Final Report for Project Entitled:

Reviewing the Standards for Wind-Driven Rain ~~(WDR)~~ Intrusion through Tracks of Sliding Glass ~~Door~~Doors Systems during Hurricanes

Revised and updated November ~~6th~~8th, 2024

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Presented to,

Florida Building Commission
State of Florida Department of Business and Professional Regulation
By

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Executive Summary:

Pursuant to Section 32 of HB ~~10 21~~1021 – 2024, the Florida Building Commission ~~(FBC)~~ has been tasked with performing a study on standards related to the prevention of water intrusion through the tracks of sliding glass doors~~,~~ (SGDs), including the consideration of devices designed to further prevent such water intrusion. By December 1, 2024, the Florida Building Commission is required to provide a written report of its recommendations to the Governor, the President of the Senate, the Speaker of the House of Representatives, and the chairs of the legislative appropriations committees and appropriate substantive committees with jurisdiction over chapter 718, Florida Statutes ~~(Senate and Florida Governor Ron DeSantis 2024).~~ .

Past hurricanes have shown that water intrusion can cause minor to severe interior content damage and property loss which led to this request. This report provides a literature review study on standards pertaining to the prevention of water intrusion through the tracks of ~~sliding glass doors (~~SGDs~~),~~, including the consideration of mitigation devices designed to further prevent such water intrusion. This report examines current water testing standards as referenced by the 8th Edition (2023) Florida Building Code, Residential and Building ~~Codes~~ and the High-Velocity Hurricane Zone (HVHZ), as well as a review of Federal Emergency Management Agency (FEMA) reports from the observations from past hurricanes.

A Research Technical Advisory Group (TAC) was formed to help in the review of current water testing standards referenced in the current Florida building ~~codes~~code. The meetings spanned 1.5 months, with the group meeting five times scheduled for one hour each. The TAC also considered mitigation devices that can be installed on ~~sliding glass doors~~SGDs to further reduce water intrusion.

The literature review includes recent ~~SGD~~SGDs wind-rainfall intrusion testing standards, academic reports and papers based on experimental testing, and impact reports from previous hurricanes, such as the FEMA Mitigation Assessment Team (MAT) reports on Hurricane Michael (P-2077 2020) and Hurricane Ian (FEMA P-2342 2023). The literature review was supported by recommendations from the Technical Advisory Committee (TAC). The FEMA MAT reports reflect high-level visual observations made after storms for which damage reports of structures are not backed by actual forensics data leading to detailed root causes.

There were not any forensic studies available for WDR through the track of SGDs. Therefore, FEMA MAT reports from Hurricane Michael and Hurricane Ian were used for the literature review. The FEMA MAT reports are based on surveys and visual observation that might lack detailed forensic analysis, however, they explicitly stated that testing standards for door and window assemblies do not appear to adequately help prevent water infiltration and that current testing standards will need adjustment. Experimental testing for a number of SGD samples was conducted at Florida International University (FIU) and the University of Florida (~~U of F~~UF). The analysis results from these tests suggested that further research into wind and ~~wind-driven rain~~WDR conditions and how those conditions may impact the building envelope may be warranted. The main findings of this literature review are that mixed-phase flow dynamics (i.e., fluctuating winds with entrained rain precipitation) through SGDs are not properly simulated in existing standardized tests and may not capture how effectively water ~~both~~ infiltrates and drains. Together with wind directionality, these intrusion effects may not be adequately simulated in traditional static-type WDR laboratory tests but could be incorporated to improve future standards. Also, the typical 15% design pressure (DP) protocols listed in TAS 202, and the AAMA standards

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did not adequately assess building envelope rain intrusion, which was much lower than what a ~~sliding glass door~~SGD might face during actual hurricanes, making it insufficient for real-world conditions.

A set of recommendations were proposed based on these findings including improvement to the current standards in terms of wind and rainfall hazard modeling. More field data should be collected to understand the nature of WDR and how field data compare with the testing results from FIU and UF. ~~Then~~Further, holistic testing of WDR impact on SGDs in a state-of-the-art testing facility (e.g., FIU Wall of Wind or the UF facility) is needed to compare the testing results with the collected field data. Modifications to the testing protocol in the industrial testing facilities used for product approvals can then be proposed to have comparable results to the holistic testing approach.

NOMENCLATURE

A

AAMA – American Architectural Manufacturers Association

ASCE – American Society of Civil Engineers

ASD – Allowable Stress Design

ASTM – American Society for Testing and Materials

C

CFM – Cubic Feet per Minute

CEE – Civil and Environmental Engineering

CSA – Canadian Standards Association

D

DBPR – Department of Business and Professional Regulation (Florida)

DP – Differential Static Pressure

F

FBC – Florida Building Commission

FEMA – Federal Emergency Management Agency

FIU – Florida International University

H

HRAC – Hurricane Research Advisory Committee

HWD – Hurricane Wind-Driven (rain)

HVHZ – High-Velocity Hurricane Zone (Broward and Miami-Dade counties).

I

IBC – International Building Code

IBHS – Insurance Institute for Business & Home Safety

IRC – International Residential Code

L

LWD – Lateral Wind-Driven (rain)

M

MAT – Mitigation Assessment Team

N

NAFS – North American Fenestration Standard

NHERI – Natural Hazards Engineering Research Infrastructure

NIST – National Institute of Standards and Technology

NOAA – National Oceanic and Atmospheric Administration

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P

PG – Performance Grade

PSF – Pounds per Square Foot

S

~~**SGD** –~~ **Sliding Glass Door** – SGD

T

TAC – Technical Advisory Committee

TAS – Testing Application Standards

U

UF – University of Florida

W

WDMA – Window & Door Manufacturers Association

~~**WDR** –~~ **Wind-Driven Rain** – WDR

WPC – Water Penetration Criteria

WOW EF – Wall of Wind Experimental Facility at Florida International University (FIU)

WSP – Water Shedding Performance

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1. Introduction

In many kinds of structures, sliding glass doors (SGDs) facilitate access to exterior spaces such as patios, lanais, balconies, and terraces. Since SGDs are placed in a multi-paneled configuration, they may span a large aperture and provide plenty of ventilation and natural light. However, damage to SGDs due to debris impact, poor installation, etc. may allow water intrusion because of breaching a large aperture during a windstorm event. During the literature review, no actual forensic investigative data or information was found as part of the research review from Florida structures that have been exposed to prior hurricanes. Forensics data includes determining the age of the structure, to which version of the FBC it was constructed, if the products obtained Florida Product Approvals that met or exceeded the required ratings for the specific location, if sill risers were installed in structures which include SGDSGDs, if products were installed according to the sliding glass doorSGDs manufacturer's instructions, and if they were properly inspected and maintained. Therefore, the literature review considered the FEMA MAT reports which are based on visual observation and surveys along with experimental wind-driven rainfall (WDR) intrusion testing on SGDs at the WoW Experimental Facility (WoW-EF) at FIU. The review also included a prior research project funded by FBC at the University of Florida's College of Engineering to simulate tropical storms and hurricane conditions through a dynamic water penetration test for fenestration and, while very small in numbers of off-the-shelf units tested due to time and budget constraints, that limited study was will also be reviewed. Both of those FBC-funded research studies are cited in the references section. In addition, prior research was funded by the Florida Building Commission and conducted at the University of Florida's College of Engineering together with Cornell University's Department of Meteorology which analyzed the impact of wind-driven rain on buildings in coastal areasstudied the spatio-temporal variation of the WDR for the entire state of Florida with the goal of developing WDR maps similar to the ASCE 7-22 wind hazard maps.

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1.1 Background:

SGDSGDs may be subject to wind-driven rain (WDR) intrusion. Wind-driven rainWDR intrusion into a structure may cause interior damage, property loss, mold, and mildew. Pursuant to Section 32 of HB 10-211021 – 2024, the FBC has been tasked with performing a literature review on standards to prevent water intrusion through the tracks of SGD, including the possible consideration of aftermarket devices designed to further prevent such water intrusion, including what role the Florida Product Approval system may play in that process. By December 1, 2024, the Florida Building Commission is required to provide a written report of its recommendations to the Governor, the President of the Senate, the Speaker of the House of Representatives, and the chairs of the legislative appropriations committees and appropriate substantive committees with jurisdiction over chapter 718, Florida Statutes~~ (Senate and Florida Governor Ron DeSantis 2024).~~. The FBC, in response to Florida legislation, has requested a study on requirements to help reduce potential water intrusion through the tracks of SGD, including the examination of potential aftermarket or ~~sliding glass door (SGD)~~SGDs manufacturer-provided devices intended to minimize or prevent water intrusion, following Section 32 of HB ~~10 21-2024. (Senate and Florida Governor Ron DeSantis 2024)~~1021-2024.

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1.2 Motivation and Purpose of the Study

This final report provides an overview of the project activities. This includes forming an advisory committee and assessing the performance of SGDs according to standards such as ASTM E331, ASTM E547, AAMA/WDMA/WDMA/CSA101/I.S.2/A440, *North American Fenestration Standard/Specification for windows, doors, and skylights* (NAFS), TAS 202, and the FBC under real-world hurricane conditions. The literature review sought to identify potential gaps and improvements that may better replicate ~~wind-driven rain~~WDR conditions. ~~the~~The adopted testing methodology for SGDs includes exposing the SGDs to certain wind and rainfall intensities for a specific amount of time with a specific testing setting that will be explained in detail in the literature review section. The goal of this review was to improve the adopted testing methodology for SGDs and propose recommendations to improve the standards and enhance the performance of ~~sliding glass door~~SGD systems against WDR.

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1.3 Project Goals

This research aims to study the current standards of testing ~~SGD~~SGDs against ~~wind-driven rain (~~WDR~~)~~ intrusion through the tracks of ~~SGD~~SGDs during storms, analyzing their performance and finding areas for improvement. This includes assessing the performance of SGDs according to standards such as ASTM E331, ASTM E547, AAMA/WDMA/WDMA/CSA101/I.S.2/A440, *North American Fenestration Standard/Specification for windows, doors, and skylights* (NAFS), TAS 202, and the ~~FBC.~~ Florida Building Code.

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The study focuses on determining how existing design and installation standards evaluate WDR intrusion under real-world hurricane circumstances supported by investigating recent experimental studies in large testing facilities. The literature review also included FEMA field reconnaissance studies after extreme hurricanes in Florida. A technical advisory committee (TAC) was formed to guide the research program. The final recommendation will be presented to the Hurricane Research Advisory Committee (HRAC) for the Florida Building Commission.

1.4 Project Tasks

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a. Formation of Technical Advisory Committee (TAC)

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The objective of this task was to form a technical advisory committee (TAC) to guide the research program. TAC members represented diverse groups of practitioners and academics, including representatives from the fenestration, and building component and cladding manufacturing industries, testing laboratories, architectural firms, engineering firms, and code officials.

b. Reviewing Existing Literature and Standards and Reporting Their Applications to WDR Testing for Tracks of ~~Sliding Glass Door~~SGD Systems and Evaluation of Mitigation Methods

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- FIU-CEE and UF-CEE reviewed current testing standards, relevant literature, and reports related to ~~wind-driven rain (~~WDR~~)~~ intrusion seeking forensics about any data available on potential water infiltration through the tracks of SGD.
- FIU-CEE reviewed research studies and test results on WDR experiments performed at the NHERI WOW EF at FIU, as well as other facilities, including the University of Florida NHERI EF.
- FIU-CEE provided a summary of the literature and testing review and outlined the recommendations and conclusions of each research study reviewed.

c. Formulate Recommendations

In collaboration with the TAC and based on the literature review conducted under Item b, FIU-CEE shall develop recommendations regarding the applicability of the existing industry standards in testing WDR intrusion through tracks of SGD and evaluation of the efficiency of mitigation devices and determine whether modifications and/or new protocols are needed for improved testing and evaluation.

d. University Consultants

Florida International University (FIU) - Civil and Environmental Engineering (CEE) will consult with the UF, with Dr. Catarelli serving as a consultant throughout the project's duration. He will provide specific assistance in several critical areas.

The UF consultant will aid in the standards review by leveraging insights from previous testing of ~~SGD~~SGDs conducted at the Powell Family Structures and Materials Laboratory. Additionally, Dr. Catarelli will contribute to the formation of the TAC.

1.~~4~~5 Deliverables

a. An interim report was prepared and delivered no later than September 16th, 2024. The interim report covered progress to date on all tasks. The interim report was formally presented to the ~~FBC'~~FBC Hurricane Research Advisory Committee by the Contractor and the Department's Program Manager on Wed 10/02/2024 1:30 PM - 2:30 PM.

b. The draft final report is planned to be submitted by November 6, 2024, for comments by the FBC's Hurricane Research Advisory Committee (HRAC). The draft final report includes a clear outline of the problem statement, a summary of the literature and standards review, and recommendations regarding testing standards for testing WDR intrusion through tracks of ~~SGD~~SGDs. The final report shall be prepared with revisions to address Hurricane Research Advisory Committee comments and delivered no later than November 15, 2024. In addition, the draft final report and the final report shall be formally presented to the Hurricane Research Advisory Committee at a time agreed to by the Contractor and Department's Program Manager.

2. Literature Review

Hurricanes have historically driven multiple direct and indirect hazards that significantly impact the building envelope and structural systems. One of the most critical hurricane-induced hazards is WDR intrusion, which has adversely affected buildings, particularly in Florida. This research aims to review the current standards for testing SGDs against WDR, reflecting on past incidents while anticipating future challenges. The review will encompass an analysis of SGD test standards.

Initially, the aim was to investigate several key areas: existing standards for testing SGDs, forensic and FEMA MAT reports detailing hurricanes' impacts on these structures, experimental testing outcomes for SGDs, and applicable peer-reviewed publications discussing the effects of ~~wind-driven rain~~WDR on SGD. The TAC initially met on September 12, meeting a total of five times with the fifth meeting concluding October 31. Therefore, the TAC literature review and discussion were limited. Therefore, the TAC literature review was limited to specific ~~SGD~~SGDs testing requirements in NAFS, the specific requirements in TAS 202, and the specific ASTM test methods prescribed by both NAFS and TAS 202.

The review was also extended to study the impact of climate change on wind rainfall intensity parameters. Climate-adjusted ~~wind-driven rain~~WDR maps are critical to identifying the requirements for conditions in Florida. This may help to accurately specify the performance requirements for individual locations and buildings rather than having constant ~~wind-driven rain~~WDR intensity parameters across the entire state. A previous research project was conducted at the University of Florida's College of Engineering, together with Cornell University's Department of Meteorology to study the correlation between wind speed and rainfall intensity (Masters et al. 2022). ~~This study is being extended and funded by the FBC to leverage the creation of wind-driven rain maps for Florida which should inform actual wind and wind-driven rain conditions in Florida, and the product specifications for water testing for those areas.~~

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2.1 Current Laboratory Test Standards for ~~SGD~~SGDs against WDR:

There are multiple laboratory test standards related to water penetration resistance under load through ~~SGD~~SGDs referenced in the currently adopted Florida building ~~codes~~code, including those listed below: **AAMA/WDMA/CSA101/I.S.2/A440-22** – Standard Specification for Windows, Doors, and Unit Skylights (NAFS)

- **ASTM E 331** – 00 (2023) Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference
- **ASTM E 547** – 00 (2016) Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference
- (TESTING APPLICATION STANDARD (TAS) 1994) **TAS 202-94** – Criteria for Testing Impact and Nonimpact Resistant Building Envelope Components Using Uniform Static Air Pressure Loading

Compliance with AAMA/WDMA/CSA 101/I.S.2/A440 or TAS 202 is required for windows and doors, particularly in areas governed by the ~~FBC~~Florida Building Code, which mandates testing and labeling for regulatory compliance. In HVHZ, all windows and doors must undergo and pass TAS 202 testing to ensure they meet stringent performance standards. TAS 202 covers HVHZ water intrusion. TAS 202 evaluates water intrusion performance by applying differential static pressure (DP) tests. The testing sequence for products that are water-evaluated to TAS 202 is as follows:

1. Evaluate the product for air infiltration resistance per ASTM E283.
2. Structurally load test the product to 75% of the positive and negative design pressure rating for a duration of 30 seconds.
3. Structurally load test the product to 100% of the positive and negative design pressure rating for a duration of 30 seconds.
4. After passing uniform static pressure testing described in steps 2 and 3 above, the door assembly receives 5 gallons of water per hour (gph) per square foot of the door area, equating to 8.02 inches of rain per hour. The water intrusion test performed according to TAS 202 must include a static air pressure that is a minimum of 15% of the product's positive design pressure (DP) rating for 15 minutes.
5. Structurally load tested to 150% of the positive and negative design pressure rating for 30 seconds.
6. Lastly, the product is tested for forced entry as applicable.

For example, a product with a Performance Grade (PG) rating of 60 must pass a water penetration resistance test at 9 pounds per square foot (psf), corresponding to 15% of its positive DP rating. The PG rating reflects the product's ability to resist water intrusion, with higher ratings indicating stronger performance. A PG 60 product demonstrates water penetration resistance at four times the pressure of a PG 15 product.

2023 Florida Building Code (FBC, R) and Florida Building Code (FBC, B) 8th Edition: Exterior windows and sliding doors shall be tested by an approved independent laboratory, and bear a label identifying manufacturer, performance characteristics, and approved inspection agency to indicate compliance with AAMA/WDMA/CSA 101/I.S.2/A440 or TAS 202 (HVHZ shall comply with TAS 202 and ASTM E1300 or Section 2404). Exterior side-hinged doors shall be tested and labeled as conforming to AAMA/WDMA/CSA 101/I.S.2/A440 or ANSI/WMA 100 or comply with Section R609.5. Exterior windows and doors shall be labeled with a permanent label, marking, or etching providing traceability to the manufacturer and product. The following shall also be required either on a permanent label or on a temporary supplemental label applied by the manufacturer: information identifying the manufacturer, the product model/series number, positive and negative design pressure rating, product maximum size tested, impact-resistance rating if applicable, Florida product approval number or Miami-Dade product approval number applicable test standard(s), and approved product certification agency, testing laboratory, evaluation entity or Miami-Dade product approval.

NAFS-22 Clause 0.2.5 Water Penetration Testing: NAFS Clauses 6 and 8 outline the minimum water penetration resistance test pressure required to achieve a specific Performance Grade (PG). For Performance Classes R, LC, and CW, the test pressure must be at least 15% of the positive Allowable Stress Design (ASD) pressure associated with the PG. For Performance Class AW, the requirement increases to a minimum of 20% of the positive ASD pressure. Regardless of product type, the water penetration resistance test pressure must never be less than 140 Pa (~2.92 psf) and is capped at 720 Pa (~15.04 psf). However, Clause 6.2.4 allows for exceptions where certain door systems can have water penetration resistance test pressures lower than these standard requirements when accessibility is needed, or overhead protection of the opening is provided.

NAFS-22 Clause 4.6.3.4 for Water Penetration Resistance Test Pressure: The Performance Grade (PG) rating for a product is sometimes limited by the structural performance rather than by water penetration resistance performance. In these cases, this can be indicated using a Secondary Designator on the label indicating that the water penetration exceeds 15% or 20% of DP depending on Product Class (R, LC, CW, AW). Reporting a water penetration resistance test pressure below the PG requirement, down to 0 Pa (0.00 psf) shall be permitted for Limited Water (LW) side-hinged doors, dual-action side-hinged doors, sliding doors, and folding door systems. ASTM E331 is referenced in NAFS-22 for products classified under the AW Performance Grade, which requires a higher level of performance among fenestration products.

ASTM E331: This test method covers the determination of the resistance of exterior windows, curtain walls, skylights, and doors to water penetration when water is applied to the outdoor face and exposed edges simultaneously with a uniform static air pressure at the outdoor face higher than the pressure at the indoor face.

The testing process utilizes specialized equipment, including a test chamber—either an open-sided box or one with a removable panel—where the specimen is installed and sealed. The air system, comprising a blower or compressed air supply, is designed to create the required air-pressure differentials across the specimen. This system must maintain constant airflow at a fixed pressure throughout the test duration to replicate real-world conditions accurately. The test provides critical data that informs product development and helps manufacturers meet stringent building codes and performance expectations for water infiltration resistance.

In addition to the test chamber and air system, the ASTM E331 standard requires specific equipment to ensure accurate measurement and effective water application during testing. One such critical component is the pressure-measuring apparatus, which is essential for determining the pressure difference across the specimen. This device must be calibrated to maintain a tolerance of 62% or 62.5 Pa (approximately 60.01 inches of water column), whichever value is greater. This precision is crucial as it directly influences the reliability of the test results, allowing for a thorough assessment of the water penetration resistance under varying air pressure conditions.

Furthermore, the water spray system is designed to apply water uniformly across the exterior surface of the test specimen. To meet the requirements outlined in the ASTM standard, the system must deliver water at a minimum rate of 3.4 liters per square meter per minute (or 5.0 U.S. gallons per square foot per hour). This uniform distribution is critical for replicating realistic conditions and simulating the impact of heavy rainfall on ~~SGD~~SGDs and other fenestration products during storm events. By maintaining these rigorous testing parameters, manufacturers can ensure that their products comply with industry standards and are capable of withstanding extreme weather conditions, enhancing the safety and durability of structures in hurricane-prone areas.

ASTM E547: The standard outlines a critical method for evaluating the water penetration resistance of exterior windows, curtain walls, skylights, and doors when subjected to cyclic air pressure. This test assesses how effectively these structures can withstand water intrusion when water is applied to the outdoor surface and edges simultaneously, alongside cyclic static air pressure that is higher on the outdoor face compared to the indoor side. ASTM E547 is specifically referenced in NAFS for products rated under R, LC, CW, and AW categories, emphasizing its importance in ensuring the durability and reliability of fenestration systems. Table 1 and Table 2 show the available performance grade (PG) requirements for the different classes of windows and sliding doors.

Table 1 Available performance grade (PG) requirements for class R and LC windows and sliding doors Source of Tables 8.1 and 8.2: AAMA/WDMA/WDMA/CSA 101/I.S.2/A440, North American Fenestration Standard/Specification for windows, doors, and skylights (NAFS), 2022 edition

Performance classes and available performance grades (PG)		ASD Design Pressures (DP)		Structural Test Pressure (STP)		Water Penetration Resistance Test Pressure	
R	**LC**	**Pa**	**(~psf)**	**Pa**	**(~psf)**	**Pa**	**(~psf)**
15		720	15.04	1080	22.56	140	2.92
20		960	20.05	1440	30.08	150	3.13
25	25	1200	25.06	1800	37.59	180	3.76
30	30	1440	30.08	2160	45.11	220	4.59
35	35	1680	35.09	2520	52.63	260	5.43
40	40	1920	40.1	2880	60.15	290	6.06
45	45	2160	45.11	3240	67.67	330	6.89
50	50	2400	50.13	3600	75.19	360	7.52
55	55	2640	55.14	3960	82.71	400	8.35
60	60	2880	60.15	4320	90.23	440	9.19
65	65	3120	65.16	4680	97.74	470	9.82
70	70	3360	70.18	5040	105.26	510	10.65
75	75	3600	75.19	5400	112.78	540	11.28
80	80	3840	80.2	5760	120.3	580	12.11
85	85	4080	85.21	6120	127.82	610	12.78
90	90	4320	90.23	6480	135.34	650	13.53
95	95	4560	95.24	6840	142.86	680	14.28
100	100	4800	100.25	7200	150.38	720	15.04

Table 2 *Available performance grade (PG) requirements for class CW and AW windows and sliding doors Source of Tables 8.1 and 8.2: AAMA/WDMA/WDMA/CSA 101/I.S.2/A440, North American Fenestration Standard/Specification for windows, doors, and skylights (NAFS), 2022 edition.*

Performance classes and available performance grades (PG)		ASD Design Pressures (DP)		Structural Test Pressure (STP)		Water Penetration Resistance Test Pressure, CW		Water Penetration Resistance Test Pressure, AW	
CW	**AW**	**Pa**	**(~psf)**	**Pa**	**(~psf)**	**Pa**	**(~psf)**	**Pa**	**(~psf)**
30		1440	30.08	2160	45.11	220	4.59		
35		1680	35.09	2520	52.63	260	5.43		
40	40	1920	40.1	2880	60.15	290	6.06	390	8.02
45	45	2160	45.11	3240	67.67	330	6.89	440	9.19
50	50	2400	50.13	3600	75.19	360	7.52	480	10.03
55	55	2640	55.14	3960	82.71	400	8.35	530	11.07
60	60	2880	60.15	4320	90.23	440	9.19	580	12.11
65	65	3120	65.16	4680	97.74	470	9.82	620	13.03
70	70	3360	70.18	5040	105.26	510	10.65	670	14.04

75	75	3600	75.19	5400	112.78	540	11.28	720	15.04
80	80	3840	80.2	5760	120.3	580	12.11	720	15.04
85	85	4080	85.21	6120	127.82	610	12.78	720	15.04
90	90	4320	90.23	6480	135.34	650	13.53	720	15.04
95	95	4560	95.24	6840	142.86	680	14.28	720	15.04
100	100	4800	100.25	7200	150.38	720	15.04	720	15.04
	No Max	No Max		1.5XASD DP				720	

The testing setup includes a test chamber—a sealed enclosure designed to facilitate the installation of the specimen—and an air system capable of generating the necessary air-pressure difference across the specimen. This system must provide consistent airflow at a fixed pressure throughout the test duration, mimicking real-world conditions that ~~SGD~~SGDs and other fenestration products would face during severe weather events.

Central to the testing apparatus is the pressure-measuring apparatus, which monitors the pressure difference with a tolerance of 62% or 62.5 Pa (approximately 60.01 inches of water column), ensuring precise data collection. Additionally, the water spray system is designed to deliver water uniformly against the test specimen at a minimum rate of 3.4 liters per square meter per minute (or 5.0 U.S. gallons per square foot per hour). This uniform application is crucial for accurately simulating the effects of ~~wind-driven rain~~WDR on these structures. Moreover, calibration of the water-spray system must align with the requirements of ASTM E331 to guarantee consistent wetting of the specimen. Water penetration is defined in Section 3.2.3 of the standard as the intrusion of water beyond a vertical plane parallel to the glazing that intersects the innermost projection of the test specimen, excluding any interior trim and hardware. This definition underscores the significance of testing in establishing the integrity of building envelope components, and the NAFS standard provides visual guidance for interpreting the critical measurements associated with this testing process.

TAS 202: The TAS 202 standard offers essential guidelines for evaluating the performance of building components under uniform air pressure, with a particular emphasis on both impact and non-impact-resistant products. A key aspect of this standard is its specification for water testing, which mandates that components must endure a minimum water pressure equivalent to 15% of the product's design pressure (DP) rating for 30 seconds. Refer to Section 2.1 above for a full description of the testing. The door assembly receives five gallons per hour (gph) per square foot of door area, equating to 8.02 inches of rain per hour. The water intrusion test performed according to TAS 202 must include a minimum static air pressure of 15% DP above the ~~sliding glass door~~SGD for 15 minutes. This requirement serves as an indirect reference to ASTM E331, ensuring that products meet stringent water resistance criteria. The testing procedure outlined in TAS 202 involves several critical steps to accurately assess the water penetration resistance of the test specimen. Initially, the test specimen must be securely installed within the test chamber to create a controlled environment for the assessment. Once in place, operable units are subjected to five cycles of opening, closing, and locking, simulating normal operational stresses before the water penetration test.

Following this preconditioning phase, the water spray is adjusted to achieve the specified rate, and the air-pressure difference is applied within a 15-second window. This pressure, combined with the water spray, must be maintained for the full 15-minute testing period to ensure that the components are thoroughly evaluated under realistic conditions. After the test duration, the air pressure and water spray are removed, and any observed water penetration is recorded. This systematic approach outlined in TAS 202-94 not only enhances the reliability of the testing process but also ensures that products meet the necessary performance standards to withstand harsh weather conditions. Table 3 presents the similarities in the testing sequences of TAS 202-94 and NAFS-22 for evaluating the performance of SGDs.

Both standards begin with air infiltration testing per ASTM E283 (ASTM 2019), followed by the application of positive loads and full positive design pressure loads to assess structural integrity. Negative load testing is also conducted to evaluate performance under suction forces, while water infiltration resistance is tested at a minimum of 15% of the positive design load. Finally, forced entry testing is performed to ensure compliance with necessary security standards, highlighting the rigorous protocols in place for ensuring resilience against adverse weather conditions.

Table 3 Similarities in Test sequence between TAS 202-94 & NAFS - 22

TAS 202-94	NAFS-22 (R, LC, and CW products)
• The sequence of testing for evaluating the performance of building components, particularly SGDs, involves a systematic approach designed to ensure comprehensive assessment under various conditions. Each load is held for 30	• The testing sequence for evaluating the performance of building components, particularly SGDs, employs a systematic approach that ensures a comprehensive assessment under various conditions. Each load during the testing process is

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seconds to allow for accurate measurement and observation. • **Air Infiltration Testing**: The procedure begins with testing for air infiltration according to ASTM E283 (ASTM 2019). This standard determines the air leakage rates of the product, establishing its energy efficiency and potential for weather resistance. • **Application of Positive Loads**: Next, the product is subjected to a load of 0.5 times the positive test load, which is calculated as 1.5 times the product's design pressure rating. This step is crucial for assessing the structural integrity of the component under reduced pressure conditions. • **Full Positive Design Pressure Load**: After the initial load, the product is then loaded to its full positive design pressure. This step ensures that the component can withstand maximum anticipated pressures during a storm or extreme weather event. • **Negative Load Testing**: The testing process is then repeated for negative loads, where steps 2 and 3 are applied again to evaluate the performance of the product under suction forces. This dual approach helps to understand how the component behaves under both positive and negative pressure conditions. • **Water Infiltration Resistance Testing**: Following the load tests, the product is assessed for water infiltration resistance at the corresponding pressure, with a minimum requirement of 15% of the positive design load. This test determines the product’s ability to prevent water penetration under pressure, which is vital	held for 30 seconds, allowing for accurate measurements and observations. • **Air Infiltration Testing** serves as the initial step, following the ASTM E283 standard (ASTM 2019), which assesses the air leakage rates of the product. This evaluation is crucial for establishing the component's energy efficiency and potential resistance to adverse weather conditions. • **Application of Positive Loads** occurs, where the product is subjected to a load of 0.5 times the positive test load. This load is calculated as 1.5 times the product's design pressure rating. This step is essential for determining the structural integrity of the component under reduced pressure conditions, thereby ensuring its reliability. • The testing progresses to **Full Positive Design Pressure Load**, where the product is loaded to its full Positive Design Pressure. This ensures that the component can endure maximum anticipated pressures that may arise during storms or extreme weather events. • **Negative Load Testing** then follows, where the same steps (application of 0.5 times and full positive design pressure) are repeated for negative loads. This dual approach provides insight into how the component performs under suction forces, allowing for a comprehensive understanding of its behavior under both positive and negative pressure conditions. • Completing the load tests, the product undergoes **Water Infiltration Resistance** Testing at the corresponding pressure, with a minimum requirement of 15% of the

for ensuring durability and functionality during heavy rainfall or storms. • **Full Positive and Negative Test Loads**: The next phase involves applying full positive and negative test loads to further validate the structural performance and resilience of the product under extreme conditions. • **Forced Entry Testing**: Finally, forced entry testing is conducted to evaluate the security features of the product. This test simulates attempts to breach the door or window system, ensuring that it meets the necessary security standards.	positive design load. This assessment is critical in determining the product's capability to prevent water penetration under pressure, which is vital for maintaining durability and functionality during heavy rainfall or storms. • The testing phase then involves applying **Full Positive and Negative Test Loads** to further validate the structural performance and resilience of the product in extreme conditions. • **Forced Entry Testing** is performed to evaluate the security features of the product. This test simulates attempts to breach the door or window system, ensuring that it complies with necessary security standards.

Essential performance requirements for windows, skylights, and glass door systems, including ~~SGD~~SGDs, are provided by the Voluntary Performance Specification for Windows, Skylights, and Glass Doors (AAMA/WDMA/CSA 101/I. S2/A440/NAFS). The standard describes how items are categorized into several classes; products classified as Architectural Window (AW), which are especially important for more demanding construction. To assess systems' capacity to tolerate high wind loads, AW products must adhere to stricter requirements for air leakage and water penetration resistance per NAFS. The specification includes the deflection limit under uniform load, which is defined at L/175 for both CW and AW products.

2.2 FEMA Mitigation Assessment Reports (MAT) after Major Hurricanes

2.2.1 MAT Report: Hurricane Michael in Florida (FEMA P-2077 2020)

As reported in FEMA MAT report P-2077, published in February 2020, A pre-MAT team was deployed two weeks after Hurricane Michael consisting of a small team of subject matter experts (SMEs) to perform a preliminary field assessment of building damage in limited areas. The Hurricane Michael MAT was deployed 88 days after the storm made landfall, which is outside of the preferred 30- to 45-day window following an event. During the 88 days between Hurricane Michael's landfall and the MAT deployment, some sites and buildings were demolished, and many

buildings, roofs, windows, doors, and walls or other systems were already repaired, being repaired, or covered with tarps, preventing detailed observations. Much debris was also cleaned up by the time the MAT arrived, which made it more difficult for the MAT to discern between damage and successful building performance and limited the data pool from which to draw conclusions and make recommendations. Although the FEMA P-2077 MAT report showed that some buildings experienced limited to no water infiltration through windows and doors, for example as shown on page 103 from the Hurricane Michael report.
FEMA MAT report for Hurricane Michael explicitly stated in section 6.4 wind-related building codes, standards, and regulations conclusions and recommendations, in conclusion, FL-6 that "testing standards for door and window assemblies did not appear to adequately help prevent water infiltration. In multiple locations, the MAT observed broken laminated glass or undamaged doors that remained in the frame but allowed water infiltration; the leakage may have been related to installation deficiencies. Although the products observed were tested for the region in which they were installed, the damage indicates the performance measures in current testing requirements may not adequately address water infiltration, especially concerning limiting the infiltration of ~~wind-driven rain.~~WDR. So, the report in recommendation #FL-6 stated that FEMA should work with AAMA/WDMA/CSA, IBHS, ASTM, ICC, and other select industry partners to incorporate more comprehensive water intrusion testing requirements that improve overall performance into testing standards."

In the same report, FEMA emphasized the damage observations made after Hurricane Michael and recommended that the FEMA Building Science Branch should collaborate with the AAMA / WDMA / CSA, IBHS, ASTM, ICC, and other select industry partners to identify trends in damage (e.g., interior finishes subject to water intrusion/~~wind-driven rain~~WDR) to consider how to help reduce potential water infiltration in the future.

2.2.2 MAT Report: Hurricane Ian in Florida (FEMA P-2342 2023)

FEMA deployed a pre-MAT on October 11–15, 2022, to perform a preliminary field assessment of building damage in limited areas which is after two weeks of Hurricane Ian landfall on the Florida coast. The FEMA MAT was deployed 110 days later. The MAT team reported visual observation from the exteriors of buildings found water intrusion, primarily through ~~SGD~~SGDs and soffits, affecting both older and newer constructions. Homeowners reported significant issues with water intrusion, particularly around ~~SGD~~SGDs, even in homes built in 2021 with protective overhangs as shown in Fig (1) and Fig (2) from the FEMA MAT report.

Some ~~SGD~~SGDs were found to lack adequate sill risers, compromising their resistance to ~~wind-driven rain.~~WDR. The FEMA MAT report from Hurricane Ian recommended revising the ~~FBC~~Florida Building Code, to modify or delete exceptions for water intrusion testing in hurricane-prone areas. In addition, the report called for modifications to the North American Fenestration Standard, to require window and door Performance Grade (PG) ratings to be equal to the Positive DP wind pressure rating. It emphasized the need for collaboration with industry stakeholders to ensure robust testing standards to protect against horizontal rain during hurricanes.

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Figure 1 Significant water intrusion occurred in a 2021-built home with two and three panel ~~SGD~~SGDs (EWS = 130 mph; DWS = 151 mph) (Punta Gorda)

The FEMA MAT report recommendation #FL-12 in the wind-related building codes, standards, and regulations conclusions and recommendations section stated in conclusion FL-12a stated that “The Florida Building Commission should collaborate with the window industry (Window and Door Manufacturers Association [WDMA], Fenestration and Glazing Industry Alliance, and key manufacturers) and other stakeholders to modify or delete the exceptions to water intrusion testing in the FBC. The FBC exempts doors from water intrusion testing required by the American Architectural Manufacturers Association (AAMA)/WDMA/Canadian Standards Association (CSA) 101/I.S.2/A440, and TAS 202 for doors installed in certain conditions. While these installations may provide sufficient protection in areas outside hurricane-prone regions, it will not protect doors from the wind-driven horizontal rain that commonly occurs during hurricanes. The entire State of Florida is within a hurricane-prone region.".

Figure 2 Due to ~~wind-driven rain~~WDR, a 2021 home with a two-panel ~~sliding glass door~~SGD suffered severe water intrusion (the two red circles indicate weep holes that allow water to depart). DWS is 11 mph, and EWS is 130 mph. (Punta Gorda)

It also stated in conclusion FL-12a stated that "The window industry should revise AAMA/WDMA/CSA101/I.S.2/A440 to require window and door Performance Grade (PG) ratings to be equal to resistance would align AAMA/WDMA/CSA 101/I.S.2/A440 with FBC Test Protocol TAS 202, which specifically requires windows and doors to be tested for water penetration resistance at 15% of the positive design wind pressure rating the positive DP wind pressure rating. The water penetration resistance of windows and doors tested to AAMA/WDMA/CSA 101/I.S.2/A440 is not directly tied to the positive design wind pressure rating. The PG rating in AAMA/WDMA/CSA 101/I.S.2/A440 ~~is the indicator of~~indicates a product's resistance to water penetration. Additionally, AAMA/WDMA/CSA 101/I.S.2/A440 does not require a correlation between a window and door product's design wind pressure rating and water penetration resistance (windows and doors with higher design wind pressure ratings are likely to primarily be used in hurricane-prone regions where exposure to ~~wind-driven rain~~WDR will be severe). Correlating product's design wind pressure rating with the water penetration."

2.3 Experimental Testing of ~~SGD~~ SGDs

2.3.1 FIU WOW Experimental Testing Findings (Chowdhury et al. 2021)

Vutukuru et al. (2020) performed holistic testing to determine quantitative ~~wind-driven rain~~WDR intrusion for shuttered and impact-resistant windows. Shutter systems are commonly implemented in hurricane-prone zones to mitigate possible breaches of building envelope against extreme winds and wind-borne debris. There is very little information on the quantity of water intrusion that is prevented (if any) by the presence of these shutters. This study focused on rain intrusion quantification into a window configuration, with and without an accordion shutter. An impact-resistant window was also tested. The tests were conducted at three different wind speeds, 28 m/s, 35 m/s, and 61 m/s corresponding to tropical storms, non-major, and major hurricanes, respectively, considering the effects of wind direction and storm duration. The experiments were conducted by the team at the Wall of Wind (WOW) Experimental Facility.

The study investigated water intrusion through three full-scale window assemblies, a non-impact, impact, and shuttered (over non-impact). These systems were compliant with the existing TAS protocols. The following points summarize the major findings deduced based on the test results: (1) Water intrusion was observed for all wind speeds and all window configurations tested in this study. This might suggest that water intrusion through double-hung windows continues to be a challenge during windstorms. However, such water intrusion can be reduced through improved design and enhanced testing protocols. The water intrusion depends on the sealing level around the window, however, in the case of tested double-hung windows, significant water intrusion was observed between the window frames at the sill location. (2) The presence of the accordion shutter system reduced the pressure differential by almost 6–14% compared to a non-impact window. This might be attributed to the sheltering effect of the shutter. (3) The accordion shutter significantly reduced the water intrusion volume through the non-impact-resistant window by 77–87%. (4) Existing test protocols might not adequately address the water intrusion due to ~~wind-driven rain~~WDR, especially under extreme wind conditions and, hence, improvements in existing fenestration test protocols might be required to improve the building envelope performance against water intrusion.

Recommendations: The findings of this study signify the importance of conducting realistic dynamic wind testing for estimating WDR intrusion through the building envelope components. The current standardized test protocols, such as Testing Application Standard (TAS), used for obtaining product approval (or Notice of Acceptance, i.e., NOA), can be improved by incorporating the following methods: (1) WDR intrusion is highly dependent on the dynamic effects of wind flow governed by the turbulence fluctuations. Such realistic effects can be simulated using fans instead of using pressure chambers that simulate only static or cyclic wind loading not representative of real ABL wind flows. Another method that can be adopted in standard testing protocols is the use of a pneumatic loading system designed using modular “pressure boxes” to apply time-varying pressures and suctions over the entire surface of the specimen (Kopp et al., 2010) subjected to simulated rain. Realistic simulation of fluctuating pressure differential across the envelope component is also of importance. (2) Though 0° wind direction has been found from the current WOW tests to be the most critical direction for WDR intrusion, other directions (say, between -15° and +15°) should be considered in standard test protocols, as those directions can also cause water intrusion based on the configuration of envelope defects (e.g., cracks), openings, or louvered systems. (3) The building itself governs the aerodynamics which in turn affects the WDR impact on building components (such as windows, curtain wall systems, etc.). So, the standard testing protocols can be further improved by testing more holistic or system-level models that not only include the component itself (e.g., window) but also simulate the realistic flow around and across the component. (4) As to the holistic testing approach, many parameters are involved in determining the amount of rainwater deposition on the building envelope. These parameters consist of rain rate, raindrop size spectrum and its integral parameters (drop number concentration and liquid water content per unit volume of air, mean-weight, and volume median diameters, etc.), and rain duration (Baheru et al., 2014a, b). The standard testing protocols should consider realistically simulating these rain parameters to capture the impact caused by raindrops on the building façade. Future research is needed to assess the improvements that can be achieved by adopting some or all ~~of~~ these methods. More research is also warranted to find how water intrusion is affected by the percentage of design pressure applied.

Another study by Vutukuru et al. (2024) delved into rain intrusion through a ~~sliding glass door~~SGD, which accounted for the effects of multiple wind directions, test durations, and wind speeds; configurations with and without shuttering systems were also considered. The study showed that significant levels of water intrusion can occur during conditions well below current design levels. The research was performed using full-scale experimental simulation at the NHERI WOW EF aimed at obtaining realistic rain characteristics as experienced by structures during tropical storms and hurricanes. This study discussed an attempt to produce full-scale raindrop size distribution (RSD) simulations using the Willis and Tatelman model obtained from target field measurements. The comparison of the experimentally simulated RSD and the field-measured RSD was satisfactory. The developed RSD could be utilized to study rain intrusion into various building components at a full scale to a large scale in the background of realistic wind. These future tests could help develop guidelines to provide overall resistance to the building envelope against undesirable WDR effects. The research findings are summarized as: (1) The highest differential pressures on the sliding glass doorSGD without any shutter system occurred at the 0° wind direction and decreased in magnitude as the model was rotated from 0° toward 45°. (2) The presence of the shutters resulted in lower (in magnitude) and more uniform net pressures on the sliding glass doorSGD when compared with those for the non-shuttered test cases at 0° and 22.5°, suggesting that the shutters provide a net pressure mitigation effect at these wind directions. This also implies the reduction of driving forces which resulted in water intrusion reduction. (3) For a pressure reduction of 34%, the overall reduction in water intrusion was 75% which proves that in addition to providing resistance to debris and wind, shutters also provide additional resistance to wind-driven rainWDR intrusion. (4) Substantial differences in the water intrusion volumes were observed between the aluminum storm panel configuration and the accordion shutter system configuration at 45 m/s and 58 m/s wind speeds. In general, accordion shutters performed better and this also signifies the importance of installation techniques. These results also signify the importance of differences in shuttering systems in terms of WDR resistance. Further research is recommended to further validate this result and investigate the reasons for these differences. (5) This study demonstrated that significant levels of water intrusion can occur during conditions well below the design level (the 45 m/s tests correlate to approximately 26% DP for the sliding glass door).SGD). (6) The point of water intrusion changed with the attachment of shutter systems which was caused by a change in the aerodynamic flow around the sliding door.

Recommendations: The results of this study confirm the importance of performing full-scale rain simulation and testing in strong winds to physically model realistic conditions experienced by the building envelope components during windstorms. WDR intrusion depends on pathways (e.g., cracks, defects, joints, etc.), sources of water (wind-driven-rain) and, driving forces (e.g., net aerodynamic pressure across a building envelope component such as sliding glass doorSGDs or window). Based on the current study, it can be observed that the typical 15% DP protocols listed in TAS 202 do not adequately assess the building envelope rain intrusion. The study also concluded that the type of shutters may have a significant impact on the amount of water intrusion into the buildings, this could be hypothesized as the effect of changing the aerodynamics of the building components as this would change the pathways and driving force for water intrusion. A similar conclusion was presented in previous studies by (Alawode et al. 2023, Alawode et al. 2022, Vutukuru et al. 2021 and Vutukuru et al. 2020). It is recommended that the developed RSD be utilized to study rain intrusion into various building components at a full scale to a large scale in the background of realistic wind. Future research is warranted into the effect of various mitigation methods, types, and geometries to determine optimal installation techniques for reducing water intrusion effects. Future research is recommended to study the effect of rain rate on building components vulnerable to water intrusion and to study the effect of wind speed on RSD simulation.

2.3.2 University of Florida (UF) Experimental Testing Findings: (Catarelli and Phillips 2023)

This study serves as an initial exploration focused on a limited selection of window and door types. It provides a foundation but does not encompass a comprehensive range of product categories, particularly excluding systems such as storefronts and curtain walls that exceed the North American Fenestration Standard (NAFS) specifications (AAMA/WDMA/CSA 101/I.S.2/A440). Specifically, this study did not include products designed for pressures above 10 psf ~~were not included in this study~~. In this study, a hurricane-like wind simulation combined with WDR was conducted on a small number of fenestration samples including different types of windows and doors. These fenestration samples included one ~~sliding glass door~~SGD that didn't pass ASTM E331/E547 testing and demonstrated water infiltration through the tracks of the SGD at water pressures below 10 psf and has not been tested further for hurricane simulation. This suggests that ASTM standards may not adequately predict performance under extreme wind conditions like tropical cyclones. The rates of ingress varied widely, with no immediate explanation, indicating potential for further research in specific areas, such as:

- **Upwind Flow Turbulence**: Turbulence and flow distortion around buildings create spatiotemporal pressure variations on the building surface.
- **Cyclic Pressure Test Limitations**: Current cyclic pressure test protocols allow for drainage lulls that don't accurately represent real-world pressure fluctuations (0.1-1.0 Hz).
- **Wind Load Intensity Definition**: The criteria for wind load intensity in water infiltration tests lack clarity and may impact pass/fail outcomes.

- **Wetting Rate Basis**: The minimum wetting rate (5.0 gph/sf) is based on thresholds needed for water sheeting but overlooks climate, wind speed, and specific building locations.
- **Definition of "Failure"**: Defining failure as a single drop entering the building doesn't account for cumulative water accumulation and, better performance-based criteria are needed to represent real-world damage during hurricanes.

This research suggested improvements to the current standards: It is challenging to connect the results of hurricane passage tests to those of ASTM tests, as success in ASTM tests doesn't reliably indicate how a specimen will perform—whether positively or negatively—in simulated hurricane conditions. Adopting more performance-based standards with prescribed performance states, rather than a simple pass-fail criterion, would be beneficial, as the current single-drop-through-plane method for defining success is inadequate under hurricane-like scenarios. It is suggested to incorporate higher loading levels (pressure and wetting rate), more flexible pass/fail criteria, and a graded performance scale instead of a binary outcome. These parameters could be fine-tuned to more accurately forecast performance in hurricane passage simulations.

Recommendations:

- **Expand Testing Sample Size**: Conduct the testing procedures outlined in Table 3—including ASTM standard tests, pressure sine sweeps, and hurricane passage simulations—on a much larger sample size. This expanded sample should ideally include multiple product models from each manufacturer category. The current study, with only four out of seven units meeting ASTM standards to advance to subsequent testing, lacks the sample size needed for robust conclusions. Increasing the sample size will strengthen the reliability and applicability of the findings.
- **Enhance ASTM Standard Tests with Variable Conditions**: Perform ASTM standard tests across a broader range of pressure levels and wetting rates to determine if these adjusted conditions more accurately predict performance under hurricane simulations. These enhanced ASTM tests could also support the establishment of new pass/fail criteria aligned with real-world hurricane conditions, enhancing the standards' relevance for assessing hurricane resilience.
- **Investigate Sine Sweep Testing for Predictive Maintenance**: Continue to explore the potential of sine sweep tests as a streamlined alternative to full hurricane passage tests, given their consistent correlation with hurricane performance. Expanding on sine sweep

testing could allow for more efficient resilience assessments while ensuring accuracy in predicting door performance under extreme weather.

- **Implement a Performance-Based Design Framework**: Develop pass/fail criteria based on performance benchmarks tailored to specific mean recurrence interval (MRI) storms. For example:
    - **10-Year MRI Storm**: No water ingress allowed.
    - **50-Year MRI Storm**: Permit limited water ingress at a specified flow rate (e.g., specific gallons per minute).
    - **500-Year MRI Storm**: Focus on structural integrity, with some water ingress accepted.

2.4 Aftermarket Mitigation Devices Tested at FIU WOW

There are some aftermarket devices designed to stop water intrusion through the tracks of SGD during extreme weather. These products include shuttering systems such as aluminum storm panels and accordion shutters which can reduce water intrusion through ~~SGD~~SGDs as explained previously in the FIU testing. The shutter system can reduce the pressure differential by almost 6–14% compared to a non-impact window. This might be attributed to the sheltering effect of the shutter. Also, the accordion shutter can significantly reduce the water intrusion volume through the non-impact-resistant window by 77–87%. There are other aftermarket mitigation products such as exterior rubber shields with a mechanism and interior plastic sheeting strips that can be installed on the tracks of ~~SGD~~SGDs. This product was tested at the FIU WOW EF in 2023. This aftermarket device was applied to four doors in testing conducted at the FIU WOW EF in 2023. However, such minimal testing on a single device cannot provide conclusive results for an entire aftermarket category, nor all SGDs. While after-market devices may potentially further reduce water intrusion through ~~SGD~~SGDs, further investigation is needed to identify if after-market devices interfere with the ~~sliding glass door~~SGDs manufacturer's water management design and further, also if the installation of the device has an impact on the ~~SGD~~SGDs manufacturer's warranty. Although the standards did not provide an approach to test aftermarket devices, the FBC provides a process to test these devices through the Florida product approval system. Approved agencies (e.g., registered design professionals) can come up with compliance criteria to test aftermarket devices and the building official can approve the test as deemed complied for quality and manner for new assemblies as provided in FBC section 104.11 Alternative materials, design and methods of construction and equipment.

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3. Summary and Conclusion:

The current standards for ~~SGD~~SGDs were reviewed along with federal reports published by FEMA as a part of the MAT reconnaissance studies after major hurricanes including Micheal, and Ian. These MAT reports are based on visual observation and field surveys that might lack some forensics information to enable detailed analysis of building envelope and/or product performance. However, there aren't any available or published forensic studies on wind-rainfall intrusion through the tracks of SGDs for detailed analysis of building envelope performance during hurricanes. The literature review was backed up with experimental testing at different reliable Facilities in Florida including the University of Florida and the WOW EF at Florida International University. Although testing at both Facilities was done to a limited number of samples that might be not fully representative of all the SGDs products but still significant to drive recommendations for this study. The outcomes and recommendations were shared with the TAC members and their comments and concerns have been addressed as deemed fit for this study.

This can be summarized as below:

1- FEMA MAT reports for both Hurricane Michael 2018 and Hurricane Ian 2022 showed significant water intrusion through SGDs. FEMA in both reports explicitly stated that the current standards testing requirements may not adequately address water infiltration, especially concerning limiting the infiltration of ~~wind-driven rain~~WDR, and more comprehensive water intrusion testing requirements are needed to improve the overall performance SGDs,

2- Wind-rainfall intrusion information across the state of Florida has been investigated by the University of Florida together with Cornell University's Department of Meteorology. ~~This~~The goal from this study is ~~extended~~ to develop ~~wind-driven rain~~WDR maps for Florida. Those maps are currently under development and should form the basis for a better understanding of actual ~~rain and wind-driven rains~~WDR for different locations in Florida rather than using constant WDR intensity parameters for the entire state. Much like ASCE-7 wind speed maps, WDR maps can also be used by product specifiers to determine what performance levels may be needed in SGDs in a Florida location.

3- NAFS allows for the use of a secondary designator in testing fenestration products. The primary designator in NAFS sets the test pressure for the structural performance of fenestration products. The secondary designator allows for subjecting a product to higher test pressures for water performance as well as a higher structural load. The secondary designator is a resource currently available through NAFS and can be used by manufacturers to provide products that meet more rigorous water testing requirements where needed, based on actual conditions like in areas of Florida that may receive higher levels of wind and wind-driven rainWDR like in tropical storms or hurricanes.

4- FIU and UF testing indicated that WDR intrusion is possible through systems (such as windows and SGDSGDs) when wind and rain parameters including turbulence are more realistically and holistically simulated in the experiments. The wind turbulence can also cause window/door components and connections to vibrate and/or deflect/deform. causing WDR intrusion.

5- The mixed-phase flow dynamics (i.e., fluctuating winds with entrained rain precipitation) through these operable systems are also not properly simulated in the existing tests, which may influence how effectively water infiltrates and drains. These effects may not be adequately simulated in traditional static-type WDR tests in labs but can be incorporated to improve the current standards. Wind directionality is also important to simulate.

3.1 Recommended Course of Action

1. Based on the review of experimental testing at different facilities and FEMA MAT reports from different hurricanes, it can be observed that the typical 15% DP protocols listed in TAS 202 do not adequately assess the building envelope rain intrusion. Therefore, more field data should be collected to understand the nature of WDR.
2. Climate-adjusted wind-driven rainWDR maps are critical to identifying the requirements for conditions in Florida. This may help to accurately specify the performance requirements for individual locations and buildings rather than having constant wind-driven rainWDR intensity parameters across the entire state.

3. It is important to perform a full-scale holistic rain simulation and testing in strong winds to physically model realistic conditions experienced by the building envelope components during windstorms.

4.3. This holistic full-scale rain simulation can inform a new testing approach based on the University of Florida study on SGDs (hurricane wind pressure trace simulations based on water injection) after calibrating the rain and wind parameters to mimic the full-scale simulation environment such as the one developed at the WOW EF.

5.4. Aftermarket mitigation devices need to go through the Florida Product Approval System to be considered. Although the standards did not provide an approach to test aftermarket devices, the FBC provides a process to test these devices through the Florida product approval system. Approved agencies (e.g., registered design professionals) can come up with compliance criteria to test aftermarket devices and the building official can approve the test as deemed complied with respect to quality and manner for new assemblies as provided in FBC section 104.11.

4. References:

Senate, T. F., and Florida Governor Ron DeSantis. 2024. "Florida House version of the bill signed into law."

The Florida House Bill 1021 (2024), section 32, https://www.floridabuilding.org/fbc/commission/FBC_0424/Commission/Research_Projects.pdf

AAMA/WDMA/WDMA/CSA 101/I.S.2/A440, North American Fenestration Standard/Specification for windows, doors, and skylights (NAFS), 2022 edition.

ASTM E331-00 (2016), Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference. https://www.astm.org/e0331-00r16.html

ASTM E547 − 00. (2016). Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference 1 This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee. 1. https://doi.org/10.1520/E0547-00R16

ASTM E283. (2019). Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen (pp. 1–3). ASTM International. https://doi.org/10.1520/E0283_E0283M-19

Testing Application Standard (TAS 202-94) – Criteria for Testing Impact and Non-Impact Resistant Building Envelope Components Using Uniform Static Air Pressure. https://codes.iccsafe.org/content/FLBCTP2001/testing-application-standard-tas-202-94-criteria-for-testing-impact-non-impact-resistant-building-envelope-components-using-uniform-static-air-pressure

Masters, F.J., & DeGaetano, A. T., Belcher, B. N., Development of ~~Wind-Driven Rain~~WDR Climatology and Coincidental Wind Speed Return Period Maps for Florida and Surrounding Coastal Areas (2022). https://www.floridabuilding.org/fbc/publications/Research_2021-2022/2022-06-01%20Final%20Report%20-%20Wind-Driven%20Rain%20Climatology.pdf

Catarelli, R. A., & Phillips, B. M. (2023) Final Report for Project Entitled: Assessing the Need to Modernize Water Penetration Resistance Test Procedures.

Chowdhury, A. G., Erwin, J., & Vutukuru, K. S. (2021). Quantification of wind driven rain (WDR) intrusion through shuttered ~~sliding glass door~~SGD systems final report. https://doi.org/10.13140/RG.2.2.36806.86081

FEMA P-2343. (2023). Mitigation Assessment Team Report Hurricane Ian in Florida Building Performance Observations, Recommendations, and Technical Guidance.

FEMA P-2077 (2020). Mitigation Assessment Team Report: Hurricane Michael in Florida, Building Performance Observations, Recommendations, and Technical Guidance, FEMA P-2077/February 2020.

Vutukuru, K. S., J. Erwin, and A. G. Chowdhury. 2024a. “Full-scale simulation of wind-driven rainWDR and a case study to determine the rain mitigation effect of shutters.” Wind and Structures, 38 (3): 171–191. Techno-Press.

ASTM. (2020). Guide for Evaluating Water Leakage of Building Walls (Pp. 1–39). ASTM International. https://doi.org/10.1520/e2128-20

ASTM. (2019). Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, And Doors Under Specified Pressure Differences Across the Specimen (Pp. 1–3). https://doi.org/10.1520/E0283_e0283m-19

Baheru, T., Chowdhury, A. G., Pinelli, J.-P., & Bitsuamlak, G. (2014). Distribution of wind-driven rainWDR deposition on low-rise buildings: Direct impinging raindrops versus surface runoff. Journal of Wind Engineering and Industrial Aerodynamics, 133, 27–38.

Alawode, K. J., Asce, A. M., Krishna, Vutukuru, S., Asce, S. M., Elawady, A., Seung, Lee, J., Arindam, Chowdhury, G., & Lori, G. (2022). Effects of Permeability on the Dynamic Properties and Weathertightness of Double Skin Curtain Walls.

Alawode, K. J., Vutukuru, K. S., Elawady, A., Lee, S. J., Chowdhury, A. G., & Lori, G. (2023). Wind-Induced Vibration and Wind-Driven RainWDR Performance of a Full-Scale Single-Skin Facade Unit with Vertical Protrusions. Journal of Architectural Engineering, 29(2). https://doi.org/10.1061/jaeied.aeeng-1393

Appendices

APPENDIX A: MEETING #1 MINUTES – 12TH SEPTEMBER 2024

Date: 12th September 2024

Time: 9:00 A.M. to 10:00 A.M. Eastern

Location: Zoom Platform (online)

Meeting Hosted by: Dr. Nofal

The FIU- CEE, was retained by the State of Florida's FBC (Department of Business & Professional Regulation) to conduct a research study to assess the impact of wind on water intrusion through conventional SGD systems installed in residential mid-rise buildings. The project Manager is Mr. Mo Madani, Mo.Madani@myfloridalicense.com. The project lead is Dr. Omar M. Nofal, Assistant Professor of the Department of Civil Engineering, onofal@fiu.edu.

Table 4 Lists of Meeting #1 (12th September 2024) Participants

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1	Steve	Strawn	SS	SStrawn@jeldwen.com	Y
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3	Brad	Fevold	BF	bradfev@marvin.com	Y
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5	Daniel	Stein	DS	danieljordanstein@gmail.com	Y
6	Greg	McKenna	GM	greg.mckenna@arconic.com	Y
7	Becky	Magdaleno	BM	bmagdaleno@aiafla.org	Y
8	Scott	'Spiderman' Mullholland	SSM	spiderman@usbuildingconsultants.com	Y
9	Mike	Silvers	MS	Silvers@floridaroof.com	Y
10	Alex	Esposito	AE	Alex_Esposito@special-lite.com	Y
11	Bradford K.	Douglas	BD	bdouglas@awc.org	Y
12	Lynn	Miller	LM	LMiller@pgtindustries.com	Y
13	Omar	Amini	OA	OAmini@awc.org	Y
14	Amal El	Awady	AEA	aelawady@fiu.edu	N
15	Jovan	Millet	JM	jmillet@studioajo.com	N
16	Kate	Wesner	KW	kate@floodcoalition.org	N

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17	Kathy	Krafka Harkema	KKH	kkrafka@fgiaonline.org	Y
18	Arindam	Gan Chowdhury	AGC	chowdhur@fiu.edu	N
19	Ryan	Catarelli	RC	ryan.catarelli@essie.ufl.edu	Y
20	Mo	Madani	MM	mo.madani@myfloridalicense.com	N

Meeting Key Questions

- How could the limitations of the current pass/fail criteria for water intrusion tests have been addressed to better reflect the real-world performance and reliability of SGDs?
- What were the implications of using different sample sizes in water intrusion studies, and how did this variability impact the accuracy and generalizability of the test results?
- How could future standards for WDR testing have been adapted to incorporate performance-based criteria instead of the existing binary pass/fail system?
- What were the potential challenges and benefits of conducting multi-facility studies to assess the water intrusion resistance of various ~~sliding glass door~~SGD models from different manufacturers?
- How did findings from field investigations, such as those from Hurricane Ian, contribute to the literature review and inform the development of more robust WDR standards and testing methodologies?

Meeting #1 Minutes

- **TAC members** offered recommendations on resources to use for an extensive review during the team's discussion of the literature review strategy.
- **Fenestration Manufacturers:** The TAS standards for structural loading before water testing in Miami-Dade were established as the design load without impact testing. The FBC contained several referenced installation standards. Better enforcement of the standards, particularly those developed by the UF regarding installation practices, was suggested. A recommendation was made to conduct a post-hurricane forensic assessment of actual buildings to identify the correlation between buildings' water penetration resistance and the fenestration and envelope construction details. The objective was to determine the minimum criteria necessary to prevent a significant number of issues. The study's findings significantly influenced standards, impacting the 15% positive DP rating for Water Damage Resistance. It was noted that current building codes

and industry practices did not adequately focus on preventing water intrusion after hurricanes, with most attention directed at structural performance and life safety.

- The Florida market was primarily concerned with structural problems, giving less attention to water leakage issues. Furthermore, no mandatory field testing existed for fenestration after installation, with testing typically conducted voluntarily—usually only mandated by architects and builders for large high-rise condominiums or similar projects.
- A performance-based assessment system would have been beneficial, as the existing pass/fail criteria—based on the infiltration of a single drop of water—could not adequately reflect real-world performance.
- The NAFS/AAMA Standard 101 A440 / CSA WDMA AAMA et al., 2017, 2022), a performance-based document, utilized thresholds at 15-20% of the design pressure, which represented low water penetration resistance compared to the ~~wind-driven rain~~WDR experienced during hurricanes.
- Current standards failed to provide an acceptable level of water penetration resistance for hurricane performance. Additionally, the Florida product approval rating system did not guarantee the survivability of products following a hurricane event.

Meeting Action Items

- **Literature Review Strategy**: During the discussions, TAC members provided recommendations on resources for conducting an extensive literature review. They emphasized the importance of covering existing research, standards, and guidelines related to water intrusion and SGD (SGDs). The team identified key databases, relevant publications, and expert opinions necessary data to enhance the depth and breadth of the review process.
- **Revisions of Current Standards**: Dr. Ryan Catarelli highlighted a significant drawback in the existing water intrusion guidelines for SGD. He pointed out that the current pass/fail criteria, relying solely on the infiltration of a single drop of water, did not adequately capture real-world performance. The TAC agreed that a performance-based assessment system would provide a more realistic evaluation of SGDs under conditions that mimicked actual weather events.

- **The Effect of Sample Size on Test Outcomes**: The discussion addressed how varying sample sizes impacted test results, particularly regarding the amount of rainwater incursion observed during testing. Members noted that smaller sample sizes could produce skewed results that did not accurately represent the performance of SGDs in real-world conditions. To enhance the robustness and generalizability of findings, the TAC recommended incorporating multi-facility testing with a diverse range of samples from different manufacturers. This approach aimed to improve the reliability of conclusions drawn from the tests.
- **Potential Standards Revisions:** The study's findings were expected to influence current standards, particularly the 15% positive Design Pressure (DP) rating for Water Damage Resistance (WDR). The TAC acknowledged that revising these standards could lead to improved performance criteria, ensuring that SGD would better withstand ~~wind-driven rain~~WDR during hurricanes.
- **Field Investigation Reports**: The TAC shared valuable reports from field investigations related to Hurricane Ian. These reports offered insightful information and data that contextualized the challenges faced by SGDs in real-world hurricane conditions. The findings provided a basis for recommendations to enhance future standards.
- **Future Research Directions:** The discussions underscored the necessity of developing performance-based standards and conducting multi-facility research to enhance the validity and applicability of WDR testing for SGD. TAC members emphasized the importance of continuing research efforts to develop more comprehensive testing protocols that reflected real-world conditions, ultimately leading to safer and more resilient building practices.

APPENDIX B: MEETING #2 MINUTES – 25TH SEPTEMBER 2024

The FIU- CEE, was retained by the State of Florida's FBC (Department of Business & Professional Regulation) to conduct a research study to assess the impact of wind on water intrusion through conventional SGD systems installed in residential mid-rise buildings. The project Manager is Mr. Mo Madani, Mo.Madani@myfloridalicense.com. The project lead is Dr. Omar M. Nofal, Assistant Professor of the Department of Civil Engineering, onofal@fiu.edu.

Table 5 Lists of Meeting #2 (25th September 2024) Participants

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6	Greg	McKenna	GM	greg.mckenna@arconic.com	Y
7	Becky	Magdaleno	BM	bmagdaleno@aiafla.org	Y
8	Scott	'Spiderman' Mullholland	SSM	spiderman@usbuildingconsultants.com	N
9	Mike	Silvers	MS	Silvers@floridaroof.com	Y
10	Alex	Esposito	AE	Alex_Esposito@special-lite.com	N
11	Bradford K.	Douglas	BD	bdouglas@awc.org	N
12	Lynn	Miller	LM	LMiller@pgtindustries.com	Y
13	Omar	Amini	OA	OAmini@awc.org	N
14	Amal El	Awady	AEA	aelawady@fiu.edu	N
15	Jovan	Millet	JM	jmillet@studioajo.com	Y
16	Kate	Wesner	KW	kate@floodcoalition.org	Y
17	Kathy	Krafka Harkema	KKH	kkrafka@fgiaonline.org	Y
18	Arindam	Gan Chowdhury	AGC	chowdhur@fiu.edu	Y
19	Ryan	Catarelli	RC	ryan.catarelli@essie.ufl.edu	Y
20	Mo	Madani	MM	mo.madani@myfloridalicense.com	Y

Meeting #2 Minutes

Date: September 25th, 2024

Time: 9:00 A.M. – 10:00 A.M. Eastern

Location: Zoom Platform (Online)

Hosted by: Dr. Omar Nofal

Meeting Overview

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The meeting commenced with Dr. Nofal introducing the focus areas of the final report, particularly the literature review and water penetration challenges associated with SGD.

Insights on Literature Review

- A TAC Jaime Gascon (RER) member emphasized the importance of referencing Chapter 17th of the FBC standards, which outlines water performance requirements for doors.
- The member Gascon stressed the need to include water performance testing for doors as a critical component of the report's final recommendations.

Addressing Current Issues

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- A TAC member suggested focusing on real-world failures rather than developing new standards, citing Hurricane Irma as an example.
- Dr. Nofal agreed, proposing that the report cover other hurricanes that have impacted SGD to provide meaningful insights.

Inclusion of Hurricane Irma's Report (FEMA P-2020, 2018)

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- Marvin A TAC member advocated for including Hurricane Irma's report to provide context on water penetration under extreme weather.
- A TAC member highlighted failures from improper door installations during hurricanes, emphasizing the role of installation in preventing water damage. The member also stressed the importance of keeping weep holes open to allow a product's water management system to allow any water that may enter to exit through weep holes.

Presentation of Research Findings

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Dr. Chowdhury shared research (Chowdhury et al., 2021) conducted at FIU, focusing on WDR impacts on SGDs.

- His tests demonstrated that shutters significantly influenced door performance.
- The study analyzed inclined and horizontal winds to assess water intrusion and the impact of oblique wind angles.

- Figures 3, 6, and 7 depicted wind-angle effects and interior water penetration through SGDs.
- Table 2 compared intrusion levels with and without aluminum shutters, highlighting how turbulence worsens WDR penetration by causing vibrations.
- Dr. Chowdhury emphasized that the report's findings are critical for improving SGD's performance in storm conditions.

Key Questions and Concerns Raised by TAC Members Included:

- Inquired if the tests included shutters and questioned the performance of SGDs under high wind speeds and oblique angles.
- Suggested that current testing standards may not fully replicate such conditions and offered to send his draft findings to Dr. Nofal for review.
- Raised concerns about the amount of water collected inside SGD SGD in Dr. Chowdhury's report, asking about its impact on performance.
- A TAC member highlighted that the installation of aftermarket shutters can affect the performance of SGDs.

Document Availability

- A TAC member informed participants that several relevant documents and research papers had been published and made available for review.

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APPENDIX C: MEETING# 3 MINUTES – 17TH OCTOBER 2024

Date: October 17th, 2024

Time: 12:00 P.M. – 1:00 P.M. Eastern

Location: Zoom Platform (Online)

Hosted by: Dr. Omar Nofal

SUMMARY IN BRIEF

Agendas:

Introduction and presentation by **Dr. Nofal** on the main research findings

Time: 12:00 P.M. – 12:20 P.M.

Presentation on the 2022 North American Fenestration Standard (NAFS)

Presenters: **Brad Fevold** and **Steve Strawn**

Time: 12:20 P.M. – 12:30 P.M.

Presentation on **ASTM Standards** and **TAS 202**

Presenter: **Lynn Miller**

Time: 12:30 P.M. – 12:45 P.M.

Interim Report Final Version Discussion

Time: 12:45 P.M. – 12:55 P.M.

Meeting Adjournment

Time: 1:00 P.M.

Table 6 Lists of Meeting #3 (17th October 2024) Participants

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1	Steve	Strawn	SS	SStrawn@jeldwen.com	Y
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5	Daniel	Stein	DS	danieljordanstein@gmail.com	Y
6	Greg	McKenna	GM	greg.mckenna@arconic.com	Y
7	Becky	Magdaleno	BM	bmagdaleno@aiafla.org	Y
8	Scott	'Spiderman' Mullholland	SSM	spiderman@usbuildingconsultants.com	N
9	Mike	Silvers	MS	Silvers@floridaroof.com	Y
10	Alex	Esposito	AE	Alex_Esposito@special-lite.com	N

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11	Bradford K.	Douglas	BD	bdouglas@awc.org	N
12	Lynn	Miller	LM	LMiller@pgtindustries.com	Y
13	Omar	Amini	OA	OAmini@awc.org	Y
14	Amal El	Awady	AEA	aelawady@fiu.edu	N
15	Jovan	Millet	JM	jmillet@studioajo.com	Y
16	Kate	Wesner	KW	kate@floodcoalition.org	Y
17	Kathy	Krafka Harkema	KKH	kkrafka@fgiaonline.org	Y
18	Arindam	Gan Chowdhury	AGC	chowdhur@fiu.edu	Y
19	Ryan	Catarelli	RC	ryan.catarelli@essie.ufl.edu	Y
20	Mo	Madani	MM	mo.madani@myfloridalicense.com	Y

Meeting #3 Minutes

Presentation on Literature Review Outcomes

Presenter: **Dr. Omar Nofal**

Dr. Omar Nofal welcomed participants to the session and presented his research findings based on the standards review, FEMA MAT reports findings, and Experimental testing at the WOW EF and UF focused on reviewing the standards for WDR intrusion through the tracks of SGDs during hurricanes.

- He **outlined** the session's primary objectives, emphasizing the importance of evaluating the effectiveness of existing standards and identifying areas for improvement. Dr. Nofal stressed that enhancing building resilience and occupant safety during extreme weather events was a key focus of the discussion.
- He **presented** the concerning parts in the current standards based on the **FEMA MAT** report from previous hurricanes including Hurricane Ian and Hurricane Michael which showed significant water intrusion through SGDs. FEMA in both reports explicitly stated that the current standards testing requirements may not adequately address water infiltration, especially concerning limiting the infiltration of ~~wind-driven rain~~WDR, and more comprehensive water intrusion testing requirements are needed to improve the overall performance SGDs,

- Dr. Nofal also presented the review of experimental tastings that have been conducted on SGDs at FIU and UF testing. These tastings indicated that WDR intrusion is possible through systems (such as windows and SGD) when wind and rain parameters including turbulence are more realistically and holistically simulated in the experiments. The wind turbulence can also cause window/door components and connections to vibrate and/ or deflect/deform. causing WDR intrusion.
- A summary of the literature review was provided to serve as a base for the draft final report recommendations.

Presentation on the NAFS 2022 Edition

Presenters: **Brad Fevold** and **Steve Strawn**

The presenters provided an in-depth overview of the NAFS (AAMA/WDMA/CSA 101/I.S.2/A440), focusing on its 2022 edition, which was published in 2023 and referenced in the 2024 International Residential Code (IRC) and International Building Code (IBC). The NAFS-22 document, consisting of 149 pages (111 pages of content and 38 pages of commentary), served as a guideline for testing fenestration products, including SGDs.

Key points discussed included:

- The necessity for exterior windows and sliding doors to be tested by approved independent laboratories and to bear labels indicating compliance with applicable standards.
- Labeling requirements, including manufacturer information, performance characteristics, and approved inspection agencies, ensuring traceability to both the manufacturer and the product.
- Exceptions to water infiltration testing, particularly for door assemblies in non-habitable areas designed to accommodate water infiltration and for those with a roof overhang ratio of 1 or more.

The presenters elaborated on **Clause 0.2.5** of **NAFS-22** (CSA Group et al. 2022), which addressed water penetration testing. They noted that minimum water penetration resistance test pressures had to meet specific requirements for different performance grades (PG), such as:

- Performance Classes R, LC, and CW require a minimum test pressure of at least 15% of the positive Allowable Stress Design (ASD) pressure.
- Performance Class AW requires an increased minimum of 20%.

In discussing **Clause 4.6.3.4**, the presenters highlighted that the PG rating for a product could be limited by structural performance rather than water penetration resistance. They noted that such limitations could appear on the product label using a Secondary Designator. Secondary Designators can be used to test products to a higher level of water penetration resistance. For example, areas that receive greater amounts of rain, including ~~wind-driven rain~~WDR, tropical storms, or hurricanes.

The presenters concluded by emphasizing the importance of water infiltration testing to help provide in ensuring product durability during extreme weather events. They explained that the 2022 edition of NAFS aimed to harmonize practices across North America, improving consistency in testing procedures and product classification.

Presentation on ASTM Standards and TAS 202

Presenter: Lynn Miller

- Lynn Miller discussed key ASTM standards related to water penetration testing of SGD and other exterior components. He focused on the ASTM E331-00 (2016) test method, which evaluates the water penetration resistance of these elements under static air pressure conditions. This test ensures that components can withstand exposure to water and air pressure differentials, simulating severe weather conditions.

Points addressed:

- **ASTM E331-00 (2016):** This standard, referenced in NAFS-22 for AW Performance Grade products, demanded the highest performance level. Miller explained the test setup, which involved specialized equipment, including a test chamber, an air system, and a pressure-measuring apparatus. He emphasized the need to maintain constant airflow and precise pressure measurements during testing to ensure reliable results.

- **Water-spray System:** Miller described how the system had to deliver water uniformly across the test specimen at a minimum rate of 3.4 liters per square meter per minute to accurately replicate heavy rainfall conditions.

- He also discussed **ASTM E547-00 (2016)**, which assesses water penetration resistance under cyclic air pressure, using similar test setups to simulate real-world conditions for SGD during storms.

- He concluded by highlighting **TAS 202-94 (2007)**, a mandatory standard for products sold within the High Velocity Hurricane Zone (HVHZ). These standard outlines essential guidelines for evaluating the performance of building components regarding water testing, specifying that components must endure a minimum water pressure equivalent to 15% of the positive ASD pressure for **15 minutes**.

- He emphasized the importance of rigorous testing to ensure the durability and safety of SGDs and other fenestration products in hurricane-prone areas.

Interim Report Final Version Discussion

Dr. Nofal led the discussion on the latest version of the interim report from 12:45 P.M. to 12:55 P.M. Participants provided feedback and insights on the report, which aimed to summarize findings from the testing and standards review process.

Meeting Adjournment

The meeting adjourned at 1:00 P.M., with Dr. Nofal thanking all participants for their contributions and engagement in the discussions.

APPENDIX D: MEETING #4 MINUTES – 24TH OCTOBER 2024

SUMMARY IN BRIEF

Agendas

Date: October 24, 2024

Time: 12:00 P.M. -12:40 P.M. (Eastern Time)

Location: Online (Virtual Meeting)

Meeting Summary

Date: October 24th, 2024

Meeting Overview: A discussion on an aftermarket water intrusion mitigation device test result, including some observations data from Hurricane Milton.

- Comparison with FIU's shutter report and related methodologies.
- Observations from residents and building managers of the Edition and Asher buildings in Tampa, FL.

Location: Virtual Meeting on Zoom

Table 7 Lists of Meeting #4 (24th October 2024) Participants

#	First Name	Last Name	Abbrev.	Contact	Present
1	Steve	Strawn	SS	SStrawn@jeldwen.com	Y
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6	Greg	McKenna	GM	greg.mckenna@arconic.com	Y
7	Becky	Magdaleno	BM	bmagdaleno@aiafla.org	N
8	Scott	'Spiderman' Mullholland	SSM	spiderman@usbuildingconsultants.com	N
9	Mike	Silvers	MS	Silvers@floridaroof.com	Y
10	Alex	Esposito	AE	Alex_Esposito@special-lite.com	Y
11	Bradford K.	Douglas	BD	bdouglas@awc.org	N
12	Lynn	Miller	LM	LMiller@pgtindustries.com	Y

13	Omar	Amini	OA	OAmini@awc.org	Y
14	Amal El	Awady	AEA	aelawady@fiu.edu	N
15	Jovan	Millet	JM	jmillet@studioajo.com	Y
16	Kate	Wesner	KW	kate@floodcoalition.org	N
17	Kathy	Krafka Harkema	KKH	kkrafka@fgiaonline.org	Y
18	Arindam	Gan Chowdhury	AGC	chowdhur@fiu.edu	Y
19	Ryan	Catarelli	RC	ryan.catarelli@essie.ufl.edu	Y
20	Mo	Madani	MM	mo.madani@myfloridalicense.com	Y
21	Mark	Fisher	MF	fsh7036@gmail.com	Y

Meeting #4 Minutes

The meeting focused on two primary topics: a presentation by an aftermarket device manufacturer, followed by a discussion led by Dr. Omar Nofal on the progress of the final report draft. The manufacturer of the aftermarket water intrusion mitigation device showed the capability of his mitigation devices based on studies that have been done internally by an engineering firm.

Discussion Points and Key Recommendations

Several strategic concerns were addressed, particularly related to funding, policy, and certification:

- **Costing and Testing:** The consensus was that private manufacturers should bear the costs of their ~~own~~ testing, shifting to percentage-based benchmarks for success rather than pass/fail models.

- **Certification:** Although the standards did not provide an approach to test aftermarket devices, the FBC provides a process to test these devices through the Florida product approval system. Approved agencies (e.g., registered design professionals) can come up with compliance criteria to test aftermarket devices and the building official can approve the test as deemed complied ~~in respect to~~concerning quality and manner for new assemblies as provided in FBC section 104.11.

Meeting Adjournment

The meeting was adjourned at 12:40 PM, with **Dr. Nofal** thanking all participants for their contributions and engagement in the discussions.

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Appendix E: MEETING #5 MINUTES – 31ST October 2024

SUMMARY IN BRIEF

Date: October 31, 2024

Time: 2:00 PM - 3:00 PM EST

Location: Online (Virtual Meeting)

Table 8 Lists of Meeting #5 (31st October 2024) Participants

#	First Name	Last Name	Abbrev.	Contact	Present
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6	Greg	McKenna	GM	greg.mckenna@arconic.com	Y
7	Becky	Magdaleno	BM	bmagdaleno@aiafla.org	N
8	Scott	'Spiderman' Mullholland	SSM	spiderman@usbuildingconsultants.com	N
9	Mike	Silvers	MS	Silvers@floridaroof.com	Y
10	Alex	Esposito	AE	Alex_Esposito@special-lite.com	Y
11	Bradford K.	Douglas	BD	bdouglas@awc.org	N
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14	Amal El	Awady	AEA	aelawady@fiu.edu	N
15	Jovan	Millet	JM	jmillet@studioajo.com	Y
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18	Arindam	Gan Chowdhury	AGC	chowdhur@fiu.edu	Y
19	Ryan	Catarelli	RC	ryan.catarelli@essie.ufl.edu	Y
20	Mo	Madani	MM	mo.madani@myfloridalicense.com	Y
21	Mark	Fisher	MF	fsh7036@gmail.com	Y

Meeting #5 Minutes

1. Call to Order: The meeting was called to order by Dr. Nofal at 2:00 PM. The primary objective was to review the draft report and solicit feedback from all attendees.

2. Key Discussion Points

- **Report Clarity and Structure:**
    - **A TAC member** emphasized the need for clear objectives throughout the report, suggesting that specific goals be outlined at the beginning to guide readers and enhance coherence.
    - **Another TAC member** echoed this sentiment, urging that the structure should facilitate understanding of the report's findings.
- **Incorporation of ~~Wind-Driven Rain~~WDR Maps:**
    - **A TAC member** discussed the critical role of WDR maps in the report, arguing that visual representations could significantly enhance comprehension.
    - **Dr. Nofal** argued that these maps are still not available to be included.
- **Development of Actionable Recommendations:**
    - **A TAC member** insisted that the recommendations outlined in the report must be realistic and actionable, emphasizing the need for them to be achievable within current practices.
    - The group discussed strategies to ensure recommendations were practical and aligned with industry standards.
- **Defining the Target Audience:**

Dr. Nofal highlighted the necessity of identifying the report’s target audience, noting that understanding who will utilize the report is essential for tailoring the content effectively.

- The team agreed that defining the audience would help refine the language and focus of the recommendations.

- **Collaboration for Data Integration:**
    - **Kathy Krafka Harkema** volunteered to reach out to **Art Degatano** for additional data sources that could support the report’s findings.

- **Marvin** and **Mo Madani** discussed the importance of collaboration among team members to integrate various data sets effectively.

3. Next Steps

- **Attendees** were asked to submit their comments and feedback on the draft report by **Wednesday, November 6, 2024**.

4. Conclusion: Dr. Nofal thanked all participants for their valuable input and contributions during the meeting. The collective feedback will be instrumental in refining the report and ensuring its effectiveness.