White Paper

STEEL WINDOW RESTORATION
EFFECTIVE STRATEGIES TO
RESTORE AND UPGRADE HISTORIC
STEEL WINDOWS

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William J. Nealon Federal Courthouse
Scranton, Pennsylvania

The 284 steel windows of the Nealon Courthouse were restored by Femenella & Associates, Inc. working in concert with C&D Waterproofing under the direction of RJMJ Architects. The project included 34 monumental windows that span the 3rd & 4th floors with cast iron ornament and marble spandrel panels. Numerous upgrades were made to the windows during the project to increase energy efficiency, ensure proper water drainage and resistance to corrosion.

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INTRODUCTION

The fenestration of historic buildings is a focal point and often the defining feature of the building's style and period. Unlike wood windows in historic buildings, steel windows are often looked upon as replaceable; not worth the effort of conservation. This is especially true of the mass-produced rolled steel windows produced from the end of the 19th century through the mid 20th century that can be found in commercial, residential and institutional buildings throughout the United States.

There are a number of reasons why steel windows are often slated for the scrap heap, but high on the list is the presumption that they cannot be made more energy efficient. The fact that there are myriad replacement options in the market often influences the decision as well. The sight lines, proportions of elements, profiles and shadow lines of many of the modern replacements do not match the original details of the windows they are intended to replace. If the windows are indeed defining elements of the historic architecture, the substitution of replacement windows can result in the loss of the original character of the building.

Beyond the aesthetic benefits of restoring steel windows, the repair and/or retrofit of existing steel windows is often more economical than the complete replacement option. Further, many of the old alloys appear to demonstrate greater resistance to corrosion than some of the modern alloys used to fabricate new steel windows.

The above notwithstanding, there are situations where window replacement makes sense. This can be in buildings where the original windows are not defining design elements and good replacements with higher energy efficiencies are available or when the windows have deteriorated to the point wherein restoration would not be economically feasible.

The purpose of this White Paper is to assist building owners and committed preservation professionals to determine the following:

- how to assess the importance of the windows to maintain the character of the building
- when restoration of steel windows is appropriate
- what to know before the project starts
- what methods and materials produce good results
- how can steel windows be made more energy efficient

BRIEF HISTORY

The first metal windows were fabricated by medieval blacksmiths in England and Europe from wrought iron. Large pieces of glass were non-

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existent at the time, and glass in general was a precious commodity so these metal windows were typically glazed with leaded glass panels - small glass diamonds or squares (quarries) held together with lead cames. Most of these windows were fixed units, but blacksmiths with greater skills could produce operable sections in the window, typically casements or center pivoted sash.

In the mid 17th century, changes in architectural design featuring Palladian fenestration favored windows made from wood, with complex moldings and varying profiles. In the mid 18th century advances in metal casting allowed for more complex metal windows to be fabricated in the factory from cast iron. Detailing only previously seen in wood windows could be carved into the wood positive that would be used to make the mold for the cast iron. This enabled the window manufacturer to offer details and profiles such as glazing T bars with rounded edges, ovolo and other complex shaped perimeter moldings only seen before in wood sash.

Cast iron windows became quite popular throughout England. They were used in housing and institutional buildings and were quite the thing for workhouses and asylums. An 1848 patent included the phrase, "...cast iron sash windows appear to posses advantages for lunatic asylums, workhouses and schools, since when open the sash bars (prevent) patients escaping or children falling...". Imagine including that line in today's window advertisements. In the 19th century, cast iron windows can be seen in cities throughout America, and in impressive public buildings such as in the 1863 iteration of the cast iron dome on the U.S. Capitol.

In 1856 England, Sir Henry Bessemer developed a process to produce hot rolled steel on a high production basis. Although a method for making rolled steel had been known as early as the 11th century in Asia, the earlier process was a very time consuming affair. The Bessemer process became so effective, it becomes a major driver of the Industrial Revolution. The Bessemer process came to the United States soon after its inception in Great Britain. It is not much used for windows in the U.S. until the 1890's when continuing technical refinements bring the process to the point that allowed for the mass production of steel windows. The demand for steel windows was further enhanced after numerous, deadly fires occurred in major U.S. cities resulting in far-reaching and strict fire codes. Steel's great strength allowed architects to design great walls of windows adding architectural interest to the exterior while flooding the interior with light, not unlike the introduction of the flying buttress allowed medieval masters to greatly enlarge the stained glass windows of ancient cathedrals.

At first, steel windows mimic those of wood design to include *double hung* and *casement* windows. Additional designs, enabled by steel's strength

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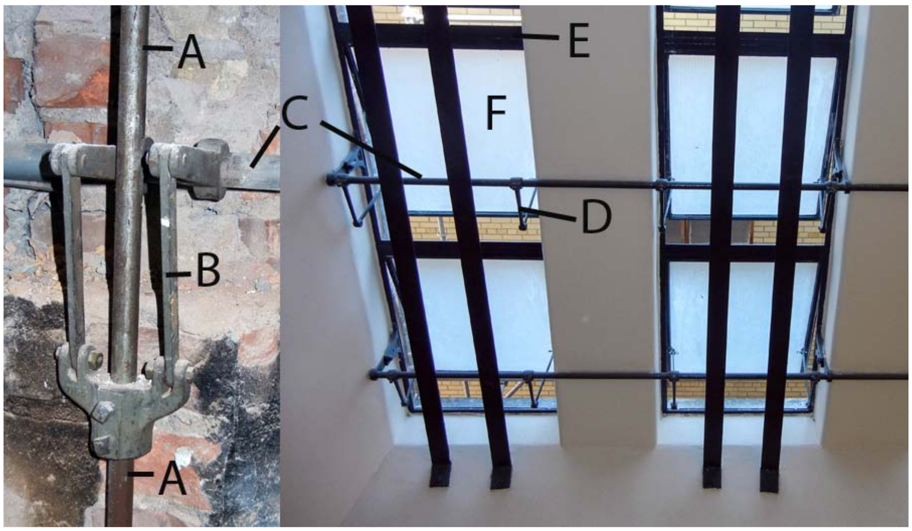
and thin profile sections, come onto the market. These include the *center pivot, hopper* or *projecting* windows and the *austral* windows wherein an upper sash section projects out while the lower sash section projects into the building. In factories and large institutional buildings, long banks of projecting windows were tied together with common, crank-type operating systems, often referred to as *continuous* windows. This would allow the ventilation of large spaces quite easily.



Typical Continuous Window - Yale University Payne Whitney Gym

The mechanism at the left of the photo is buried within a cavity in the exterior wall. Section "A" is a continuous vertical rod that is connected to all of the horizontal rods "C" in the window. The bottom of "A" is connected to a screw mechanism that rises or falls as the operator turns a geared crank that is accessible on the interior of the building. As the crank is turned, the screw mechanism rises causing "A" to rise. As "A" rises, the hinged lever arms at "B" transfer the upward displacement into rotational movement of "C". As "C" passes through the wall, it is connected to lever arms "D" that transfer the rotational movement of "C" into horizontal displacement of "F" the opening sash. "E" indicates the hinge location of the sash.

At this particular installation at the Yale Payne-Whitney Gym, one operator can open 45 sash simultaneously by operating one geared crank. These systems often fall into disrepair due to lack of maintenance. Any corrosion that develops in the lever arm connections restricts operability. However, with a good understanding of the system, the window can be successfully returned to full and easy operation.

TO RESTORE OR REPLACE

The first order of business is to determine if the windows should be restored or replaced. Engage with a preservation professional that is conversant in the style and period of construction of your building.

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Determine if the steel windows are a defining design element such that the loss of which would denigrate the architectural esthetic of the building or confuse the viewer as to its original design intent. Major differences between historic steel windows and new aluminum replacements are the scale and dimension of the individual window members: stiles, muntins, mullions, shadow lines, etc. Even if the primary use of the building changes, i.e. manufacturing facility to residential, if the windows are central to the historic character and feel of the building, they should be retained and restored. Surface rust always looks worse than it is; oxidized steel occupies seven times the thickness of new steel. Unless severe corrosion has resulted in extreme loss of material and/or complete loss of frame and sash members, or rust jacking of the subframe has dramatically displaced the window, restoration can often be quite successful and economical.

DEVELOP SCOPE AND MAGNITUDE

The next step in the process is to assess the condition of the windows. This will determine if the overall project is feasible and if the windows can be restored in situ or must be removed to the shop. Develop a logical and comprehensive numbering system for the windows to be addressed on a floor plan or elevation drawings, to include identifiers for the disparate parts that may have to be disassembled. Complete an initial window survey and develop a window schedule with attendant photographs that indicate the types and extent of problems found on a window by window basis. Moisture/standing water is the prime enemy of steel windows resulting in corrosion. This effect is exacerbated if the windows are not properly maintained or if the moisture is trapped in certain areas of the windows due to poor initial design.

The level of corrosion is the primary factor that will determine if the work can be completed in situ. On most projects, there is a mix of minor, moderate and severe corrosion. The extent of the corrosion is often determined by the elevation on which the window is found; the design of the window; and what section of the window is subject to standing water. Minor corrosion: appears primarily on the surface of the metal; moderate corrosion: reaches deeper into the metal, resulting in a rough, bubbling surface but no rust jacking; and severe corrosion: results in structural damage and/or rust-jacking of the members as rust has eaten deeply into the metal. During this inspection, determine if surrounding building fabric is allowing the infiltration of damaging water. Asses the original design details to determine if water shedding is encouraged throughout the system. Check to see if the metal sections are bowing or are twisted and inhibit operation of the window. Inspect the condition of hardware such as latches, hinges, hold-opens, fasteners and the window glass and glazing (putty or sealant).

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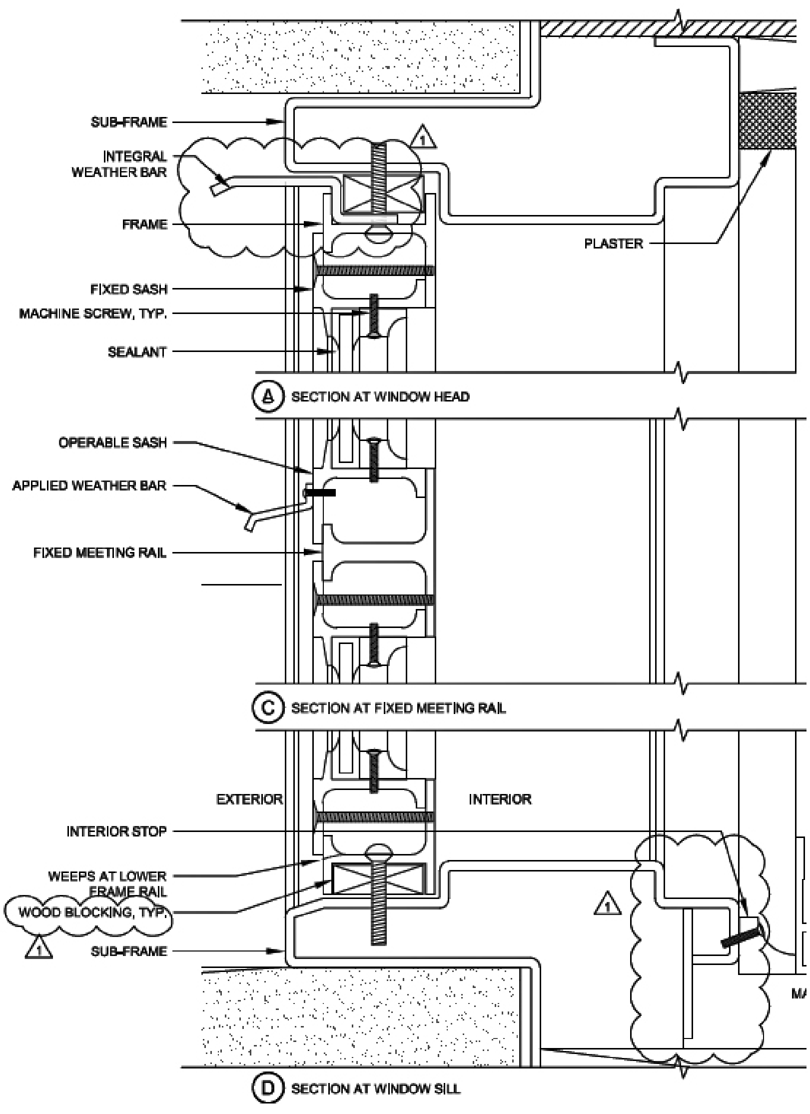
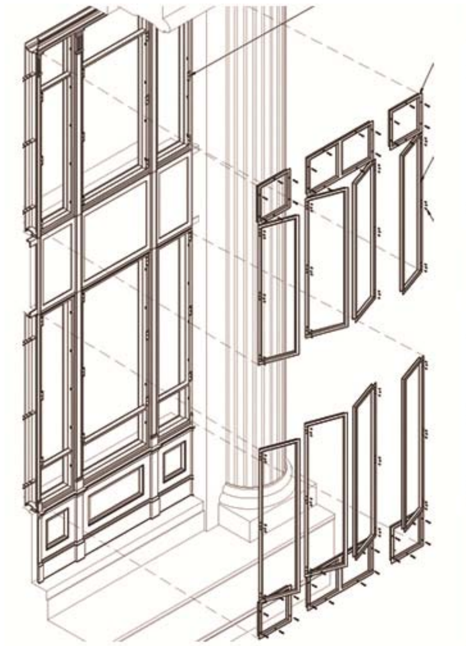
The next step is to dismantle a window to reveal how it is put together and installed. Myriad profiles, styles and methods of installing steel windows were employed. Due to the great strength of steel, the windows were often installed into the building as it was being built, rather than installed into a framed out rough opening later in the building process. The subframes of these built in windows are so integrated into the building fabric that too much damage and added cost may result when trying to completely remove them. In this case, it may be possible to restore the sash and frames off site, but the primary subframe must be addressed in the field. This was the condition at the Nealon Courthouse Project.

NEALON COURTHOUSE - TYPICAL WINDOW DETAILS

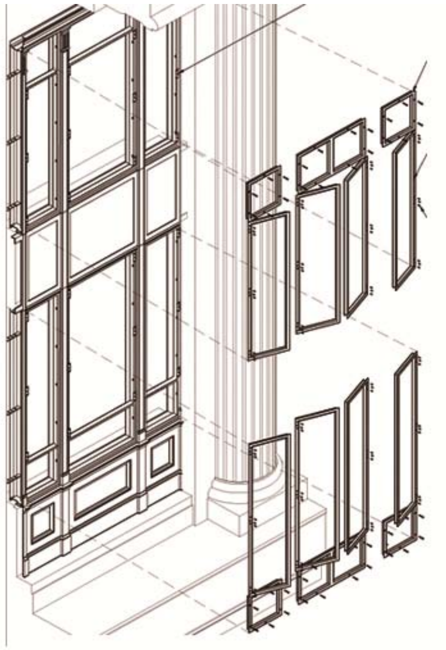


REMOVAL PROCESS

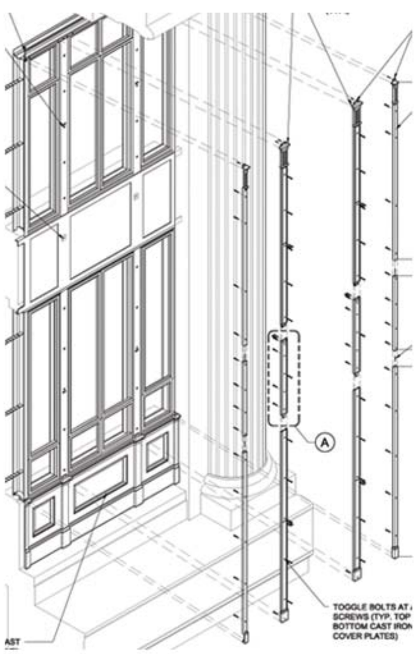
As part of the Nealon Project, drawings were developed indicating what sections of the window were removable and what sections would have to be addressed in situ. These drawings are for the monumental upper windows with cast iron ornament and marble spandrel panels.



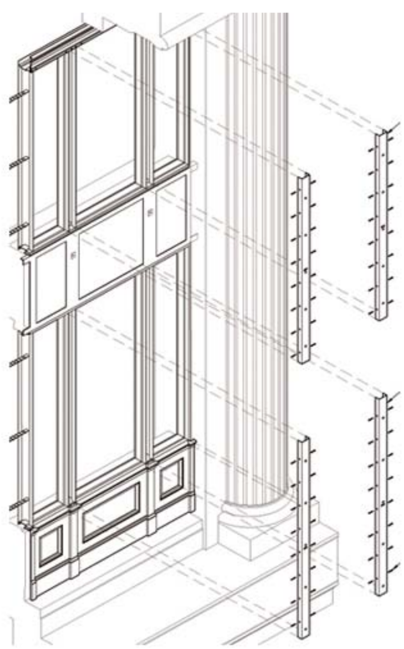
Stage 1 - Remove Sash



Stage 2 - Remove Frames



Stage 3 - Remove Cast Iron



Stage 4 - Remove Mullion Covers

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The operable and fixed sash were removed first. This allowed access to hidden fasteners that were securing the frames. Due to inaccessibility or severe corrosion, many of the fasteners had to be cut out. All fasteners used during the reassembly were stainless steel.

The cast iron columns, capitals and pedestals, which were attached with plain steel toggle bolts through holes in the mullion covers, were removed. The mullion covers were removed next; they are structural in design and function. The larger cast iron base spandrel and base moldings were restored in situ; they were attached from the interior and would have required substantial demolition to get access to the fasteners. The stone spandrels found between the upper and lower sash were removed. In the original survey, many of the stone panels were slated for replacement due to surface deterioration. C&D Waterproofing, the GC and masonry contractor for the project, proposed polishing the back sides of the stones and installing them with the newly polished side facing out. This approach saved a great deal of original historic fabric and is emblematic of the constant analysis and scope adjustment that is critical to the success of large steel window restoration projects.

RESTORATION PROCESS

Now that it is all apart, it is time to address the problems of the windows. On most projects, the conditions vary from elevation to elevation and even between similar windows on the same elevation. As mentioned before, water is the enemy and wherever water is allowed to collect or breaches the paint film, corrosion will occur. Take special note of areas where water collects and ensure that design changes are made during the restoration to facilitate the rapid shedding of water in these areas. The following will discuss specific steps for the restoration process.

MINOR CORROSION

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If the windows exhibit minor corrosion with no rust jacking, and the paint is in fairly good condition, repairs can typically be completed in situ. For remediating minor corrosion and damage, complete the following:

1. Establish if lead paint or other hazardous materials will be disturbed during the repair process and take appropriate steps to isolate the work area. Ensure that the owner and all workers are aware of the possible hazard.
2. Remove loose and flaking paint and all corrosion. This can be accomplished with hand tools. With proper protection of surrounding materials, power tools with wire wheels may be employed. For more experienced craftsmen, a pneumatic needle scaler may be used. Removal of paint with chemical strippers can also be appropriate. Ensure all surfaces are neutralized prior to application of paint. Clean all bare metal surfaces with a solvent such as denatured alcohol or follow paint manufacturer's instructions. Prime with a rust-inhibiting primer immediately after cleaning to prevent continued corrosion.
3. Inspect all hinges, fasteners, hold-opens, latches and other hardware. Replace all missing elements, lubricate and repair all hardware that does not operate properly. Missing elements are often available from online restoration hardware supply houses.
4. Often, operating hardware is bronze or architectural brass. Remove from the window, strip off paint and polish before reinstalling.
5. Replace all broken or missing glass and inspect setting compounds. Be cognizant of the *character* of the glass in the window. Window glass made before WW II tends to have some distortion due to the older manufacturing process. This can be a distinctive feature of the windows and should be maintained. Replacement glass can be salvaged from old windows or Restoration Glass® as provided by S. A. Bendheim of Passaic, NJ is also an excellent replacement. If the setting compound needs to be replaced, consider using a setting tape/tooled caulk system rather than the old hard-setting putty. This allows for some movement of the glass within the sash and setting putty no longer contains lead and thereby does not weather as well as old putty.
6. Finish paint complete window, frame and subframe.
7. Investigate possible thermal upgrades through the addition of weather stripping. The use of adhesive backed foam tapes is not recommended; they typically fail after a short duty life. On many steel windows, there may not be sufficient clearance to install metal or plastic weather stripping. A custom gasket can be made in situ employing a bond break tape and silicone caulk. Apply the bond break tape to the surface of the operable sash that closes against the frame rebate. Apply a small bead of caulk to the

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rebate and close the window. It works best if the sash can be secured in a position just short of full closure. Allow the silicone to cure, open sash and remove bond break tape. The silicone will slightly compress when the sash is closed.

8. Remove and replace sealant at the intersection of the subframe and surrounding building materials employing appropriate primers, backer rod and bond breaking tape.
9. Check surrounding building fabric to ensure that water is being directed away from the windows and the building.

MODERATE CORROSION

For windows with moderate corrosion, the above steps outlined for minor corrosion are followed as well. In addition, minor straightening of the sash or frame may be required.

1. To straighten the sash in situ, remove the glass and glazing. Using a wood or metal member to distribute the load, use clamps or an improvised come along to exert pressure on the affected window member. Often, due to "metal memory" the section has to be forced slightly beyond the ultimate desired plane to effect a good fit. The frame can be returned to plane in a similar manner.
2. Corrosion may be so great that the proper closing of the sash is not possible. In these conditions, grind the uneven portion of the frame or sash back to its original design plane.
3. Moderate corrosion may result in divots or uneven surfaces once the corrosion is removed. These can be filled with special epoxies impregnated with steel filaments that are designed for these repairs.

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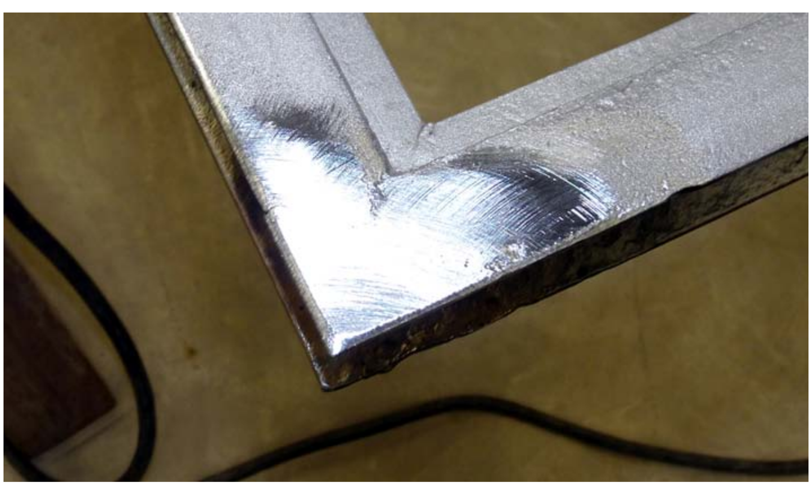
SEVERE CORROSION

Windows exhibiting severe corrosion can often be economically and effectively restored by qualified craftsmen with extensive field experience. Severe corrosion is evidenced by sections of the sash or frames that are corroded to the point they have no structural integrity; severely deformed or misaligned frames or sash; or missing metal sections. Again, all of the methods discussed to solve minor and moderate corrosion are employed first.

1. Window sash and frames that exhibit severe corrosion typically must be repaired in the shop. As mentioned above, determine how much of the window can be economically dismantled and treated off site.
2. Once in the shop, abrasive blasting is the best way to remove paint and corrosion. This allows a very clean surface for welding patches or applying steel filled epoxy.
3. Severe corrosion as pictured above can be repaired by cutting away material back to the solid metal. New metal is then welded to the old, rough cut to shape and ground down to the original profile. The result can be seen below.



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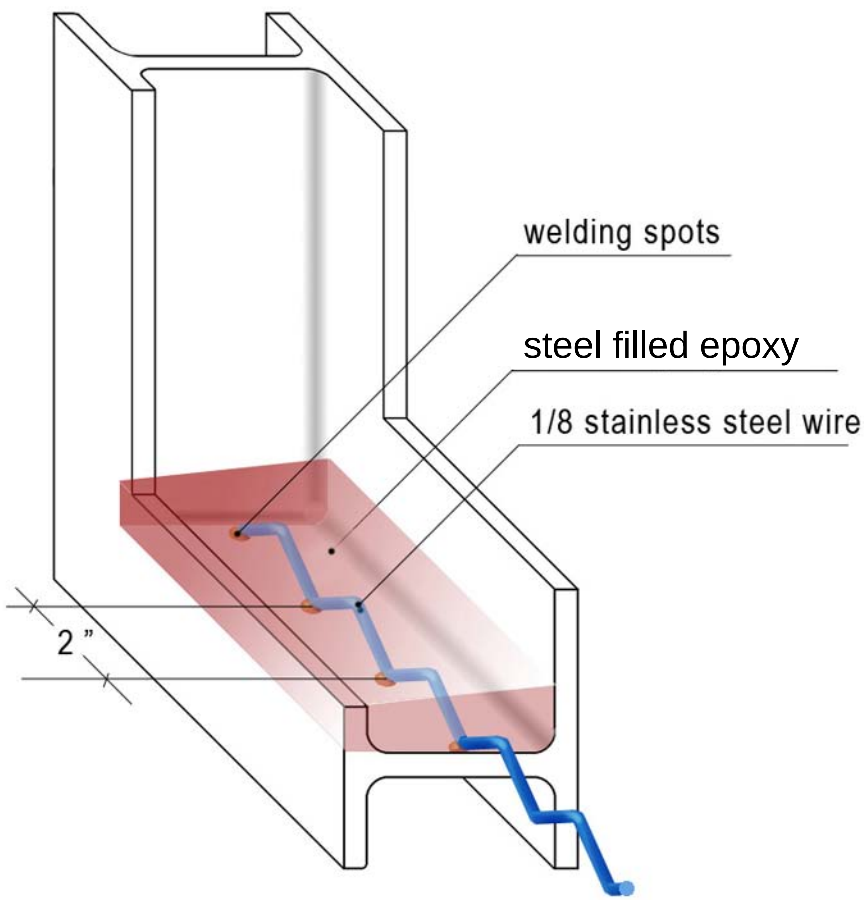
4. Deflected or misaligned sash and frames can be effectively straightened in the shop employing vises, clamps, come alongs and use of heat.
5. Check all threaded fastening points. If corroded, weld shut, redrill and tap if the fastening location cannot be moved.
6. Check initial documentation and note where standing water occurred and corrosion was most severe. At Nealon, we found that the all of the lower sections of the frames were severely corroded. This was due to the design that created a water trap. Our repair to these sections corrected this original design flaw. We filled the trough of this section with epoxy filler that was pitched to the exterior. We reinforced this repair with stainless steel 1/8" wire that was welded to the steel frame. See below.



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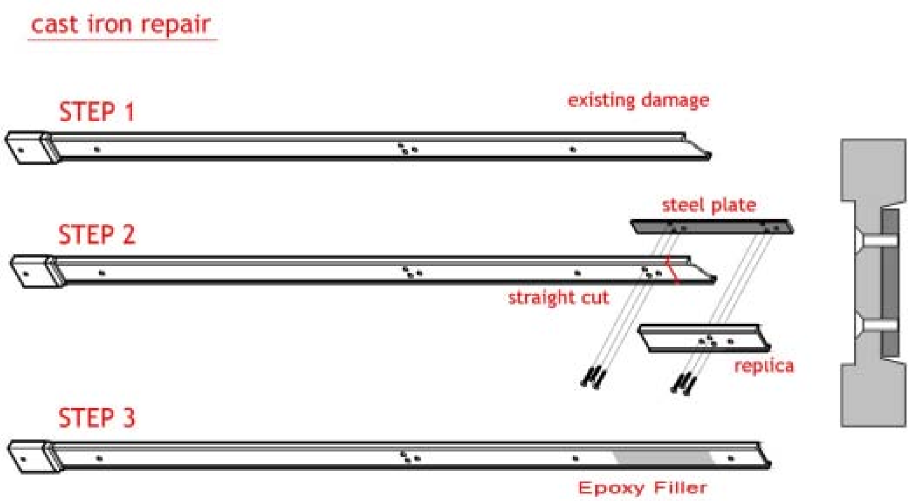
7. Cast iron ornament was one of the distinguishing features of the windows at Nealon; it was decorative and not part of the supporting structure. Many of the sections were damaged or had missing segments. It is imperative to retain as much of the original fabric as possible. We had runs of the different profiles cast. We cut the damaged sections from the cast iron and cut pieces of the new iron to fit, attaching them with stainless steel splints.



8. The subframe assembly at Nealon had to be repaired in situ. This involved the cutting out and replacement of sills and headers. We had runs of the various profiles fabricated. At the site, damaged sections were cut away leaving plumb and straight edges. New sections were cut and welded in place.

Photo of replacement section tack welded in place. There is a stainless steel backing plate that spans the joint. Welds will be made continuous along the joint and ground flat to the profile. Where required, epoxy patch material will be added.

9. When all repairs are complete, the finished steel is given a light blasting to clean away any corrosion that has formed during the shop work. The metal should be immediately painted with a rust

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inhibitive primer. It is important that the complete paint system comes from a single manufacturer, we chose Tnemec. We used a Series 1 Omnithane primer for all plain steel and cast iron, the Hi-Build Epoxoline II primer for stainless steel and the Flouranor satin as a top coat.

CONCLUSION

Steel window fenestration is often a defining feature of an historic building. If so, all reasonable attempts should be made to restore and preserve the windows. If the windows have not suffered extensive, severe corrosion and rust jacking, the cost of restoration can often be competitive with replacement with new windows. If properly maintained, steel windows can offer a very long service life. Regardless of the as-found conditions of the windows, it is imperative to put together a knowledgeable and experienced team of preservation professionals to ensure a successful project.

NEALON FEDERAL COURTHOUSE, SCRANTON, PA

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Arthur Femenella is the President of Femenella & Associates, Inc., a full service stained glass, historic wood and steel window conservation studio. Mr. Femenella began as an apprentice in 1968 at the Greenland Studio of New York and later became co-owner. In 1988 he joined forces with Jack Cushen and developed the Jack Cushen Studio. Both studios went on to be highly respected for stained glass conservation.

Arthur formed Femenella & Associates in 1993 to address a new way to approach conservation projects. He has been responsible for the restoration of thousands of windows, doors, panels and artifacts, including hundreds of works by John La Farge, Louis Comfort Tiffany, Frank Lloyd Wright, Maitland Armstrong, Mary Tillinghast and other artists of equal importance. Mr. Femenella is active in a number of preservation groups and he lectures across the country. The firm is an approved provider of AIA/CES learning credits.

Mr. Femenella is a founder, past President and Vice-President of the American Glass Guild, LLC; a past Chair of the Restoration Committee, former Board Member and former Treasurer of the Stained Glass Association of America. In this capacity, Mr. Femenella was the primary author of the booklet Standards and Guidelines for the Preservation of Historic Stained Glass Windows. Mr. Femenella sat on the Board of Governors of the Census of Stained Glass Windows in America, and was the primary author of the technical section of the booklet produced by the Census titled, The Conservation of Historic Stained Glass: An Owner's Guide. Arthur is a Professional Associate of the AIC, a past Board Member of APTI and a member of the National Trust.

Arthur Femenella has written over fifty articles on subjects specific to stained glass and historic window restoration. He has presented papers at numerous international and national symposiums and conferences. Art was the consultant to the Protective Glazing Task Force. This was a group of architects, engineers, and preservationists charged by the Department of the Interior to develop national guidelines for the fabrication and installation of protective glazing.

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