group is:

- Evaluate the Florida Building Code "the Code" requirements relating to design and testing of exterior envelope and fenestration and determine:
    - Whether the Code requirements should be modified to provide better resistance to water intrusion during high wind events, and/or…
    - Whether installation/maintenance of fenestration as well as the installation of the building envelope in general is suspect and should be better defined and more effectively monitored.
- Formulate a proposed code change language/recommendation for addressing water leakage due to wind-driven rain.

To help fulfill this Work Group's scope, the fenestration industry proposes a two-step research project.

Part one: post-storm survey and analysis of building envelope systems

After the next major storm, researchers would physically survey mid-rise and high-rise buildings in the path of the storm.

Buildings will be classified in two primary categories:

- Buildings with reported water penetration during the storm.
- Buildings without reported water penetration during the storm.

Surveying buildings from both categories close to each other would be ideal for this study since they likely would experience the same storm conditions.

The construction/makeup of the building envelope of these buildings will then be analyzed and documented using investigative methods in AAMA 511 and ASTM E2128.

Features of the analysis should include:

- **Architectural and Structural Drawings**
    - Acquire architectural drawings that show how each building envelope component was intended to be constructed and fastened, including — at a minimum — a dimensioned installation drawing of the fenestration product(s) and associated flashings.
- **Product Specifications**
    - Obtain a copy of fenestration specifications and surrounding condition specifications.
    - Verify that the fenestration products installed were rated to meet or exceed the design pressure requirements of the building.
- **Test and Inspection Reports**
    - Obtain and review any prior test, investigative or inspection reports (for example, AAMA 502 and AAMA 503.)
- **Fenestration Assembly Shop Drawings**
    - Obtain a copy of elevation drawings, dimensioned sections, profiles, and material descriptions/properties of fenestration assemblies.

- **Interview Building Staff**
    - Interview knowledgeable personnel (i.e. anyone with credible information relating to the project performance) to obtain an account of the reported leaks, including the location, durations, time of leak with respect to precipitation events, start and stop times, and volume of each leak, any photos and/or security video which may be available from during storm conditions, etc. Additionally, acquire information about the direction and magnitude of the wind during leak events and the repair history of the interior and exterior wall components (including fenestration products) at, and adjacent to, all leak locations during this interview. The number of occurrences of water penetration over a specific time period is critical information that will determine the test pressures used in this guideline.
- **Interior and Exterior Observations**
    - Perform detailed observations of interior and exterior wall surfaces at, and adjacent to leak locations. Staining on building surfaces may be indicators of areas for further investigation. Certain construction details (i.e. expansion joint, flashing/coping joints, penetration of the building envelope) are areas which shall be considered in the forensic investigation.
    - *For buildings that had reported water penetration*, the collection of data during this phase shall include the identification of workmanship deficiencies and ascertain whether or not the architectural, structural and fenestration product shop drawings match the as-built conditions. If these drawings do not match the as-built conditions, alterations (which may be destructive) to the material surrounding the product or installation being evaluated are most likely needed to create accurate drawings of the installed assemblies, and to understand the performance characteristics of the wall system.
    - Additionally, it is necessary to collect information about environmental exposures (elevation, orientation, adjacent structures, awnings, etc.) of all specimens scheduled for testing. This information, in conjunction with climatic data and information about leak history, will enable the forensic investigator(s) to calculate approximate wind pressures during the reported water penetration.

After data collection is completed, the features of the building envelopes should be compared and contrasted to identify any emerging trends. This analysis will identify features of the envelope that performed well, features that did not perform, and features that require further investigation.

Part Two: Forensic Testing

The second stage of the project will involve testing using the investigative techniques found in AAMA 511. Ideally, this testing will be performed on buildings where water leakage identified in part one of this study was reported. This will require the cooperation of the building owners/managers and may be disruptive to occupants.

- If it is not possible to conduct testing on occupied buildings, then a series of mockups could be created to replicate building envelopes that reported water penetration.
- Testing should focus on features of the building envelope identified in part one that require further investigation and identifying the actual source of water penetration.
- Results of this study could be submitted to the Florida Fenestration Water Resistance Work Group to help them fulfill their mandated scope. Study results could also be submitted to the Florida Hurricane Research Advisory Committee (HRAC) to help fulfill their role as well.