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Steel Window Restoration: Effective Strategies for Restoring and Upgrading Historic Steel Windows

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Fig. 1.
Floyd Bennett Field Hangar, 3159 Flatbush Avenue, Brooklyn, New York, built 1928, showing upgraded steel windows, 2016. All photographs by Femenella & Associates, unless otherwise noted.

The fenestration of historic buildings is a focal point and often the defining feature of a building's style and period (Fig. 1). Steel windows may be looked upon as replaceable and not worth the effort of conservation. This is especially true of the mass-produced rolled-steel windows manufactured from the end of the nineteenth century through the mid-twentieth century found in commercial, residential, industrial, and institutional buildings throughout the United States.

One of the primary reasons that historic steel windows are often replaced is the presumption that they cannot be made more energy efficient. Another is the fact that there are myriad replacement options on the market, including aluminum and new steel windows. However, the sightlines, proportions of elements, profiles, and shadow lines of many of the modern replacements do not match the details of the original windows. Hence, the substitution of replacement windows can result in the loss of the original character of the building.

Windows that are original to the building also tend to fit their openings more consistently than replacement windows. Replacement window perimeter sealant joint sizes are typically 25 to 50 percent larger than the originals, altering the overall aesthetic of the façade. When classified by size and operation, a building can have 20 or 30 different types of windows. Some may vary in size only by ½ inch or less from type to type. The more window types a project includes, the more expensive it is to replace them, and a significant number of types may be eliminated through value engineering. For example, if two window types are identical except that a single dimension exceeds the required size by ¼ inch, the outlier is often eliminated and the smaller window installed in its place. While this reduction in types extrapolated over the entire project yields minimal savings, it also increases the reveal of the sealant in elevation in a typical fashion.

Beyond the aesthetic benefits of restoring steel windows, the repair and/or retrofit of existing steel windows is often more economical than complete replacement. Some purchasing ramifications, such as trade tariffs or carbon credits, should also be considered in this decision. Nevertheless, there are situations in which window replacement makes sense, such as in buildings where the original windows are not character-defining features and good replacements with higher energy efficiencies are available. A new purchase can also be considered when the windows have deteriorated to the point where restoration (and potential abatement of any hazardous materials found) would not be economically feasible.

The purpose of this *Practice Point* is to assist building owners and dedicated preservation professionals in assessing the role of steel windows in preserving the character of a building, deciding whether restoration is appropriate, preparing for and undertaking restoration, and increasing energy efficiency.

Brief History

The first metal windows were fabricated by medieval blacksmiths in England and other parts of Europe using wrought iron. Because large sheets of glass were unavailable and glass itself was precious, these metal windows were typically glazed with leaded-glass panels—small glass diamonds or squares (quarries) held together with lead cames. Most were fixed units, but blacksmiths with greater skill could produce operable sections within the frame, typically casements (hinged on the left or right jamb) or center-pivot sash.

In the mid-seventeenth century, changes in architectural design featuring Palladian fenestration favored windows made of wood because of their moldings and varied profiles. In the mid-eighteenth century, advances in metal casting allowed factories to fabricate cast-iron windows with greater detail. Detailing once limited to wood windows—such as glazing bars with rounded edges, ovolo moldings, and other ornate perimeter moldings—could be carved into the wood pattern used to make the mold for the cast iron. This enabled manufacturers to offer details and profiles previously found only in wood sash.

In England in 1856, Sir Henry Bessemer developed a process to produce hot-rolled steel on a high-volume basis. The Bessemer process was so effective that it became a major driver of the Industrial Revolution. The process came to the United States soon after its introduction in Great Britain, but was not widely used until the 1890s, when technical refinements allowed for the mass production of steel windows.[1] Demand for steel windows increased after numerous deadly fires in major cities across the United States and Canada led to strict new fire codes. Steel's strength allowed architects to design expansive walls of windows, adding delicate architectural details to the exterior while flooding interiors with light—similar to the flying buttress, which enabled medieval builders to enlarge the stained-glass windows of cathedrals.

At first, steel windows mimicked wood design, including single-hung and casement windows. Additional designs soon appeared, made possible by steel's strength and slender profiles. These included center-pivot, hopper, projecting, and austral-style windows, the last characterized by an upper sash projecting outward and a lower sash projecting inward. In factories and large institutional buildings, long banks of projecting windows were connected to crank-type operating systems, often referred to as continuous-window systems, allowing large spaces to be ventilated efficiently.

Preliminary Tasks

When analyzing a project, the first step is to determine whether the windows should be restored or replaced. It is essential to work with a preservation professional familiar with the style and period of the building to assess whether the steel windows are a character-defining feature whose loss would diminish the aesthetic or confuse the building's original design intent. Major differences between historic steel windows and new steel or aluminum replacements relate to the scale and dimensions of the new window members—stiles, muntins, mullions, shadow lines, and so on. Even if the building's use changes (e.g., from manufacturing to residential), if the windows are central to its historic character, they should be retained and restored. Surface rust should not deter restoration, as it usually looks worse than it is because oxidized steel is much thicker than the original metal. Unless severe corrosion has caused major loss of material and/or complete loss of frame and sash members, restoration remains a viable option. Even when surface corrosion progresses to "rust jacking," where expansion causes displacement, restoration can often still be successful and economical.

Once restoration is chosen, during project planning two key factors must be considered: whether to repair the windows in place or remove them to a shop, and the safety protocols for handling hazardous materials.

In situ vs. removal. With few exceptions, any task that can be performed in situ with average results can be performed in a shop with superior results. This has partly to do with the windows' work position—vertical versus horizontal—which makes the work far easier. Removing the surrounding construction also eliminates obstacles, a benefit so valuable to the final product that it cannot be ignored. Once the desired finish quality is determined, it is important to determine whether the work can realistically be done in situ.

In-situ work is often limited by the windows' surrounding environment. Access, weather, and adjacent construction activities are all limiting factors. Preservation literature from the early 1980s suggests that racking repairs can be performed in situ.[2] From a contractor's perspective, this is impractical. Designing an intricate cable system for a specific window type, engineering all attachment points for safety, applying controlled pressure, and leaving the window undisturbed for days—while also preventing water infiltration—can strain any schedule or budget. Some repairs, including de-racking, require hot work such as welding, cutting, grinding, and soldering. These activities require permits and strict compliance with safety regulations, including mandatory fire watches.

De-racking in situ is a complex task that makes delivering consistent quality difficult. In contrast, a restoration shop provides a controlled environment, allowing for optimal results and improved worker safety. This topic is discussed further in the "Restoration" section of this *Practice Point*.

Hazardous-materials safety. All original elements that will be disturbed during the work must be tested for hazardous materials. Abatement procedures for hazardous materials are mandatory and take precedence over all other methods by law. The legal requirements represent the minimum standard; owners and design teams may impose stricter protocols. Abatement is costly and can affect the overall project budget. Discovery of hazardous materials must occur before construction begins. In some cases, the law requires that the separation of the frame and subframe be performed by a certified abatement company. Close coordination during abatement is essential to prevent further damage.

The health and safety of workers are the top priorities. Disturbing even a single element of the original installation can release hazardous, friable materials, potentially causing irreversible harm. Paints, coatings, sealants, lubricants, mastics, and other materials may contain hazardous substances. Comprehensive sampling and testing are essential to detect their presence. All elements must be properly abated before any abrasive-media blasting. Failing to do so can make the hazardous materials friable and unsafe for workers.

Guidance for retrieving samples containing potentially hazardous materials includes:

- *Use of qualified personnel*. To obtain valid test results, qualified personnel are essential. Always hire a professionally certified company for this work. These services are often solicited by the owner during the design phase. Careful attention in this area enhances safety for everyone involved.

- *Sufficient sample size*. Collect samples from a variety of locations and windows where work will be performed.
- *Proper sample-retrieval technique*. All samples must be collected completely by qualified personnel. A utility knife can be used to penetrate existing sealants and remove all layers down to the substrate. For coatings, a flat glass razor is effective for sample removal. Collected samples should be sealed in containers and delivered to the testing agency.
- *Photos of retrieval locations*. Ensure all locations where samples are collected are photographed and submitted with the hazardous-materials report from the testing agency.
- *Multiple work locations*. If elements must be taken off site for repair, precautions are required. On-site abatement of removed items eliminates the need to track hazardous materials and avoids potential issues with transporting them across state lines.

Proper planning around the work site and completing hazardous materials evaluations proactively will help define the final scope of work responsibly for both the client and contractor.

Develop Scope and Magnitude

Before performing any assessment, develop a logical and comprehensive numbering system for the windows on a floor plan or elevation drawings that includes identifiers for the different parts that may need to be disassembled. Typically, this system is prepared by the design team before construction documents are issued.

Next, complete an initial window condition assessment (commonly referred to as a window survey) and develop a window repair schedule with accompanying photographs that illustrate the types and extent of problems on a window-by-window basis. While it is important to note any water infiltration through the sash or frame, the surrounding building fabric must also be thoroughly inspected. Ensure that water is being directed away from the windows and the building. Flashing details may be needed to redirect water and ensure proper drainage. Assess original design details to determine whether water shedding is effective throughout the system. Check the metal sections for bowing or twisting that may inhibit window operation. Inspect hardware such as latches, hinges, hold-opens, fasteners, and the window glass and glazing. If possible, operate the windows and note any members chafing one another, as well as areas of paint loss. Although the typical restoration may be the same for a building elevation, the level of intervention and required tasks can vary from window to window.
All of this information should be entered into a window repair schedule for use by the entire project team. This document, usually presented in spreadsheet form, is vital for tracking each unique prescription throughout the restoration process. Below are examples of categories commonly found in window schedules:

- Window number
- Facing elevation
- Dimensions
- New vs. restored (some projects are a hybrid of both)
- Hardware set
- Corrosion levels
- Glass thickness or type
- Finish notes
- Operability and type
- Quantity per type
- Hazardous-materials status
- Individual notes

Often, a subframe is keyed into the surrounding masonry where the steel frames and sash are installed. In such cases, it may be possible to restore the sash and frames off site, but the keyed subframe must be addressed in the field. The presence of a subframe should also be recorded in the window schedule.

After the initial removal of sash and frames, a second assessment of all newly exposed surfaces should be performed. Any new conditions revealed at this stage must be integrated into—or may even alter—the initial inspection goals. This step should be discussed with the owners and design team so they are prepared for issues as they arise.

Removal Process

Drawings, typically prepared by the design team, indicate which sections of the window will be removed and which will be addressed in situ.

The operable sash is usually removed first. This provides access to hidden fasteners that secure the frames and other fixed sash (non-operable sections) to the surrounding subframes. If accessibility or corrosion is an issue, many of the fasteners can be drilled or cut out. All plating and base metals for fasteners used during reassembly must be carefully selected to avoid galvanic action, an electrochemical process in which one metal corrodes preferentially when in contact with a dissimilar metal in the presence of an electrolyte.[3] In general, contact between dissimilar metals should be avoided, and dielectric isolation should be considered when dissimilar-metal contact cannot be avoided.

The order in which structural and decorative parts of steel windows are disassembled and removed is critical. Maintaining the proper removal sequence helps prevent racking or damage to supported adjacent elements. Each element receives a unique embossed-metal tag that stays with it until it is reinstalled in its original opening.

Restoration

During restoration, it is very important to keep the final product in mind. A step-by-step process can then be developed by working backwards. This approach helps manage the work, ensuring each step aligns with the next and minimizing repetition of tasks. Each stage of work should be inspected for quality and effectiveness before moving on to the next.

A typical restoration project includes the following stages:

Corrosion classification and repair. There are three levels of corrosion, each of which requires a different method of repair. These include:

- *Minor corrosion*. Minor corrosion occurs when the surface coating is lost, exposing white metal that begins to oxidize and form visible rust. Areas that have lost less than 10 percent of their original thickness and are non-systemic throughout an element are considered minor corrosion. If the edges of the affected area can be abraded and feathered down to the profile, this method, combined with the application of thicker, high-performance coatings, can sometimes be sufficient. When minor corrosion is deeper, the repair typically involves a steel-impregnated epoxy system with coefficients of expansion and contraction similar to the substrate.
- *Moderate corrosion*. As a general rule, areas that have lost more than 10 percent but less than 40 percent of their original thickness and may be systemic in frequency throughout an element are considered moderate corrosion. If repaired without epoxy filler, moderate corrosion leaves a visible depression in the finish, which distinguishes it from minor corrosion. The appropriate repair method uses a steel-impregnated epoxy system with coefficients of expansion and contraction similar to the substrate. Point loading on epoxy repairs should be avoided, as should the use of heat, such as welding or torch work. High temperatures can burn the epoxy and damage the substrate bond, causing delamination.
- *Severe corrosion*. Any area that has lost more than 40 percent of its original thickness is considered severe (Fig. 2). Severe corrosion almost always requires hot work; mechanical repairs alone are rarely sufficient. Using a plasma cutter, cut-off wheel, or torch, degraded material must be removed until solid white metal is reached. The repair typically involves a steel dutchman repair matching the original profile (Fig. 3). Dutchman repairs may also be made from a composite of commercially available materials. Some projects require precise matching of the existing profile. Special attention is needed here, as producing custom steel lengths is very costly.

Fig. 2.
Severe corrosion requiring new steel, 2011.

Fig. 3.
Completed repair of severe corrosion by replacement of missing metal, 2011.

Fig. 4.
Replacement subframe section tack-welded in position in situ, 2011.

There are several factors to consider when repairing corrosion. These include:

- *Threaded fastening points*. Assess the condition of all threaded fasteners. If corroded, weld shut, redrill, and tap the hole if the fastening location cannot be moved.
- *Subframe repair*. Subframes typically must be repaired in situ regardless of corrosion level. This involves cutting out and replacing sills and headers. Matching profiles must be fabricated. On-site, damaged sections are cut away to leave plumb, straight edges; new sections are then cut and welded in place (Fig. 4).
- *Rolled vs. cast elements*. It is important to distinguish between rolled and cast elements of an installation. Decorative cast elements of iron, aluminum, or bronze often accentuate steel windows. Cast elements have a rougher, mottled texture compared to smoother rolled members, and are more brittle. They also react differently to heat. Cast iron, in particular, can be difficult to weld. Because welds and mechanical fastenings may exert opposing stresses on castings, this approach may not always work. However, using welds together with mechanical fasteners can provide a useful safety measure; if a weld fails, fasteners can prevent injury to pedestrians below.
- *Check initial conditions*. Review the original assessment and note where standing water was present and corrosion was most severe. Lower sections of frames are often most affected because the design created water traps. These flaws can sometimes be corrected by encouraging water to shed naturally by gravity.
- *Final surface preparation and priming*. After all repairs are complete, lightly blast the steel to remove corrosion that formed during the shop work and strip older coatings that could emit hazardous fumes during hot work. This also reveals the full scope of repair. The metal should be primed immediately to prevent flash rust. The complete coating system should come from a single manufacturer, and all instructions must be followed closely. Deviation from the manufacturer's instructions may void the warranty.

High-performance coatings. The finish coating of a steel window is its lone line of defense against the elements. Once the coating breaks down, the window begins a downward spiral of deterioration. Advances in high-performance paints—especially epoxy- and fluoropolymer-based coatings—have provided effective solutions for restoring steel windows. These formulas give century-old steel the best chance to withstand the elements and resist oxidation.

The manufacturers' application instructions must be strictly followed. Typical guidelines may include:

- *Substrate tooth profile*. The microscopic geometry of the substrate is called its tooth profile. Each element must be cleaned, prepared, and abraded by media blasting to a specific standard. Factors such as blasting media, pressure, and dwell time determine the proper profile—the mechanical connection that allows coatings to bond to the substrate. The height and frequency of the profile should be measured before applying the first coat. Coating systems specify required tooth heights, typically measured in mils.[4]
- *Ambient conditions*. Manufacturers' requirements for temperature, humidity, and dew points must be strictly followed.
- *Timing requirements*. If specified timing instructions are not followed, the workpiece must be re-blasted to the proper profile and the process restarted. Key timing considerations include:
  - *Prep-to-prime window*: the maximum allowable time between achieving the substrate tooth and applying the first coat, before flash corrosion can occur.
  - *Handling time*: the minimum waiting period before pieces can be safely picked up and moved by hand.
  - *Recoat window*: the time limit for applying subsequent coats in the system (primer, intermediate, and finish coats).
  - *Final cure time*: the required waiting period before pieces can be installed.
- *High volatile organic compounds (VOCs)*. Many high-performance coatings contain elevated levels of VOCs. These coatings must be applied in well-ventilated

areas and are rarely suitable for occupied spaces. In some jurisdictions, VOC regulations may restrict product selection.

Hardware. Key questions to consider when planning hardware decisions include:

- Will all restored windows remain operable after restoration?
- Which windows must remain operable to meet code requirements?
- Do any occupants require or prefer operable windows?
- Are there energy-modeling goals that affect window operation?
- Has the client approved the restorer's reuse of hardware from windows with matching sets, particularly when some windows are being fixed or made inoperable? Repurposing hardware in this way can help avoid very costly castings or historic reproductions.

Operating window hardware is best addressed in the shop, regardless of alloy. Some damaged elements can be repaired to working order through retooling or brazing; others may require new castings. All hinges, fasteners, hold-opens, latches, and related components should be inspected. Missing commercially available elements should be replaced, and all hardware that does not operate properly should be repaired and lubricated (Fig. 5).

Fig. 5.
Olin Library, Middletown, Connecticut, built 1928, showing a restored window handle made by breaking the bronze cremone operating handle down into its original 12 pieces, recasting the broken splines and worn operating arms, and refinishing the handle, 2018.

Glass and glazing. Replace all broken or missing glass and inspect existing setting compounds. Attention should be given to the character of the glass, as window glass manufactured before WWII often exhibits distortion from historic production methods. This distortion is a distinctive feature that contributes to the window's character and should be preserved where possible. Suitable replacement options include salvaged glass from comparable windows or newly manufactured restoration-style glass.

Traditional linseed-oil-based putty becomes chalky and brittle once it dries and loses its natural oils. As the surface develops cracks and fissures, water infiltration begins. Rust then forms on the steel substrate, and the remaining putty bevel typically detaches, exposing the interior to further water damage. To avoid this cycle of deterioration, flexible perimeter settings are recommended. These products allow for expansion and contraction without debonding from either surface. Appropriate materials include neutral-cure (non-acetic-acid) silicones or polyurethane sealants. Acetic-acid-based products should be avoided, as their outgassing can irreparably damage adjacent encapsulated materials, such as caming in leaded or stained-glass panels.

Improving energy efficiency. Evaluating options for improved efficiency should be a standard task for any building owner undertaking a restoration project. Whether pursuing a Leadership in Energy and Environmental Design (LEED) certification or another sustainability standard, such credentials can open doors to grants and funding opportunities that help offset project costs. To identify where these improvements are most applicable, each window's details must be carefully reviewed. Methods and materials for enhancing energy performance may include:

- *Weatherstripping*. Evaluate potential thermal upgrades by adding or improving weatherstripping when reinstalling a restored frame in its opening or subframe. Adhesive-backed foam tapes are not recommended, as they typically fail after a short service life. Many steel windows do not have sufficient clearance for standard metal or plastic

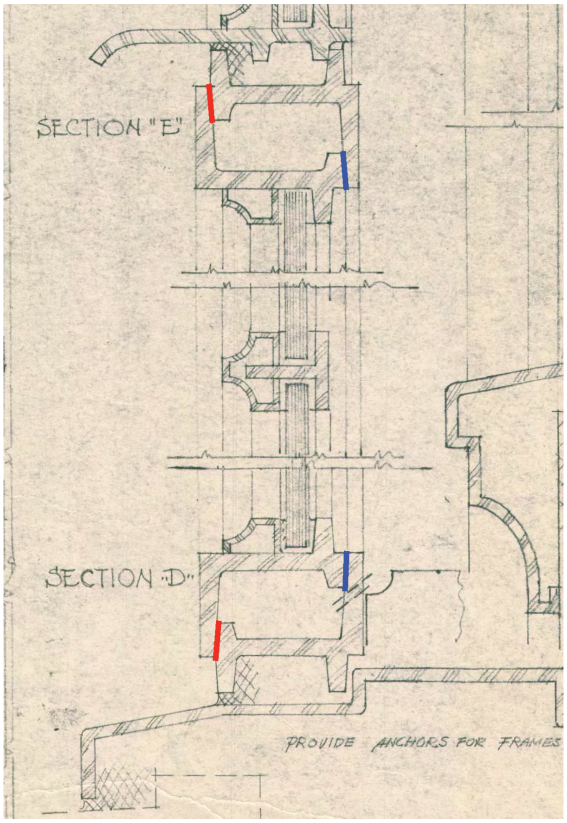

Fig. 6.
Rundell Memorial Library, Rochester, New York, 1934, drawing showing the ideal sealant weatherstripping location in blue. Collection of the Rochester Public Library Local History & Genealogy Division.

weatherstripping. Custom gaskets can be fabricated in situ using bond-break tape and silicone caulk. Rolled-steel windows often have two surfaces of contact when fully latched. In such cases, weatherstripping must be applied to the innermost surface to prevent moisture from becoming trapped (Fig. 6). First, apply bond-break tape to the innermost surface of the operable sash that closes against the frame rebate. Then apply a small bead of silicone caulk to the rebate. Close the sash, ideally securing it just short of full closure, and allow the silicone to cure. Open the sash and remove the bond-break tape. The cured silicone will slightly compress when the sash is closed, creating an effective seal.

- *Applied films*. In the mid-1960s, methods were developed to reduce the sun's negative effects on automobile drivers. Over decades of technological advancement, modern solar films are far more effective at rejecting solar radiation than at absorbing it. During warm months, solar films can reduce solar heat gain through glass by up to 75 percent. In colder months, they provide an insulating layer between heated interiors and cooler glass surfaces. Most solar films also block nearly 99 percent of transmitted UV light, protecting both occupants and interior materials—a critical consideration for museums and historic interiors. Security films are available for a range of applications, from light-impact and anti-graffiti solutions to blast-mitigation products. Depending on the product and its intended purpose, it may not be necessary to cover the entire glass surface edge to edge. While security films typically require full coverage, solar films can often be cut to sight size and applied in situ.
- *IGU and VIG retrofitment*. In some cases, it is possible to replace existing monolithic glass with a more efficient insulated glass unit (IGU) or vacuum-insulated glass (VIG), depending on the dimensions of the existing window system (Fig. 7). First, confirm that the glazing pocket has sufficient depth to accommodate the proposed unit. If the space is adequate, the next consideration is weight: IGUs can weigh two to three times more than monolithic glass, which may place significant stress on the supporting hinges of the sash. In casement windows, wider units relative to their height exert increased stress on operating hinges, potentially affecting long-term functionality and durability.
- *Storm windows*. Storm windows have been used for over a century to improve the performance of existing windows. For less than the cost of a full restoration, replication, or replacement, storm windows can reduce water infiltration, improve energy efficiency, and even lessen street noise. Installation may occur on either the interior or exterior of the window, and window operability should be considered when selecting placement and type. Exterior installation is generally preferred when water infiltration is the primary concern. Interior installation is generally favored when air infiltration and thermal comfort are the main issues. Additional factors should also be considered, including condensation potential, compatibility of dissimilar metals, glass types, and sound attenuation, among others.

Conclusion

Steel window fenestration is often a defining feature of a historic building. When this is the case, all reasonable efforts should be made to restore and preserve the windows (Fig. 8). For windows that have not experienced

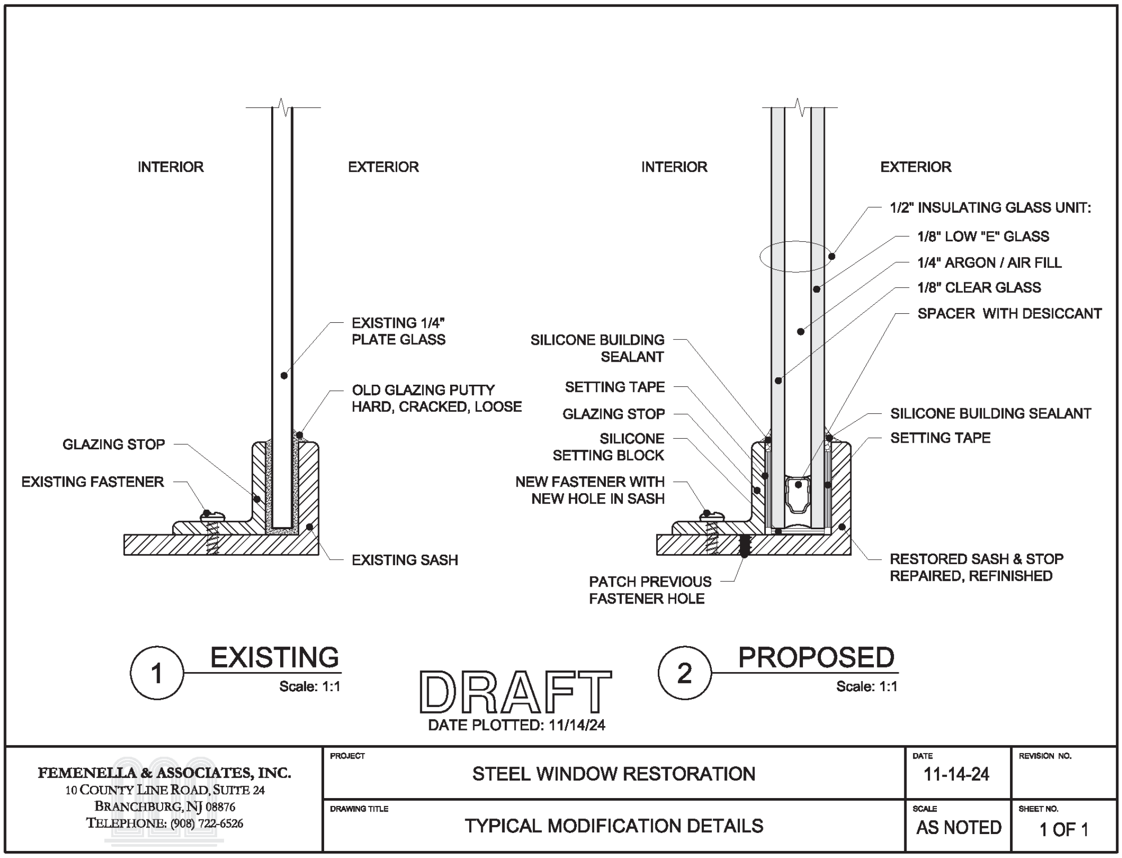

Fig. 7.
Restoration detail drawing, glazing retrofitment, 2025.

Fig. 8.
Dillon Gymnasium, Princeton University, Princeton, New Jersey, built 1947, showing a restored window, 2025.

extensive, severe corrosion or rust jacking, restoration costs can often be competitive with replacement. Properly maintained steel windows can provide an exceptionally long service life. Regardless of their initial condition, it is essential to assemble a knowledgeable and experienced team of preservation professionals to ensure a successful project.

Arthur Femenella Sr. was a pillar of the preservation community. He was responsible for the restoration of thousands of windows, doors, panels, and artifacts, including hundreds of works by Louis Comfort Tiffany, John LaFarge, Frank Lloyd Wright, Maitland Armstrong, Mary Tillinghast, and other notable artists.

Arthur Femenella Jr. is co-president of Femenella & Associates. Hand-puttying stained glass at age seven, Arthur gained a unique early experience in historic preservation under the close guidance of his father. Today, he manages projects nationwide involving all types of metal, wood, and stained glass. Arthur can be reached at ArtJr@femenellaassociates.com.

Notes

1. For more on the history of the manufacture of steel and wrought iron, see G. Reginald Bashforth, *The Manufacture of Iron and Steel* (London: Chapman and Hall, 1964).

2. Sharon C. Park, *The Repair and Thermal Upgrading of Historic Steel Windows*, Preservation Brief 13 (Washington, DC: Technical Preservation Services, National Park Service, US Department of the Interior, 1984).

3. NASA Kennedy Space Center, “Forms of Corrosion: Galvanic Corrosion,” Public KSC Corrosion, accessed Sept. 24, 2025, public.ksc.nasa.gov/corrosion/forms-of-corrosion/#Galvanic-Corrosion.

4. Surface preparation standards recommended by the Association for Materials Protection and Performance (AMPP) are available at ampp.org.

APT’s mission is to advance appropriate traditional and new technologies to care for, protect, and promote the longevity of the built environment and to cultivate the exchange of knowledge throughout the international community.

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