

What (Not) to Expect When You Are Expecting New Fenestrations

— A Case Study

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Figure 1. View of the case study building.

When working in a particular industry for an extended length of time, an individual may begin to think that they have seen it all. The knowledge gained over valuable years of experience comes through a variety of circumstances and trying projects. But at times, there are those projects that leave even the most experienced and knowledgeable individuals shaking their heads in disbelief. Notwithstanding, attempting to provide plausible engineering reasoning and reassurance to a group of laypeople that their newly installed fenestrations will perform and function as designed can be a challenge.

The focus of this case study is just that. For a repair project, the scope of work was considered

to be fairly straightforward: remove and replace the existing windows and sliding glass doors and perform water penetration testing to confirm proper installation at an oceanfront high-rise building that was approximately 25 years old. As design professionals and building enclosure consultants, we may become complacent due to the simplicity of this type of repair that has been designed and executed countless times in the past. However, as such individuals, we should be mindful of the axiom “expect the unexpected.” When unexpected issues cause the proverbial head shake for experienced and knowledgeable design professionals and building enclosure consultants, the issues demand attention.

THE CASE STUDY

Those who have a background of working on new construction and renovation projects in

coastal environments—especially those located on hurricane-prone coastlines—understand the unique set of challenges with the design and installation of new windows and sliding glass doors. As building codes and standards keep evolving, so do the minimum requirements regarding the design of fenestrations. High winds, high relative moisture, and salt-laden air produce a harsh environment that requires careful design to minimize corrosion and damage.

For this particular case study, the high-rise structure is located in a harsh oceanfront environment that produces significant hurricane-level wind speeds (Figure 1). Compounded with the high relative moisture and salt-laden air, the new fenestrations will have to be robust enough to not only adequately transfer the load of the code-prescribed wind pressures to the structure, but also minimize



Figure 2. View of water penetration testing.

the potential of corrosion. Since the existing fenestrations had exceeded their service life expectancy, the recommendation to replace all the fenestrations was unanimously approved by the homeowners' association.

The existing fenestrations were replaced with new architecturally and code-compliant fenestrations consisting of extruded aluminum frames with a bronze anodized finish. The fenestrations were impact-resistant, insulated glazing (IG) units that included tempered glass and heat-strengthened glass with a low thermal emissivity coating. As with most repair projects of this nature, a water penetration testing program was established by the design professional and building enclosure consultant, in accordance with published industry standards. The testing program would demonstrate the adequacy and proper installation methods of the new fenestrations. But contrary to what was expected, the collective team of design professionals, contractors, and owners was introduced to a series of water penetration issues that were unexpected. This was in addition to a full investigation and analysis into unforeseen glass surface blemishes (in the form of scratches) following the completion of the repair project.

WATER PENETRATION TESTING

The topic of water penetration testing has been discussed meticulously over the years by experienced and knowledgeable individuals in the construction industry. These discussions have typically been focused on common issues frequently observed, and they provide different methods to reduce the chance repetition of

such an issue. But in the event of observing anomalous water penetration testing issues, where should one look for guidance? In an effort to provide some context to this question, a brief overview of water penetration testing is required.

A Brief Overview

Fundamentally, the intent of the commercial and residential codes (building codes) is to provide the design professional, building enclosure consultant, and contractor with the minimum requirements to which a building and its fenestrations must be constructed. The building codes include both prescriptive and performance-based requirements that provide methods for installation and testing of fenestrations, based on standards produced from industry groups, which include the American Architectural Manufacturers Association (AAMA), Window & Door Manufacturers Association (WDMA), Canadian Standards Association (CSA), and American Society of Civil Engineers (ASCE). The code-referenced standard, AAMA/WDMA/CSA 101/I.S.2/A440, *North American Fenestration Standard / Specification for Windows, Doors, and Skylights*,



is used in the testing and rating of windows and doors and is internationally accepted as the performance standard/specification.

ASTM International (ASTM) developed and produced the technical standard ASTM E1105, *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference*. The scope of this standard includes test methods that determine the resistance of window and door components to water penetration testing when subjected to an air pressure differential across the cross section of the product (Figure 2). The air pressure differential across the fenestration system is created by a sealed chamber, installed either from the

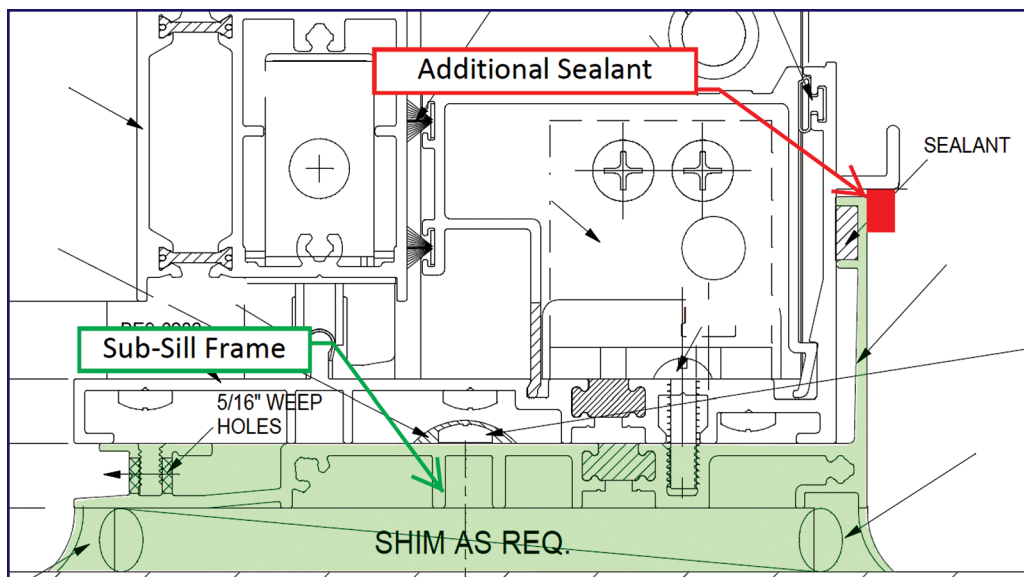


Figure 3. View of location of sealant.

interior or exterior, that includes an air source that supplies air (positive pressure) or exhausts air (negative pressure) at a required calculated rate while simultaneously spraying water onto the exterior surface of the fenestration system.

The scope of AAMA 502, *Voluntary Specification for Field Testing of Newly Installed Fenestration Products*, is to establish the requirements for field test specimens, apparatus, sampling, test procedures, and test reports for verifying water penetration resistance performance of newly installed fenestration systems. This specification is applicable during construction, prior to issuance of the building occupancy permit, but no later than six months after installation. It should be noted that the fenestration products defined with AAMA 502 are based on the requirements of AAMA/WDMA/CSA 101/I.S.2/A440. The test methods outlined within this water penetration reference standard are required to be in general accordance with ASTM E1105.

If water intrusion is observed during testing, and the source of the leakage cannot be readily determined, a forensic evaluation using the procedures outlined in AAMA 511, *Voluntary Guideline for Forensic Water Penetration Testing of Fenestration Products*, shall be performed while maintaining the test pressures and the methods defined in AAMA 502. It should be noted that the AAMA 511 forensic evaluation of fenestration systems is often not included in testing protocols.

ASTM developed and produced the technical standard ASTM E2112, *Standard Practice for Installation of Exterior Windows, Doors and Skylights*. This standard provides specifications regarding the installation of new and existing fenestration systems, as well as commentary

about field testing fenestration systems as a quality assurance procedure or proof of compliance with project specifications. Specifically, the installer shall be familiar with the procedures and requirements outlined with both the ASTM E1105 and AAMA 502 water testing standards.

CASE STUDY: WATER TESTING ISSUES AND SOLUTIONS

Most design professionals, building enclosure consultants, and contractors understand that repair projects often offer an array of atypical issues. Results from the water penetration testing performed during this particular repair project presented eight different types of failures among fourteen water penetration tests. The majority of the water penetration issues found were easily identifiable and resolved. However, there were subsequent issues that required further research to provide a confidence level to the collective team—design professionals, building enclosure consultants, contractors, and owners—that the new fenestrations would function as intended.

Water Testing Issue #1

Fenestration systems installed in areas of high wind speeds, such as a hurricane-prone coastline, need to be designed to adequately transfer the wind pressures to the main structural elements of a building. Typical storefront window and door systems are not necessarily designed to properly transfer this type of high loading without supplemental reinforcement. In order to provide windows and sliding glass doors with sufficient support to adequately transfer the wind load, an independent structural sub-framing was installed at the head and

sill with the new windows and doors simply snapped into the sub-framing.

During a water penetration testing session, a sliding glass door with an architectural window (AW) product performance class was subjected to Procedure 'A' of AAMA 502. During the 15-minute static-air water penetration resistance test, evidence of water leakage was observed at the intersection of the fenestration-to-sub-sill framing. When the two different framing systems are intimately joined together, it is critical to ensure that the joints are properly sealed to prevent water intrusion. For this particular repair project, the critical location was at the rear vertical leg of the sub-sill where a bead of sealant was installed into a prefabricated slot

to ensure intimate contact with the fenestration framing (Figure 3). However, during installation, the fenestration framing can move slightly, creating small voids or holes in the sealant. These small voids or pinholes can be exposed during water testing, especially when the interior chamber pressure is significant.

Following discussions with the manufacturer and contractor, an additional bead of sealant was installed on the exterior surface of the fenestration-to-sub-sill intersection. This supplemental bead of sealant was then installed at all previously installed and newly installed sliding glass door locations, resulting in a mode of failure that was not observed during subsequent water penetration testing. Though these types of fenestrations experience rigorous manufacturer laboratory testing, unforeseen errors in the installation can result in the potential of future water intrusion issues, if left in an uncorrected condition.

Water Testing Issue #2

As discussed previously, when two different framing systems are intimately joined together, such as the sub-framing and fenestration framing, it is critical to ensure that the joints are properly sealed to prevent the occurrence of water intrusion. In an effort to prevent water intrusion, supplemental sealant will be installed where the sub-framing terminates adjacent to the fenestration framing. For example, sealant will be installed between the sub-sill end dam and jamb mullion of the fenestration frame.

During a water penetration testing session, evidence of water leakage was observed at the intersection of the sub-sill end dam and fenestration jamb of one of the sliding glass doors (Figure 4). Closer examination of these intersections did not exhibit any open gaps or

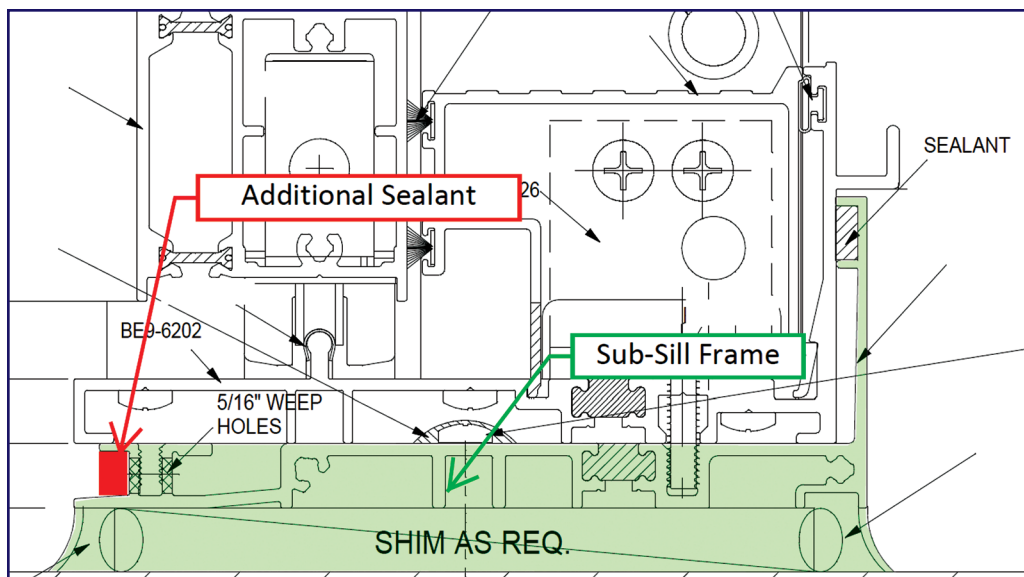


Figure 4. View of location of sealant.

holes in the sealant following the water penetration testing. The manufacturer's design of the sub-sill included the installation of weepholes to allow for any incidental water to exit.

Following extensive discussions with the manufacturer and contractor, it was concluded that the weepholes located within the sub-sill needed to be closed with a bond breaker and sealant. Though the sub-sill was designed with weepholes, the incidental water drawn into the sub-sill during water testing was not being purged, thereby creating a head of water within the sub-sill and subsequently overtopping the back dam. The installation of the new sealant over the weepholes of the sub-sill would create a barrier-type system as an alternative to the originally designed drainage system. This supplemental bond breaker and sealant system was installed at all previously installed and newly installed sliding glass door locations. Subsequent water penetration testing was not able to recreate this specific type of water leakage. It should be clearly noted that this type of change could be considered an undesirable consequence and a potentially problematic maintenance issue for the owner. However, by working with the manufacturer, specific design changes could be implemented on future fenestration systems.

Water Testing Issue #3

Standard AAMA/WDMA/CSA 101/I.S.2/A440 defines performance class requirements for fenestration systems based on the minimum performance grades, design pressures, uniform load structural test pressures, and water penetration resistance test pressures. The pressure used during water penetration resistance testing is defined in the standard as two-thirds of

15% of the rated laboratory performance. For example, a fenestration with an 80 psf rated laboratory performance would be tested with a chamber pressure of eight pounds per square foot ($80 \text{ psf} \times (2/3) \times 0.15 = 8.0 \text{ psf}$). Therefore, the test chamber pressure is proportionate to the rated laboratory performance pressure.

Depending on the rated laboratory performance, the pressure differential across a fenestration system can be magnitudes different. As such, small voids and pinholes in the sealant can be exposed during water penetration testing due to the pressure differential across the fenestration. Though the pressure differential during a small-to-moderate wind event may not produce a substantial pressure differential between the exterior and interior, an extreme wind event (for example, a Category 4 hurricane) can produce significant pressure differentials that would allow water to penetrate to the interior in the presence of small voids and/or pinholes in the sealant.

During a water penetration testing session, the water level was observed to be increasing along the back dam of the newly installed sliding glass door. Inspection of the sealant with the use of a smoke pen following the water penetration testing concluded that a small hole in the exterior sealant joint allowed water to fill and overtop the sill pan due to the pressure differential across the sliding glass door (Figure 5). These types of small voids and/or pinholes can be caused by the thinning out of the sealant, improper tooling, or adhesion failure.

It may be difficult to observe and locate small voids and/or pinholes in the sealant during an inspection of a fenestration. These types of issues are considered to be difficult to determine in the absence of water pene-

tration resistance testing. Nonetheless, design professionals, building enclosure consultants, and contractors should be proactive in being mindful of such locations where sealant may be difficult to install in the field. This type of mindset can alleviate the potential of failure during a water penetration resistance test and instill confidence that the fenestration system will function as designed.

GLASS SURFACE BLEMISH OBSERVATIONS

Likely an unfamiliar and/or isolated issue to many design professionals and building enclosure consultants is glass surface blemishes in newly installed windows and sliding glass doors. Commonly referred to as scratches, this type of issue can result not only in an

unpleasing aesthetic effect, but may increase the possibility of localized glass failure during high-wind events due to the cross-sectional loss of material. Though this topic has not been discussed within the industry as frequently as water penetration testing, there are specific standards and guides that provide assistance in determining the degree and severity of a blemish that dictates the type of repair recommendations, if considered to be necessary.

A Brief Overview

As a starting point, it should be noted that the building codes do not provide any assistance with reference to glass surface blemishes. Therefore, design professionals and building enclosure consultants are compelled to rely on the industry standards and guidelines that are considered to be relevant to glass surface blemishes.

The Insulating Glass Manufacturers Alliance (IGMA) has developed and produced the technical guideline TM-3100-09, *Voluntary Guidelines for the Identification of Visual Obstructions in the Airspace of Insulating Glass Units*. The scope of these guidelines is to assist in determining the criteria for observing visual obstructions for sealed IG units. A visual obstruction is defined by the IGMA guidelines as "anything located inside the sealed insulating glass unit that unintentionally and materially inhibits a person's view through the glazed daylight opening from either interior-to-exterior or exterior-to-interior, when inspected." Examples of visual obstructions include adhesive residue, desiccant dusting, dirt/debris, fingerprints, fogging, blemishes, and optical effects. The IGMA guidelines provide commentary regarding the inspection and

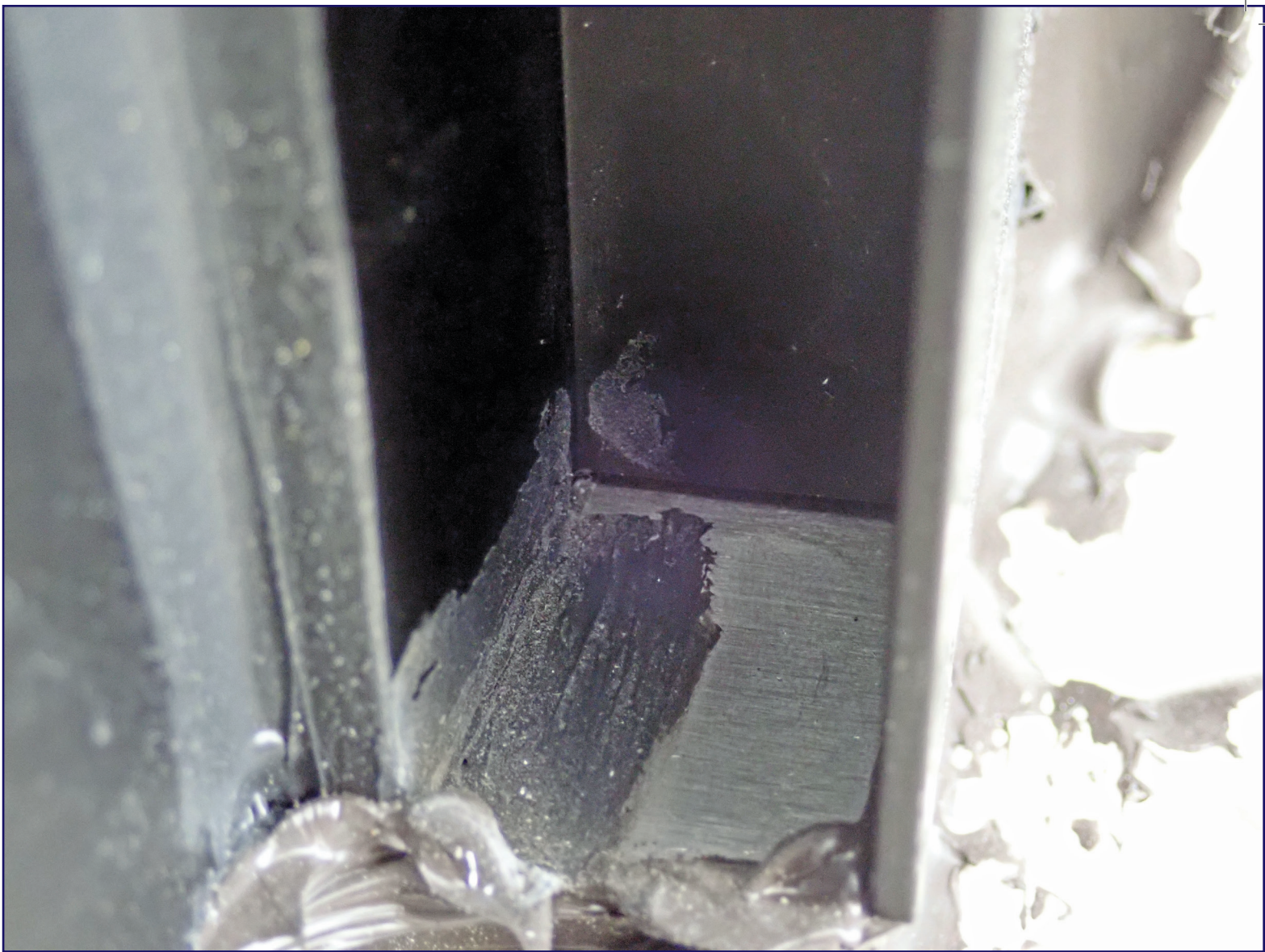


Figure 5. View of thinned-out sealant and void.

conformance requirements of the observed visual obstructions. Specifically, the guidelines state that the glass is to be inspected from a distance of 10 ft. at a viewing angle of 90° against a bright, uniform background.

ASTM has developed the technical standard ASTM C1036, *Standard Specification for Flat Glass*. The scope of this standard is to provide specification regarding quality requirements of flat, transparent, clear, and tinted glass for use in architectural glazing products (for example, coated glass, IG units, and laminated glass). This standard includes prescriptive test methods for the detection of linear blemishes (for example, scratches, rubs, and digs) on the top surface (exterior side) of the glass. Section 6.1.1, Test Methods, of ASTM C1036 states that the viewer shall be

positioned perpendicular to the glass surface using daylight (without direct sunlight) or other uniform diffused background lighting (**Figure 6**). The viewer must have 20/20 vision (naked eye or corrected). Additionally, Section

6.1.1.3 of of ASTM C1036, *Detection for Linear Blemishes (Scratches, Rubs, Digs, and other Similar Blemishes)*, states that the glass shall be viewed at a distance of 3.3 m (130 in. or 10.8 ft.). The inspection of the glass shall progress

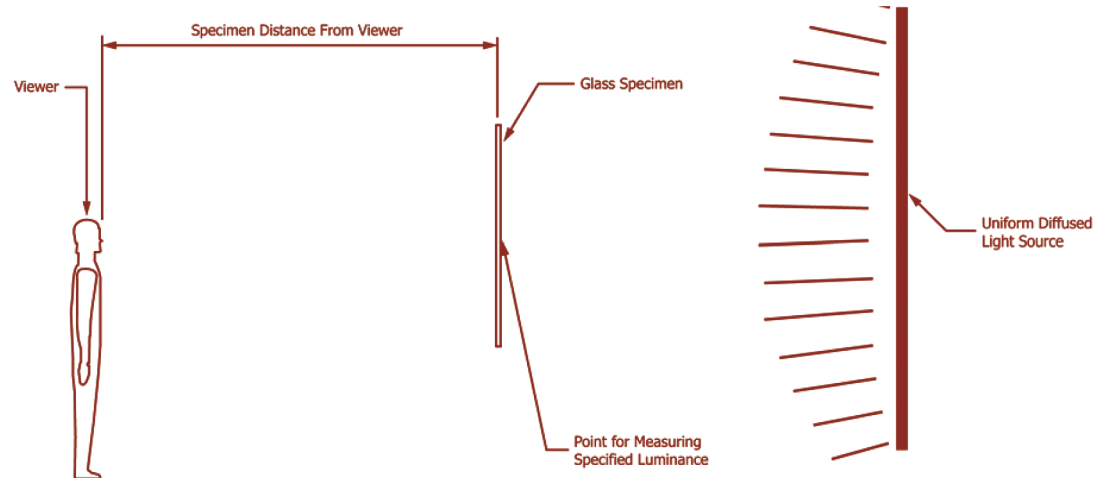


Figure 6. Viewer position from ASTM C1036, Standard Specification for Flat Glass.

Detection Distance	Blemish Intensity
3.3 m (130 in.)	Heavy
1 m (39 in.)	Medium
0.2 m (8 in.)	Light
Less than 0.2 m (8 in.)	Faint

Figure 7. Viewer distances; from ASTM C1036, Standard Specification for Flat Glass.

sequentially to each of the shorter distances for other applicable blemish intensities. The blemish intensity is based on the detection distance (Figure 7). Any blemishes detected from these distances shall be compared with the length and separation criteria for allowable blemishes (Figure 8).

The scope of ASTM C1048, *Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass*, is to provide requirements for monolithic, flat, heat-strengthened, and fully tempered coated and uncoated glass produced on a horizontal tempering system used in general building construction and other applications. This standard includes prescriptive test methods for the detection of linear blemishes (for example, scratches, rubs, and digs) on the top surface of the glass. Specifically, Section 10.5, Blemish Detection for Linear Blemishes (Scratches, Rubs, Digs and Other Similar Blemishes), references ASTM C1036 for the required test methods and evaluation criteria for linear blemishes on fully tempered flat glass.

CASE STUDY: GLASS SURFACE BLEMISH ISSUES AND SOLUTIONS

After substantial completion of the repair project, several of the newly installed windows and sliding glass doors were identified to have various types and intensities of glass surface blemishes. An inspection protocol was established and performed in general accordance with ASTM C1036 as a guideline to identify the type and intensity of glass surface blemishes. Specifically, all the fenestrations were observed from three different distances, perpendicular to the glass with sufficient backlighting, in an effort to identify all surface glass blemishes.

As previously discussed, the new windows and sliding glass doors are considered to be architectural glass products with impact-resistant IG units that include tempered glass and heat-strengthened glass. Based on ASTM C1036, the classification of the glass is Type 1, Class 1 (transparent and clear flat glass), and it is of Quality Q3 (architectural glass products). Based on the classification of the glass for the subject fenestrations, ASTM C1036 details the allowable blemishes for Quality-Q3 glass.

During the visual inspection, a combination of medium and heavy blemishes were identified on the top surface of the individual IG unit panels for the windows and sliding glass doors (Figure 9). Several of the glass panels were observed to have one linear blemish, while several of the glass panels were observed to have a series or grouping of closely spaced linear blemishes. Of the 300 individual IG unit panels observed within all of the windows and sliding glass doors, 29 glass panels required removal and replacement with new IG units.

As part of the original recommended outline scope of repair following the inspection of the windows and sliding glass doors, any identified medium-surfaced glass blemish that was considered to be allowed by ASTM C1036 could be polished. Based on preliminary research, the design professional understood that the polishing technique was proven to be an effective repair for light- to medium-surfaced glass blemishes. However, supplemental research and discussions with regard to this repair technique resulted in an issued addendum that revised the scope of repair to include all IG units with a medium-surfaced glass blemish to be removed and replaced. This revision was determined on the premise that there is a likelihood that a reduction in the cross-sectional thickness of the glass could result in failure or breakage due to the significant wind pressures produced during a high-wind event.

CONCLUSIONS

When individuals believe that they have seen it all, given very similar scope-of-repair work scenarios, there are those projects that

Linear Blemish Size ^A Intensity Length	Q1 Quality 1 Distribution	Q2 Quality 2 Distribution	Q3 Quality 3 Distribution	Q4 Quality 4 Distribution
Faint ≤ 75 mm (3 in.)	Allowed with a minimum separation of 1500 mm (60 in.)	Allowed with a minimum separation of 1200 mm (48 in.)	Allowed	Allowed
Faint > 75 mm (3 in.)	None allowed	None allowed	Allowed	Allowed
Light ≤ 75 mm (3 in.)	None allowed	Allowed with a minimum separation of 1200 mm (48 in.)	Allowed	Allowed
Light > 75 mm (3 in.)	None allowed	None allowed	Allowed	Allowed
Medium ≤ 75 mm (3 in.)	None allowed	None allowed	Allowed with a minimum separation of 600 mm (24 in.)	Allowed
Medium > 75 mm (3 in.)	None allowed	None allowed	None allowed	Allowed
Heavy ≤ 150 mm (6 in.)	None allowed	None allowed	None allowed	Allowed with a minimum separation of 600 mm (24 in.)
Heavy > 150 mm (6 in.)	None allowed	None allowed	None allowed	None allowed

Figure 8. Blemish criteria from ASTM C1036, Standard Specification for Flat Glass.

remind them that unforeseen issues or a combination of issues are within the realm of possibility. As a reminder, this project was presumed to be fairly straightforward: remove and replace the existing windows and sliding glass doors, and perform water penetration testing to confirm proper installation at an ocean-front high-rise building that was approximately 25 years old. As it would happen, a mixture of issues presented themselves throughout this project, including a multitude of water penetration issues, compounded with the egregious glass surface blemish issue, that forced the collective team of design professionals, building enclosure consultants, and contractors to research and develop

alternative repair solutions. In an attempt to instill confidence in an owner that their new windows and sliding glass doors were properly


installed, design professionals and building enclosure consultants need to be reminded to always expect the unexpected. 



Figure 9. Views of glass surface blemishes (highlighted with red).

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The Biden Administration and Construction



Photo by Andy Feliciotti on Unsplash

In his first few days in office, President Joe Biden made several executive orders related to the construction industry, many of them simply revoking executive orders created by his predecessor. Here's a quick rundown of a few of them.

Paris Climate Agreement: President Joe Biden signed an executive order beginning the 30-day process for the US to reenter the global pact. The US was the only country who had formally withdrawn from the pact since it was adopted.

Biden also plans to host a climate summit of world leaders on Earth Day, April 22, where he will roll out the US' goal for reductions of carbon emissions by 2030, known as the nationally determined contribution under the Paris accord.

Department of Energy: Former Governor Jennifer Granholm, known for pushing clean energy technologies, was confirmed by the Senate to serve as the 16th Secretary of Energy. She is expected to champion Biden's campaign promises which include a push for a "100% clean energy economy," for the United States to reach "net-zero emissions no later than 2050," and for a "historic investment in clean energy and climate research and innovation."

Coronavirus: OSHA maintains a website that reflects developments in science, best practices, and standards. www.osha.gov/coronavirus/safework.