THE WINDOW HANDBOOK
SUCCESSFUL STRATEGIES FOR REHABILITATING
WINDOWS IN HISTORIC BUILDINGS

CHARLES E. FISHER, III, EDITOR

U.S. Department of the Interior
National Park Service
Technical Preservation Services
Washington, D.C.

and

The Center for Architectural Conservation
College of Architecture
Georgia Institute of Technology
Atlanta, Georgia

1991
THE WINDOW HANDBOOK:
SUCCESSFUL STRATEGIES FOR REHABILITATING
WINDOWS IN HISTORIC BUILDINGS

Windows are usually significant in defining the historic character of older buildings, contributing as highly visible features of the exterior and often as distinctive elements of the interior as well. Because of their age and lack of maintenance over the years, however, they are all too frequently sacrificed in favor of expedient solutions. Many people involved in rehabilitation fail to evaluate properly the condition of historic windows, to identify options for repairing and upgrading their performance, and to fully explore sources for sensitive replacement units. As a result, inappropriate treatments are frequently undertaken.

Certainly, the selection of appropriate treatments for historic windows is one of the most difficult issues for property owners, contractors, building managers, architects, and preservation commissions and agencies to deal with in rehabilitation projects. Until recently, little information was available on the rehabilitation of windows in historic buildings. This handbook and its companion publication, “The Window Workbook for Historic Buildings,” fills this void and demonstrates how much progress has been made.

The Window Handbook is divided into six sections. The information and guidance in section one includes an overview of rehabilitation work involving historic buildings, Preservation Briefs on wooden and steel windows, and the Secretary of the Interior’s “Standards for Rehabilitation” and a chapter on the accompanying Guidelines on windows. The remaining five sections include Preservation Tech Notes from the window series which identify problems in rehabilitating historic windows and, by means of detailed case studies, show how those problems were handled through both traditional and innovative solutions.

Additional material for The Window Handbook will be published periodically. The 3-ring binder format will allow its users to insert future publications in appropriate sections. To be kept informed of forthcoming material, however, it will be necessary to return the enclosed response card.

All techniques and practices described herein conform to established National Park Service policies, procedures, and standards. Reference to any specific commercial product, process, or service by trade name, trademarks, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or preference over another comparable product, either by the National Park Service or the Georgia Institute of Technology.

This handbook was prepared in part pursuant to the National Historic Preservation Act Amendments of 1980 which direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Copies of The Window Handbook are for sale to the general public by the Historic Preservation Education Foundation, P.O. Box 27080, Central Station, Washington, D.C. 20038. Portions of the handbook are protected by copyright law. Inquiries about reprinting should be addressed to the Historic Preservation Education Foundation.

Published 1986, by the National Park Service, Washington, D.C., and Georgia Institute of Technology, Atlanta, Georgia. Revised 1990, by the Historic Preservation Education Foundation, Washington, D.C.
TABLE OF CONTENTS

PART 1—INTRODUCTION AND GUIDANCE
Rehabilitating Windows in Historic Buildings: An Overview
The Secretary of the Interior’s Standards for Rehabilitation and Accompanying Guidelines on Windows
The Repair of Historic Wooden Windows
The Repair and Thermal Upgrading of Historic Steel Windows

PART 2—PLANNING AND EVALUATION
Planning Approaches to Window Preservation
Temporary Window Vents in Unoccupied Historic Buildings

PART 3—REPAIR AND WEATHERIZATION
Reinforcing Deteriorated Wooden Windows
Repairing and Upgrading Multi-Light Wooden Mill Windows
Repair and Retrofitting Industrial Steel Windows

PART 4—DOUBLE GLAZING HISTORIC WINDOWS
Installing Insulating Glass in Existing Steel Windows
Exterior Storm Windows: Casement Design Wooden Storm Sash
Interior Metal Storm Windows
Thermal Retrofit of Historic Wooden Sash Using Interior Piggyback Storm Panels
Interior Storm Windows: Magnetic Seal
Installing Insulating Glass in Existing Wooden Sash Incorporating the Historic Glass
Interior Storms for Steel Casement Windows

PART 5—REPLACEMENT SASH AND FRAMES
Replacement Wooden Frames and Sash: Protecting Woodwork Against Decay
Replacement Wooden Sash and Frames with Insulating Glass and Integral Muntins
Aluminum Replacements for Steel Industrial Sash
Aluminum Replacement Windows with Sealed Insulating Glass and Trapezoidal Muntin Grids
Replacement Wooden Frames and Sash with True Divided Lights and Interior Piggyback Storm Panels
Aluminum Replacement Windows with True Divided Lights and Interior Piggyback Storm Panels, Utilizing Historic Wooden Frames

PART 6—SCREENS, AWNINGS AND OTHER ACCESSORIES
Window Awnings
D: Second Floor, South Elev. S218

- Replace molding
- Spall - Repair with mortar
- Replace with nine light sash to match upper

E: Second Floor, North Elev. N221

- Replace rail or consolidate with epoxy
- Sash weights missing - install new to match; replace all sash cord using sash chain
- Interior - consolidate apron using epoxy

E: Second Floor, East Elev. E208

- Replace molding
- Spall - Repair with mortar
- Install new glass
- Replace outer tracks and parting stops
- Interior: Replace soffit of head

E: Second Floor, South Elev. S211

- Transom missing
- Weatherstripping missing - install new to match
- Interior: Fill open joints, repair transom mechanism
- Right transom missing - install new wood transom to match
Rehabilitating Windows in Historic Buildings: An Overview
by Charles E. Fisher, National Park Service

Today, greater attention is being placed on selecting appropriate window rehabilitation treatments for historic buildings. As a result, more contractors employ workers skilled in the repair of wooden windows; a number of leading manufacturers of commercial windows have modified existing window lines or introduced new ones specifically for the historic market; and the process for selecting appropriate windows has grown more complex as treatment options have expanded and owners and historic preservation review boards insist on more sensitive solutions.

With these changes, architects, building managers, and developers are confronted with the need for sensitive rehabilitation of windows in historic buildings; a subject about which little has been written and few are sufficiently experienced. This is particularly troublesome considering the high financial stakes often involved. On a medium to large size building rehabilitation, the window component typically accounts for 10 percent of the total project costs.

Windows are frequently replaced without careful and objective examination of repair and upgrading alternatives, often leading to unnecessary costs. Then, too, replacement windows are often selected based on initial costs, without sufficient attention to quality of construction, performance, and appearance.

Taking the time for proper architectural planning early in the project is crucial. This is essential in order to explore thoroughly the various repair and replacement options, test possible solutions, and allow the time necessary for any custom work.

Assessing Historic Windows

The first step in the planning process is to assess the historic significance and architectural qualities of the historic windows in the building, since this assessment can limit the number of suitable rehabilitation options. The most striking feature of a 1920s factory may very well be the large steel industrial windows with their multiple lites, projecting operating units, and narrow channel bars and mullions. And while the more common double-hung wooden window with multiple dividing lites may be only one of a number of character-defining features of a late nineteenth-century hotel, it may represent the most distinguishing architectural feature on a New England textile mill. In each case, the relative importance of the windows to the building must be understood and taken into account. In assessing the significance of windows to a building, there are at least four major areas that need to be examined.

Material integrity. The fact that windows are an integral part of the historic fabric of a building must be acknowledged, particularly since windows may comprise 20 to 30 percent of the surface area of an older building. Historic windows should thus be preserved whenever possible. To be considered historic, the windows need not be original to a building; although each building needs to be assessed individually, a 50-year rule of thumb can often be applied in establishing whether existing windows are historic and worthy of preservation.

Degree of visibility. The second factor is visibility. Where all elevations of the building are highly visible and equally articulated, appropriate window treatments are more limited than with a building that has only one principal facade, side party walls, and a secondary rear elevation not readily seen from the public right of way. Similarly, there are numerous late nineteenth and twentieth-century highrises with monumental windows of impressive design on the lower two or three stories, simply detailed windows on the intermediate floors, and more elaborate ones on the top one or two stories. The degree of visibility in this case might lead to the use of several window treatments on the same building.

Interior appearance. A third and commonly overlooked factor in the assessment is that windows are viewed from the inside as well as from the outside. Windows frequently contribute to an interior design scheme, or are located in significant interior spaces where appearance is an important consideration.
Historic window design. The fourth factor in assessing windows directly concerns design and detail. The design and operation of historic buildings may reflect the technology of the time, as is the case with "Chicago style" windows. Muntin pattern and muntin widths, mullion profiles, decorative elements such as arched tops and brick molding, construction detail such as O.G. lugs, the setback or reveal of the window relative to the wall plane, the color of the sash and frame, and even the reflective qualities of the glass all play important roles in window design and appearance.

The Condition Survey

The next planning step in almost every window study is to evaluate the condition of the windows by undertaking a detailed survey. Peeling paint, broken glass, loosely fitted windows, and apparent sill rot are not necessarily solid evidence that windows are beyond repair. For a majority of older buildings, failure to examine the existing window conditions closely precludes an objective evaluation of repairing and upgrading the existing windows versus partial or total replacing.

The surveys are often conducted by a window consultant, although some architectural firms have benefited by having a staff member develop the skills to perform the survey. Without an objective and detailed condition survey (along with the window assessment), it is difficult to weigh accurately the rehabilitation alternatives to ensure that the most appropriate window treatment is chosen.

Too often the contractor is expected to give repair and replacement costs with little guidance from the architect. There are inherent problems in such an approach. Most contractors will not examine the windows carefully because it is a time-consuming process, and in-

Figure 1. Careful consideration must be given to preserving the size and proportions of the historic window frames and sash, the mullion profiles, the muntin and lite configuration, the setback of the window from the wall plane, the amount of glass exposure, and the manner in which the window operated. Photo: Charles Fisher
stead will bid close to replacement cost for repair work. Replacing windows admittedly is easier to plan and budget for, but in the final analysis it is not necessarily most cost-effective or appropriate.

If the window condition survey and the window significance assessment clearly support retention of the historic windows, then the next planning step is to examine the numerous options for repairing and upgrading the existing units. Often the assessment will prove inconclusive, thus requiring examination of other alternatives, including replacing many or all of the windows with others offering matching features and enhanced performance.

Based on the window assessment, there may be cases where replacement windows could appropriately match only the overall appearance of the historic window rather than the exact design. This makes possible the use of modern commercial windows that have been adapted to the historic rehabilitation market, yet that consist of different materials. Once the options are identified and preliminary cost estimates are derived, other factors may influence final decisions about window work.

An energy study of the overall building—not just the windows—coupled with cost-payback analysis may lead to the conclusion that, for a particular building, double glazing (retrofitted either to existing windows or in replacement units) is simply not cost-effective. Such findings are not necessarily confined to geographic areas with mild climates. Taking steps to reduce air infiltration, however, is usually always cost-effective where older, poorly maintained windows are involved.

**Repairing and Upgrading Existing Windows**

Generally, wood found in nineteenth and many early twentieth-century windows is a dense or heart wood (often pine) and of higher quality than most woods used today. A 100-year-old window, if properly reconditioned and maintained, can reasonably be expected to serve another century.

In many major cities, there is usually at least one firm specializing in window maintenance work. With experienced teams, such firms can be quite efficient at reconditioning hardware, replacing sash ropes and broken pulleys, replacing or adding weatherstripping, tightening loose sash joints, and replacing worn or broken sash stops. They can undertake deferred maintenance
work at a reasonable cost, providing the building owner with a good payback by reducing air infiltration and prolonging the life of the existing windows.

In vacant or poorly maintained buildings, however, windows usually require more extensive repairs. On wooden windows, extensive deterioration is most prevalent at the sills, the lower ends of the frames, and the bottom sash rails. For sills with surface cracking, some of the newer paints on the market hold considerable promise because of their durability; these are usually preferable to metal panelling, which can hide ongoing deterioration and tends to promote decay over the long term, since tight permanently sealed joints are difficult to achieve.

Epoxy consolidants and fillers may also be used where more extensive sill deterioration occurs. This is a cost-effective alternative to total sill replacement. Epoxy can be used to recondition the bottom of sash frames at the sill junction, although splicing-in new treated wood is another acceptable option. Bottom sash rails sometimes require total replacement; this work can be done easily and is less drastic than total sash replacement.

Establishing a complete workshop at the site to make repairs has been a successful approach on a number of projects. Some millworks will locate a field unit at a job site. Such work is labor intensive, but material and transportation costs are low and the onsite shops can undertake other project work, adjusting to work schedules more easily.

Decisions must also be made about the amount of surface preparation to undertake. Removing paint down to a sound surface; application of water-repellent coatings on bare wood and at joints; and sanding where ultraviolet degradation of exposed wood has occurred are important steps that may be necessary to achieve a good substrate for repainting and increase the length of the painting cycle.

Reducing air infiltration in existing windows is another principal concern in upgrading existing windows. Air infiltration, rather than single glazing, is the principal reason why older windows tend to be poor energy performers. Reducing air infiltration is usually the most cost-effective way of improving the energy performance of older windows, even in cold weather climates. This can easily be achieved by caulking around the frames, making sure the glazing putty is sound, tightening loose-fitting sash, replacing cracked panes, and most important, installing good weatherstripping.

Rather than running tests on existing windows, it is far more practical to take a typical window, make necessary repairs, upgrade its performance by adding high-quality weatherstripping, and then run standard air infiltration tests. In most cases, it is possible to surpass the minimum industry standards established for new windows; test standards for the contract work can then be specified.

**Double Glazing**

**Exterior storm windows.** The traditional method of double glazing is the use of exterior storm windows, which achieves a U-value for the window comparable to insulating glass. The typical exterior storm window greatly reduces air infiltration, lowers the maintenance cost of the historic window, and extends its useful life. Unfortunately, exterior storms can affect the visual appearance of the historic windows, although less so where single-lite historic sash are involved. While it was common at the turn of the century to match the divided lite pattern in the primary sash with that of the exterior storm, today's single-lite storm panels tend to alter the reflective qualities and shadow lines cast by the primary window, and also obscure features such as muntins.

Several steps can be taken to lessen the visual impact of storm windows. The simplest is to have the storm factory window painted to match the color of the primary window and trim. The second step is to specify a half-screen to be mounted on the inside, since it is the screening material in the typical storm/screen combination that most dramatically affects the appearance of a historic window. By mounting a half-screen on the inside (a typical feature earlier in the century), the sight lines of the storm unit are simplified by the reduction from a typical three-track to a two-track frame. Also commercially available are custom single-track, two-panel units with a simple subframe set within the jamb. Some single-track systems are designed so that the panels can be removed from the inside for cleaning and, for summer use, screen panels inserted for ventilation. This single-track system, compared to the more common triple-track design, can significantly reduce the storm unit's impact on the window's historic appearance. In either case, the storms will also result in considerable sound reduction, which is important to buildings exposed to high street noise.

**Interior storm windows.** Generally, an interior-mounted storm unit preserves the visual qualities of historic windows better than an exterior one. There are unobtrusive, high-performance, commercial quality interior storms intended to be jamb-mounted rather than affixed to the casing. Some of the interior storms are side- or top-hinged, although the more common styles are double- or triple-track units. Where fixed windows are appropriate, single or double panels attached to a subframe can be used, thus saving on initial costs while still allowing occasional removal for cleaning and maintenance. Condensation may be more of a problem with interior rather than exterior storm applications, particularly with residential buildings in extremely cold weather climates; however, the problems encountered in buildings with interior storm applications can be minimized with most windows if weatherstripping, caulking, and weep holes are part of the upgrading process and there is good quality construction and installation work.

**Existing steel windows.** Double-glazing historic steel windows can be an easy operation. With small residential steel casement units common in early twentieth-century high-rise apartments, application of a horizontally-sliding aluminum storm unit mounted on the inside reduces noise from the outside while improving energy performance. When finished in a dark color, this type of interior storm tends to have little visual impact from the outside and can also be unobtrusive from the inside. There is some sacrifice in the optimum performance of the casement for natural cooling and ventilation, since as much as 50 percent of the venting capacity of the window is blocked by the slider window. In an age of mechanical cooling, however, this may not be a concern.

On larger steel windows such as those found in me-
mium-sized factories, the steel sections sometimes were
designed to accommodate either single or dual glazing.
Where these windows are in repairable condition and
sized to accept either dual or single glazing, it may be
possible to install sealed insulating glass units in place
of the single glazing. An evaluation should be made
beforehand, with particular attention to the operable por-
tion of the window, to determine whether the steel win-
dows can accept the additional weight of the insulating
glass. While this retrofit approach to double glazing has
been effectively used, most steel windows installed
in the past were not designed to accept dual glazing; the
glazing bars (muntins) are too shallow or too narrow in
width.

**Existing wood sash frames.** With single-lite wooden
sash, it may be possible to retrofit insulating glass
within the existing sash frame. The sash frame needs to
be in relatively good condition and of sufficient size to
handle the additional glass weight. Mechanical routing
of the glazing rabbet is usually required to accommodate
the additional thickness of the insulating unit. In addi-
tion, the sash weights probably will need to be aug-
mented if operable windows are desired. It is always
important to establish beforehand whether there is suffi-
cient room in the weight pockets to allow for the addi-
tional weight balancing.

For the same single-lite sash, another alternative is
to “piggyback” an aluminum-frame storm panel onto
the interior portion of the sash. This procedure requires
that the inside edge of the rails and stiles on the room
side be rabbeted to allow insertion of the storm panel.

As with retrofitting insulating glass, the approach
to double glazing has an advantage over separate storms
in ease of operation and lower maintenance. In piggy-
backing the storm panel onto the sash, care must be
taken to get as good a seal as possible where the metal
frame abuts the wood sash frame.

A good weatherstripping system should be used on
the back side of the metal storm frame, and the metal
frame should fit snugly. These measures are necessary
to reduce the likelihood of condensation between the
two pieces of glass. Weep holes should be provided,
preferably on the stiles rather than the rails. Removable
clips or set screws to secure the storm panel to the wood
sash are recommended; these permit occasional cleaning
of the glass and allow access for maintenance work. Lo-
cal glass shops can provide the necessary materials.

The use of retrofit fitted insulating glass or piggyback
storm panels is generally limited to single-lite sash, al-
though it may be possible on some two-lite sash to
achieve similar results, provided the muntin is wide
enough and strong enough.

One additional use of insulating glass with existing
wood sash is worth mentioning. For buildings in down-
town urban areas or along busy highways, there is an
increased desire to reduce noise from the outside. While
sound reduction can be achieved through good weather-
stripping, the addition of a storm window with insulat-
ing glass in combination with the existing window can
yield superior sound attenuation over a triple-glazed re-
placement sash.

**In-kind Replacement Windows**

**Selective replacement.** The window condition study
may establish that a number of sash needs to be re-
placed altogether. Windows exposed to harsh weather
and those prone to vandalism are often prime candidates
for selective replacement; this is a common practice, yet
one that requires careful attention. To compensate for
the poorer quality wood used in windows today, water
repellents should be used. For warm, moist climates,
wood preservatives should be used as well. Since the
end grain is particularly susceptible to decay, water
repellants should be applied after pieces are cut, yet prior
to assembly where dip and spray preservative methods
are used.

Knives may be custom-cut to replicate the historic
shapes of muntins and mullions. Various options for in-
tegral weatherstripping, jamb liners, and sash balances
exist—all variables that may be influenced by the num-
ber of replacement windows involved and repair and
maintenance work needed for the remaining historic
sash.

Special care must be taken in measuring the win-
dow opening (especially where only the sash are being
replaced) due to irregularities in the historic sash and the
racking of the window over the years.

**Total replacement.** When total sash replacement is
necessary, careful consideration should be given to re-
placing the window with units that match in color, de-
tail, material (i.e., wood or steel), and manner of
installation.

Today, there are numerous retrofit features to con-
sider. For single-lite sash, insulating glass can easily be
used. In some instances, such as in Italianate style
buildings with thin sash rails, the bottom rail may need
to be increased in width or reinforcing rods inserted to
provide sufficient strength when using insulating glass.
Where O.G. lugs are present on the historic sash stiles,
the decorative nature of this feature—intended to give
additional joint strength—can be retained, if only as an
applied piece.

Where circle or segmented top sash exist, this fea-

![Figure 4. Retrofitting an energy panel onto the room side of existing single-lite sash is a technique for double glazing that has been used with success. Drawing: Sharon Park, AIA](image-url)
ture should be duplicated in detail and applied aprons not used. Replacement windows should be custom made to fit each opening. The opening should not be blocked in to accommodate standard size units; the width of the frame and sash and the amount of glass exposure should be the same as the historic windows.

For the typical double-hung window, the upper and lower sash in the replacement units should be in the same plane as the historic sash, regardless of whether the new window is single or double hung or fixed in place. The distinctive meeting rail and the strong shadow lines it casts are important features to retain. With single-hung windows, the common renovation practice of installing exterior half-screens in the same plane as the upper sash should not be used, since the historic double-hung appearance will be greatly changed.

Two-lite sash. For the two-lite sash, common during the latter half of the nineteenth-century, it is often possible to duplicate the units using insulating glass and a true wood muntin. Where the width of the historic muntin is narrower than $1\frac{5}{8}$" on an average size window, some problems may be encountered in keeping the muntin width narrow enough when installing insulating glass. A typical $\frac{3}{8}$" wide historic muntin on certain size windows can be increased to perhaps 1" on the new sash without altering the appearance of the window. It may be necessary to use one of the new thinner metal spacers in the sealed insulating glass unit. If there is any concern about the shiny aluminum being visible at an angle from the outside, the commercially available brown color spacers could be used.

Increasing muntin width too much causes a marked change in a window’s historic appearance. Where excessive widening of the muntin is necessary for adequate performance of the window and the insulating glass, alternate solutions should be considered. Obviously, with particularly thin historic muntins, such as a $\frac{3}{8}$" wide Gothic muntin, the sash will need to be single glazed, and possibly combined with an interior storm unit.

For some windows, there is the possibility of using insulating glass in four- and six-lite wood replacement sash. Again, the historic muntin width becomes a limiting factor. A mock-up may be necessary to ascertain whether the metal spacer, which would be close to the muntin edge, creates any serious visual problem; generally it will not. In some instances, it may be advisable to run wind-loading tests, particularly where the muntins are very narrow. Where there are both vertical and horizontal muntins, some millworks use oak to provide additional strength at the muntin joint. In all cases, it is important to ensure that the sealed insulating glass will properly function.

Multi-lite sash. The use of insulating glass in multiple-lite replacement windows can be quite expensive, especially when the lites are numerous. One alternative is to copy a practice common in the first half of the twentieth century, using a true divided lite sash, but incorporating a single-lite storm panel piggybacked onto the room side of the sash. Besides retaining the visual qualities of the historic sash, this solution features ease of operation, resulting from not having a completely separate storm frame. This window design utilizes a metal frame, single-lite storm panel set into a rabbet along the inside rail and stile edge on the room side, secured with clips or set screws. There are instances where the existing jamb tracks may be used with the replacement sash, provided the original window was “overdesigned” so that the muntin depth can be shaved to provide sufficient clearance to attach the storm panel flush with the sash. In most cases, however, it would be necessary to modify the jamb tracks, since the rails and stiles would need to be of a thicker stock so as not to affect the structural integrity and visual qualities of the muntins. As with retrofitting a storm panel onto an existing single-lite sash, careful attention to detail in the design and fabrication of the piggyback unit is required.

Bow windows, popular in the Victorian era, require additional planning efforts when duplicating in-kind. Generally, they contain only single lites—a distinct advantage in working with replacement design. Glass in historic bow windows can be found in both curved and straight pieces. In the latter case, standard insulating glass can be used in the replacement wood window. On the other hand, where curved glass is present, sufficient time should be allotted in the planning stage to locate the sealed insulating glass and have it custom-manufactured in a bow shape that conforms to the original.

There are a number of suppliers of curved insulating
glass; while this is expensive, most buildings have only a few curved windows, and their distinctive appearance should be retained in either a single- or double-glazed replacement unit.

**Replacement steel windows.** When confronted with steel windows deteriorated beyond repair, the owner or architect will often not consider replacement with matching steel windows. Spalling concrete around the subframe, racked windows, and rusted metal glazing channels suggest to many that this is an antiquated window system with no place in the rehabilitation market today.

Most steel windows being replaced in historic buildings are in old factories or commercial buildings that have long been under-used or vacant and have consequently suffered through several decades of neglect. Steel windows that were originally hot-dip galvanized have fared better under such circumstances, but even steel windows still in relatively good condition must be maintained. This includes painting to protect against rust, keeping the caulk and putty glazing sound, and cleaning the weep holes. Steel windows in 50- to 70-year-old institutional buildings, offices, and large apartment buildings generally have been better maintained than those in factories and often are in good or repairable condition.

Steel windows, with their multiple lites, typical narrow framing members, glass set within the same building plane, and often large glass exposure, have distinctive appearances that are extremely difficult to match with either aluminum or wood. This reinforces the need to consider carefully the use of steel replacement windows.

While a steel unit might not outperform a good quality aluminum window system, the differences are not as great as most would believe. Steel windows are available with modern weatherstripping around the venting unit, reducing air infiltration as well as outside noise. Where flat T-bar glazing channels exist in the historic windows, manufacturers can easily provide replacement units that will accommodate sealed insulating glass (though thicker or wider sections may be required). At least one manufacturer markets a steel window with a partial thermal break feature. Also, steel is a poorer conductor than aluminum and, with its greater strength, less metal exposure to the weather is necessary. To help reduce maintenance costs, a variety of modern priming systems and paint finishes are available, with the best-performing ones naturally costing a bit more.

Steel windows with more decorative metal sections, such as a cover-bead profile, were designed with very shallow glazing bars and are available today for use only with single glazing. A few decorative shapes are unavailable at this time altogether. While many buildings with severely deteriorated steel windows can be replaced with matching steel units that have upgraded performance features, those with particularly thin glazing bars or decorative shapes may require less than optimal solutions.

**Replacement Windows with Substitute Materials**

For most small residences, offices, factories and institutional buildings, replacement windows, should be of the
same material with features matching those on the historic windows, such as true divided lites. Where significant interior spaces are involved with windows as a contributing feature, in-kind replacement should also be specified. On large buildings, however (especially late nineteenth- and early twentieth-century highrises), double-hung, single-lite wooden sash that are beyond repair can often be replaced successfully with an aluminum window. Differences in construction, detail, and finish are not readily apparent from the street below, if certain conditions are followed.

First, the appearance of a double-hung window should be retained whether one or both sash are operable. Even for a fixed window, two glass panels should be used, set in planes corresponding to the original glazing. A dividing bar matching the width and depth of the historic meeting rails is also essential. For new double-hung windows, this generally means higher quality units should be specified because the thin sash frames found on cheaper windows rarely maintain the shadow lines, planar qualities, and overall appearance of the historic sash.

If the historic sash had a circle top, this feature should be duplicated through matching framing and not through an applied metal apron. As to finish, historically appropriate paint colors for the building should be used, especially in light of other changes being made to the window. For example, historic white sash on a red brick building would be dramatically changed if a brown color finish were used on the new sash. On a job with 150 or more windows, specifying a custom color may well result in little or no additional markup, depending on the painting facilities of the manufacturer. Sometimes a custom color job requires additional lead time in order to ensure a close color match, but this is easily achieved through careful planning.

It is common practice to retain the existing wood frame when replacing the window, since retention saves on demolition costs and reduces the likelihood of damage to both interior and exterior finishes. Whenever this is done, however, efforts should be taken not to reduce the glazed surface area. This is difficult to achieve with the installation of both an aluminum sub-frame, which is attached to the old wood frame, and the sash itself. Considerable improvements have been made in this area by some companies, cleaning up sight lines along the metal frames and tracks. Still, there are problems with sill detailing, since the additional metal sub-sill applied over the metal-panned historic wood one creates a double sill detail.

Two other features that should be specified apply to actual detailing. Where windows on the lower floors are readily visible at a close-up view, it is important that a beveled edge be used on the inside of the rail and stile to maintain the general appearance of the old painted putty glaze. The other detail concerns trim around the frame. Flat paning over the old wood frame where trim detail exists should be avoided. Custom-contour paning should be specified so that the appearance of the existing brick or staff molding is matched through use of custom extruded aluminum. The cost of such custom work is mainly that of having the die cut, which is inexpensive.

All of the features described above are marketed by at least some manufacturers of aluminum windows. Companies offering such specialty work tend also to manufacture good quality lines of windows.

On large commercial, institutional, and residential buildings with existing two-lite sash, the option may exist of using an aluminum window with true divided lites as a replacement. Depending on the size of the window and the muntin width and thickness, it may be possible to match the width and appearance of the historic wood windows, provided good shadow lines occur at the muntin. The outside muntin should be at least $\frac{1}{8}$" deep and in many cases, may have to be even deeper where a thick vertical muntin exists on the historic sash. It may also be possible to use insulating glass, particularly where the original muntin was wide and the sash of normal size. Where O.G. lugs existed on the historic sash, this feature can easily be duplicated as an applied piece by casting them in aluminum; the costs for this are low.

One of the more problematic areas in aluminum replacement windows is the use of false muntin. The common industry solution in the 1970s was to use flat muntins sandwiched between the glass in a sealed insulated unit. Another alternative was to apply flat grids to the outside. Neither of these solutions comes close to matching the visual qualities of true divided-lite windows.

Over the past four years, window manufacturers for the commercial retrofit market have developed a new

---

**Figure 7.** Where aluminum replacement windows are appropriate, care should be taken to minimize sight-line changes; maintain the historic double-hung appearance and window reveal; and match the color of the historic windows. Drawings: Penelope Watson
generation of applied muntins for use on high quality windows. Unlike the muntins mentioned above, they are applied to the outside and have a trapezoidal shape with a considerable increase in depth over previous applied-muntin systems. By increasing the depth of the applied muntin bar to between $\frac{1}{2}\" and $\frac{3}{4}\", the shadow lines of the applied muntin begins to approximate the historic appearance on some buildings. These muntin grids can be accommodated on some existing DH-NC40 rated windows, with some of the increased depth achieved by reduction in the thickness of insulating glass. Whether integrated as the window is assembled or screwed-on as a grid afterward, the ones that are most acceptable visually have a clean intersection between the beveled edge of the rail and the stile and the muntin bar.

While there are those who are philosophically opposed to such a solution, it has become a generally accepted practice for use on many highrises, with a marked visual improvement over previous solutions involving aluminum windows. For these windows, custom color, closely matching sight lines, retention of the historic sash reveal, and custom contour panning should be sought. Assessing whether false muntins (applied exterior grids) is an acceptable solution for a particular building can be problematic, depending on the character of a building and the importance of the historic windows in defining that character. Prior approval from local architectural review boards and applicable federal agencies is always recommended. If the existing windows are beyond repair and in-kind replacement is determined infeasible, then it is recommended that several aluminum window companies install field mock-ups in the building. Not only will the field mock-ups clearly show what the windows will look like, this process will reveal whether a particular company has the experience and capability of delivering what is specified.

Some general guidance can be provided regarding the suitability of this type of replacement window. First, it is important to realize that, close up, it will not look like a wood window. Thus for small residences, commercial buildings, and institutional buildings, this treatment is not recommended. Also, for large buildings.

Figure 8. This aluminum replacement window incorporates custom contour panning to recall the historic wood trim and a beveled edge on the inside of the rail and stile to maintain the general appearance of the old painted putty glaze.

Photo: Charles Fisher

Figure 9. Flat panning over old wood frames usually causes a marked change in the appearance of the historic windows.

Photo: Charles Fisher
with significant interior spaces, most state-of-the-art aluminum windows still fail to address interior preservation concerns. The best results with this type of aluminum window have been achieved on highrise buildings, typical of the late nineteenth and early twentieth centuries. These buildings often have windows on the first two floors that are more articulated and highly visible—requiring careful repair or replacement in-kind—while the majority of upper floor windows may be aluminum replacements that feature the special detailing described above. Viewed from the street level, the new windows on the middle and upper floors generally retain the appearance of the historic ones. For large, low-rise buildings such as textile mills or schools, the results are less satisfactory, thus requiring closer scrutiny with decisions made only on a case-by-case basis.

Aluminum replacements impose a size limitation for operable windows. This precludes their use for large-scale, monumental historic windows in order to avoid inappropriately redividing the window. Thus, large, monumental windows tend to remain the exclusive market for wood millworks.

**Striving for Solutions**

Window technology today, suitably applied to the historic preservation market, presents both traditional techniques and state-of-the-art practices. Many historic windows are no longer prime candidates for replacement but, rather, are being repaired and upgraded in their performance—the first preservation priority for windows in historic buildings. Where replacement windows are necessary, there are numerous options today that need to be considered. Only through a careful window study that includes historic preservation considerations can the right decision be assured and the character of a historic building preserved.

Figure 10. Field mock-ups should be used when considering aluminum replacement windows. Shown is a reconditioned historic window (left) with a proposed aluminum replacement. Photo: Charles Parrott

Figure 11. Historic windows can be so significant that they should be preserved at all cost. Photo: Charles Fisher

Substantial portions of the text have been reprinted from an article appearing in the July 1986 issue of The Construction Specifier. We would like to thank the Construction Specification Institute for its kind permission to use the copyrighted material. Special thanks go to the following Preservation Assistance Division staff who contributed to the production: Kay Weeks, Theresa Robinson, Michael Auer, and Brenda Siler.
STANDARDS FOR REHABILITATION AND GUIDELINES FOR REHABILITATING HISTORIC BUILDINGS (Windows)

The following section consists of the ten Standards for Rehabilitation and one chapter from the Guidelines for Rehabilitating Historic Buildings on Windows. The Standards and Guidelines together constitute a 59 page publication, "The Secretary of the Interior’s Standards for Rehabilitation with Guidelines for Rehabilitating Historic Buildings (Rev. 1983)" that may be purchased from the Superintendent of Documents, U.S. Government Printing Office.

The Secretary of the Interior’s Standards for Rehabilitation

The Secretary of the Interior is responsible for establishing standards for all programs under Departmental authority and for advising Federal agencies on the preservation of historic properties listed or eligible for listing in the National Register of Historic Places. In partial fulfillment of this responsibility, the Secretary of the Interior’s Standards for Historic Preservation Projects have been developed to direct work undertaken on historic buildings. The Standards for Rehabilitation (36 CFR 67) comprise that section of the overall historic preservation project standards addressing the most prevalent treatment today—Rehabilitation. Rehabilitation is defined as "the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural, and cultural values."

In the past several years, the most frequent use of the Secretary’s "Standards for Rehabilitation" has been to determine if a rehabilitation project qualifies as a "certified rehabilitation" pursuant to the Tax Reform Act of 1976, the Revenue Act of 1978, and the Economic Recovery Tax Act of 1981, as amended. The Secretary is required by law to certify rehabilitations that are "consistent with the historic character of the structure or the district in which it is located."

The Standards are used to evaluate whether the historic character of a building is preserved in the process of rehabilitation. In terms of specific project work, preservation of the building and its historic character is based on the assumption that (1) the historic materials and features and their unique craftsmanship are of primary importance and that (2) in consequence, they will be retained, protected, and repaired in the process of rehabilitation to the greatest extent possible, not removed and replaced with materials and features which appear to be historic, but which are—in fact—new.
The Standards for Rehabilitation are as follows:

1. Every reasonable effort shall be made to provide a compatible use for a property which requires minimal alteration of the building, structure, or site and its environment, or to use a property for its originally intended purpose.

2. The distinguishing original qualities or character of a building, structure, or site and its environment shall not be destroyed. The removal or alteration of any historic material or distinctive architectural features should be avoided when possible.

3. All buildings, structures, and sites shall be recognized as products of their own time. Alterations that have no historical basis and which seek to create an earlier appearance shall be discouraged.

4. Changes which may have taken place in the course of time are evidence of the history and development of a building, structure, or site and its environment. These changes may have acquired significance in their own right, and this significance shall be respected.

5. Distinctive stylistic features or examples of skilled craftsmanship which characterize a building, structure, or site shall be treated with sensitivity.

6. Deteriorated architectural features shall be repaired rather than replaced, wherever possible. In the event replacement is necessary, the new material should match the material being replaced in composition, design, color, texture, and other visual qualities. Repair or replacement of missing architectural features should be based on accurate duplications of features, substantiated by historic, physical, or pictorial evidence rather than on conjectural designs or the availability of different architectural elements from other buildings or structures.

7. The surface cleaning of structures shall be undertaken with the gentlest means possible. Sandblasting and other cleaning methods that will damage the historic building materials shall not be undertaken.

8. Every reasonable effort shall be made to protect and preserve archeological resources affected by, or adjacent to, any project.

9. Contemporary design for alterations and additions to existing properties shall not be discouraged when such alterations and additions do not destroy significant historical, architectural, or cultural material, and such design is compatible with the size, scale, color, material, and character of the property, neighborhood, and environment.

10. Wherever possible, new addition or alterations to structures shall be done in such a manner that if such additions or alterations were to be removed in the future, the essential form and integrity of the structure would be unimpaired.

Note: This is the program requirement: each rehabilitation project must meet all ten Standards in order to be certified.
Guidelines for Rehabilitating Historic Buildings

The Guidelines were initially developed in 1977 to help property owners, developers, and Federal managers apply the Secretary of the Interior's "Standards for Rehabilitation" during the project stage by providing general design and technical recommendations. Unlike the Standards, the Guidelines are not codified as program requirements.

The Guidelines pertain to historic buildings of all sizes, materials, occupancy, and construction types; and apply to interior and exterior work as well as new exterior additions. Those approaches, treatments, and techniques that are consistent with the Secretary of the Interior's "Standards for Rehabilitation" are listed in the Recommended column on the left; those approaches, treatments, and techniques which could adversely affect a building's historic character are listed in the Not Recommended column on the right. Those complex design issues dealing with new use requirements such as alterations and additions are highlighted to underscore the need for particular sensitivity.

Windows

<table>
<thead>
<tr>
<th>Recommended</th>
<th>Not Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Identifying, retaining, and preserving windows</strong>—and their functional and decorative features—that are important in defining the overall historic character of the building. Such features can include frames, sash, muntins, glazing, sills, heads, hoodmolds, panelled or decorated jambs and moldings, and interior and exterior shutters and blinds.</td>
<td>Removing or radically changing windows which are important in defining the overall historic character of the building so that, as a result, the character is diminished.</td>
</tr>
<tr>
<td><strong>Protecting and maintaining</strong> the wood and architectural metal which comprise the window frame, sash, muntins, and surrounds through appropriate surface treatments such as cleaning, rust removal, limited paint removal, and re-application of protective coating systems.</td>
<td>Changing the number, location, size or glazing pattern of windows, through cutting new openings, blocking-in windows, and installing replacement sash which does not fit the historic window opening.</td>
</tr>
<tr>
<td>Making windows weathertight by recaulking and replacing or installing weatherstripping. These actions also improve thermal efficiency.</td>
<td>Changing the historic appearance of windows through the use of inappropriate designs, materials, finishes, or colors which radically change the sash, depth of reveal, and muntin configuration; the reflectivity and color of the glazing; or the appearance of the frame.</td>
</tr>
<tr>
<td>Evaluating the overall condition of materials to determine whether more than protection and maintenance are required, i.e. if repairs to windows and window features will be required.</td>
<td>Obscuring historic window trim with metal or other material.</td>
</tr>
<tr>
<td><strong>Repairing</strong> window frames and sash by patching, splicing, consolidating or otherwise reinforcing. Such repair may also include replacement in kind of those parts that are either extensively deteriorated or are missing when there are surviving prototypes such as architraves, hoodmolds, sash, sills, and interior or exterior shutters and blinds.</td>
<td>Stripping windows of historic material such as wood, iron, cast iron, and bronze.</td>
</tr>
<tr>
<td>Retrofitting or replacing windows rather than maintaining the sash, frame, and glazing.</td>
<td>Failing to provide adequate protection of materials on a cyclical basis so that deterioration of the windows results.</td>
</tr>
<tr>
<td>Failing to undertake adequate measures to assure the preservation of historic windows.</td>
<td>Replacing an entire window when repair of materials and limited replacement of deteriorated or missing parts are appropriate.</td>
</tr>
<tr>
<td>Using a substitute material for the replacement part that does not convey the visual appearance of the surviving parts of the window or that is physically or chemically incompatible.</td>
<td>Failing to reuse serviceable window hardware such as brass lifts and sash locks.</td>
</tr>
</tbody>
</table>
Windows (continued)

**Recommended**

**Replacing** in kind an entire window that is too deteriorated to repair—if the overall form and detailing are still evident—using the physical evidence to guide the new work. If using the same kind of material is not technically or economically feasible, then a compatible substitute material may be considered.

**Not Recommended**

Removing a character-defining window that is unrepairable and blocking it in; or replacing it with a new window that does not convey the same visual appearance.

The following work is highlighted to indicate that it represents the particularly complex technical or design aspects of rehabilitation projects and should only be considered after the preservation concerns listed above have been addressed.

**Design for Missing Historic Features** Designing and installing new windows when the historic windows (frame, sash and glazing) are completely missing. The replacement windows may be an accurate restoration using historical, pictorial, and physical documentation; or be a new design that is compatible with the window openings and the historic character of the building.

Creating a false historical appearance because the replaced window is based on insufficient historical, pictorial, and physical documentation.

Introducing a new design that is incompatible with the historic character of the building.

**Alterations/Additions for the New Use** Designing and installing additional windows on rear or other-non character-defining elevations if required by the new use. New window openings may also be cut into exposed party walls. Such design should be compatible with the overall design of the building, but not duplicate the fenestration pattern and detailing of a character-defining elevation.

Installing new windows, including frames, sash, and muntin configuration that are incompatible with the building's historic appearance or obscure, damage, or destroy character-defining features.

Providing a setback in the design of dropped ceilings when they are required for the new use to allow for the full height of the window openings.

Inserting new floors or furred-down ceilings which cut across the glazed areas of windows so that the exterior form and appearance of the windows are changed.
The windows on many historic buildings are an important aspect of the architectural character of those buildings. Their design, craftsmanship, or other qualities may make them worthy of preservation. This is self-evident for ornamental windows, but it can be equally true for warehouses or factories where the windows may be the most dominant visual element of an otherwise plain building (see figure 1). Evaluating the significance of these windows and planning for their repair or replacement can be a complex process involving both objective and subjective considerations. The Secretary of the Interior's Standards for Rehabilitation, and the accompanying guidelines, call for respecting the significance of original materials and features, repairing and retaining them wherever possible, and when necessary, replacing them in kind. This Brief is based on the issues of significance and repair which are implicit in the standards, but the primary emphasis is on the technical issues of planning for the repair of windows including evaluation of their physical condition, techniques of repair, and design considerations when replacement is necessary.

Much of the technical section presents repair techniques as an instructional guide for the do-it-yourselfer. The information will be useful, however, for the architect, contractor, or developer on large-scale projects. It presents a methodology for approaching the evaluation and repair of existing windows, and considerations for replacement, from which the professional can develop alternatives and specify appropriate materials and procedures.

Architectural or Historical Significance

Evaluating the architectural or historical significance of windows is the first step in planning for window treatments, and a general understanding of the function and history of windows is vital to making a proper evaluation. As a part of this evaluation, one must consider four basic window functions: admitting light to the interior spaces, providing fresh air and ventilation to the interior, providing a visual link to the outside world, and enhancing the appearance of a building. No single factor can be disregarded when planning window treatments; for example, attempting to conserve energy by closing up or reducing the size of window openings may result in the use of more energy by increasing electric lighting loads and decreasing passive solar heat gains.

Historically, the first windows in early American houses were casement windows; that is, they were hinged at the side and opened outward. In the beginning of the eighteenth century single- and double-hung windows were introduced. Subsequently many styles of these vertical sliding sash windows have come to be associated with specific building periods or architectural styles, and this is an important consideration in determining the significance of windows, especially on a local or regional basis. Site-specific, regionally oriented architectural comparisons should be made to determine the significance of windows in question. Although such comparisons may focus on specific window types and their details, the ultimate determination of significance should be made within the context of the whole building, wherein the windows are one architectural element (see figure 2).

After all of the factors have been evaluated, windows should be considered significant to a building if they: 1) are original, 2) reflect the original design intent for the building, 3) reflect period or regional styles or building practices, 4) reflect changes to the building resulting from major periods or events, or 5) are examples of exceptional craftsmanship or design. Once this evaluation of significance has been completed, it is possible to pro-
ceed with planning appropriate treatments, beginning with an investigation of the physical condition of the windows.

Physical Evaluation

The key to successful planning for window treatments is a careful evaluation of existing physical conditions on a unit-by-unit basis. A graphic or photographic system may be devised to record existing conditions and illustrate the scope of any necessary repairs. Another effective tool is a window schedule which lists all of the parts of each window unit. Spaces by each part allow notes on existing conditions and repair instructions. When such a schedule is completed, it indicates the precise tasks to be performed in the repair of each unit and becomes a part of the specifications. In any evaluation, one should note at a minimum, 1) window location, 2) condition of the paint, 3) condition of the frame and sill, 4) condition of the sash (rails, stiles and muntins), 5) glazing problems, 6) hardware, and 7) the overall condition of the window (excellent, fair, poor, and so forth).

Many factors such as poor design, moisture, vandalism, insect attack, and lack of maintenance can contribute to window deterioration, but moisture is the primary contributing factor in wooden window decay. All window units should be inspected to see if water is entering around the edges of the frame and, if so, the joints or seams should be caulked to eliminate this danger. The glazing putty should be checked for cracked, loose, or missing sections which allow water to saturate the wood, especially at the joints. The back putty on the interior side of the pane should also be inspected, because it creates a seal which prevents condensation from running down into the joinery. The sill should be examined to insure that it slopes downward away from the building and allows water to drain off. In addition, it may be advisable to cut a dripline along the underside of the sill. This almost invisible treatment will insure proper water run-off, particu-

larly if the bottom of the sill is flat. Any conditions, including poor original design, which permit water to come in contact with the wood or to puddle on the sill must be corrected as they contribute to deterioration of the window.

One clue to the location of areas of excessive moisture is the condition of the paint; therefore, each window should be examined for areas of paint failure. Since excessive moisture is detrimental to the paint bond, areas of paint blistering, cracking, flaking, and peeling usually identify points of water penetration, moisture saturation, and potential deterioration. Failure of the paint should not, however, be mistakenly interpreted as a sign that the wood is in poor condition and hence, irreparable. Wood is frequently in sound physical condition beneath unsightly paint. After noting areas of paint failure, the next step is to inspect the condition of the wood, particularly at the points identified during the paint examination.

Each window should be examined for operational soundness beginning with the lower portions of the frame and sash. Exterior rainwater and interior condensation can flow downward along the window, entering and collecting at points where the flow is blocked. The sill, joints between the sill and jamb, corners of the bottom rails and muntin joints are typical points where water collects and deterioration begins (see figure 3). The operation of the window (continuous opening and closing over the years and seasonal temperature changes) weakens the joints, causing movement and slight separation. This process makes the joints more vulnerable to water which is readily absorbed into the end-grain of the wood. If severe deterioration exists in these areas, it will usually be apparent on visual inspection, but other less severely deteriorated areas of the wood may be tested by two traditional methods using a small ice pick.

An ice pick or an awl may be used to test wood for soundness. The technique is simply to jab the pick into a wetted wood surface at an angle and pry up a small sec-
tion of the wood. Sound wood will separate in long fibrous splinters, but decayed wood will lift up in short irregular pieces due to the breakdown of fiber strength.

Another method of testing for soundness consists of pushing a sharp object into the wood, perpendicular to the surface. If deterioration has begun from the hidden side of a member and the core is badly decayed, the visible surface may appear to be sound wood. Pressure on the probe can force it through an apparently sound skin to penetrate deeply into decayed wood. This technique is especially useful for checking sills where visual access to the underside is restricted.

Following the inspection and analysis of the results, the scope of the necessary repairs will be evident and a plan for the rehabilitation can be formulated. Generally the actions necessary to return a window to “like new” condition will fall into three broad categories: 1) routine maintenance procedures, 2) structural stabilization, and 3) parts replacement. These categories will be discussed in the following sections and will be referred to respectively as Repair Class I, Repair Class II, and Repair Class III. Each successive repair class represents an increasing level of difficulty, expense, and work time. Note that most of the points mentioned in Repair Class I are routine maintenance items and should be provided in a regular maintenance program for any building. The neglect of these routine items can contribute to many common window problems.

Before undertaking any of the repairs mentioned in the following sections all sources of moisture penetration should be identified and eliminated, and all existing decay fungi destroyed in order to arrest the deterioration process. Many commercially available fungicides and wood preservatives are toxic, so it is extremely important to follow the manufacturer’s recommendations for application, and store all chemical materials away from children and animals. After fungicidal and preservative treatment the windows may be stabilized, retained, and restored with every expectation for a long service life.

**Repair Class I: Routine Maintenance**

Repairs to wooden windows are usually labor intensive and relatively uncomplicated. On small scale projects this allows the do-it-yourselfer to save money by repairing all or part of the windows. On larger projects it presents the opportunity for time and money which might otherwise be spent on the removal and replacement of existing windows, to be spent on repairs, subsequently saving all or part of the material cost of new window units. Regardless of the actual costs, or who performs the work, the evaluation process described earlier will provide the knowledge from which to specify an appropriate work program, establish the work element priorities, and identify the level of skill needed by the labor force.

The routine maintenance required to upgrade a window to “like new” condition normally includes the following steps: 1) some degree of interior and exterior paint removal, 2) removal and repair of sash (including reglazing where necessary), 3) repairs to the frame, 4) weatherstripping and reinstallion of the sash, and 5) repainting. These operations are illustrated for a typical double-hung wooden window (see figures 4a-f), but they may be adapted to other window types and styles as applicable.

Historic windows have usually acquired many layers of paint over time. Removal of excess layers or peeling and flaking paint will facilitate operation of the window and restore the clarity of the original detailing. Some degree of paint removal is also necessary as a first step in the proper surface preparation for subsequent refinishing (if paint color analysis is desired, it should be conducted prior to the onset of the paint removal). There are several safe and effective techniques for removing paint from wood, depending on the amount of paint to be removed. Several techniques such as scraping, chemical stripping, and the use of a hot air gun are discussed in “Preservation Briefs: 10 Paint Removal from Historic Woodwork” (see Additional Reading section at end).

Paint removal should begin on the interior frames, being careful to remove the paint from the interior stop and the parting bead, particularly along the seam where these stops meet the jamb. This can be accomplished by running a utility knife along the length of the seam, breaking the paint bond. It will then be much easier to remove the stop, the parting bead and the sash. The interior stop may be initially loosened from the sash side to avoid visible scarring of the wood and then gradually pried loose using a pair of putty knives, working up and down the stop in small increments (see figure 4b). With the stop removed, the lower or interior sash may be withdrawn. The sash cords should be detached from the sides of the sash and their ends may be pinned with a nail or tied in a knot to prevent them from falling into the weight pocket.

Removal of the upper sash on double-hung units is similar but the parting bead which holds it in place is set into a groove in the center of the stile and is thinner and more delicate than the interior stop. After removing any paint along the seam, the parting bead should be carefully pried out and worked free in the same manner as the interior stop. The upper sash can be removed in the same manner as the lower one and both sash taken to a convenient work area (in order to remove the sash the interior stop and parting bead need only be removed from one side of the window). Window openings can be covered with polyethylene sheets or plywood sheathing while the sash are out for repair.

The sash can be stripped of paint using appropriate techniques, but if any heat treatment is used (see figure 4c), the glass should be removed or protected from the sudden temperature change which can cause breakage. An
Figure 4a. The following series of photographs of the repair of a historic double-hung window use a unit which is structurally sound but has many layers of paint, some cracked and missing putty, slight separation at the joints, broken sash cords, and one cracked pane. Photo: John H. Myers

Figure 4b. After removing paint from the seam between the interior stop and the jamb, the stop can be pried out and gradually worked loose using a pair of putty knives as shown. To avoid visible scarring of the wood, the sash can be raised and the stop pried loose initially from the outer side. Photo: John H. Myers

Figure 4c. Sash can be removed and repaired in a convenient work area. Paint is being removed from this sash with a hot air gun while an asbestos sheet protects the glass from sudden temperature change. Photo: John H. Myers

Figure 4d. Reglazing or replacement of the putty requires that the existing putty be removed manually, the glazing points be extracted, the glass removed, and the back putty scraped out. To re-glaze, a bed of putty is laid around the perimeter of the rebate, the pane is pressed into place, glazing points are inserted to hold the pane (shown), and a final seal of putty is beveled around the edge of the glass. Photo: John H. Myers

Figure 4e. A common repair is the replacement of broken sash cords with new cords (shown) or with chains. The weight pocket is often accessible through a removable plate in the jamb, or by removing the interior trim. Photo: John H. Myers

Figure 4f. Following the relatively simple repairs, the window is weathertight, like new in appearance, and serviceable for many years to come. Both the historic material and the detailing and craftsmanship of this original window have been preserved. Photo: John H. Myers
overlay of aluminum foil on gypsum board or asbestos can protect the glass from such rapid temperature change. It is important to protect the glass because it may be historic and often adds character to the window. Deteriorated putty should be removed manually, taking care not to damage the wood along the rabbet. If the glass is to be removed, the glazing points which hold the glass in place can be extracted and the panes numbered and removed for cleaning and reuse in the same openings. With the glass panes out, the remaining putty can be removed and the sash can be sanded, patched, and primed with a preservative primer. Hardened putty in the rabbets may be softened by heating with a soldering iron at the point of removal. Putty remaining on the glass may be softened by soaking the panes in linseed oil, and then removed with less risk of breaking the glass. Before reinstalling the glass, a bead of glazing compound or linseed oil putty should be laid around the rabbet to cushion and seal the glass. Glazing compound should only be used on wood which has been brushed with linseed oil and primed with an oil based primer or paint. The pane is then pressed into place and the glazing points are pushed into the wood around the perimeter of the pane (see figure 4d). The final glazing compound or putty is applied and beveled to complete the seal. The sash can be refinished as desired on the inside and painted on the outside as soon as a “skin” has formed on the putty, usually in 2 or 3 days. Exterior paint should cover the beveled glazing compound or putty and lap over onto the glass slightly to complete a weathertight seal. After the proper curing times for the paints and putty used on the sash. One of the common work items is the replacement of the sash cords with new rope cords or with chains (see figure 4e). The weight pocket is frequently accessible through a door on the face of the frame near the sill, but if no door exists, the trim on the interior face may be removed for access. Sash weights may be increased for easier window operation by elderly or handicapped persons. Additional repairs to the frame and sash may include consolidation or replacement of deteriorated wood. Techniques for these repairs are discussed in the following sections.

The operations just discussed summarize the efforts necessary to restore a window with minor deterioration to “like new” condition (see figure 4f). The techniques can be applied by an unskilled person with minimal training and experience. To demonstrate the practicality of this approach, and photograph it, a Technical Preservation Services staff member repaired a wooden double-hung, two over two window which had been in service over ninety years. The wood was structurally sound but the window had one broken pane, many layers of paint, broken sash cords and inadequate, worn-out weatherstripping. The staff member found that the frame could be stripped of paint and the sash removed quite easily. Paint, putty and glass removal required about one hour for each sash, and the reglazing of both sash was accomplished in about one hour. Weatherstripping of the sash and frame, replacement of the sash cords and reinstallation of the sash, parting bead, and stop required an hour and a half. These times refer only to individual operations; the entire pro-

ess took several days due to the drying and curing times for putty, primer, and paint, however, work on other window units could have been in progress during these lag times.

**Repair Class II: Stabilization**

The preceding description of a window repair job focused on a unit which was operationally sound. Many windows will show some additional degree of physical deterioration, especially in the vulnerable areas mentioned earlier, but even badly damaged windows can be repaired using simple processes. Partially decayed wood can be waterproofed, patched, built-up, or consolidated and then painted to achieve a sound condition, good appearance, and greatly extended life. Three techniques for repairing partially decayed or weathered wood are discussed in this section, and all three can be accomplished using products available at most hardware stores.

One established technique for repairing wood which is split, checked or shows signs of rot, is to: 1) dry the wood, 2) treat decayed areas with a fungicide, 3) waterproof with two or three applications of boiled linseed oil (applications every 24 hours), 4) fill cracks and holes with putty, and 5) after a “skin” forms on the putty, paint the surface. Care should be taken with the use of fungicide which is toxic. Follow the manufacturers’ directions and use only on areas which will be painted. When using any technique of building up or patching a flat surface, the finished surface should be sloped slightly to carry water away from the window and not allow it to puddle. Caulking of the joints between the sill and the jamb will help reduce further water penetration.

When sills or other members exhibit surface weathering they may also be built-up using wood putties or homemade mixtures such as sawdust and resorcinol glue, or whiting and varnish. These mixtures can be built up in successive layers, then sanded, primed, and painted. The same caution about proper slope for flat surfaces applies to this technique.

Wood may also be strengthened and stabilized by consolidation, using semi-rigid epoxies which saturate the porous decayed wood and then harden. The surface of the consolidated wood can then be filled with a semi-rigid epoxy patching compound, sanded and painted (see figure 5). Epoxy patching compounds can be used to build up

---

**Figure 5. This illustrates a two-part epoxy patching compound used to fill the surface of a weathered sill and rebuild the missing edge. When the epoxy cures, it can be sanded smooth and painted to achieve a durable and waterproof repair. Photo: John H. Myers**
missing sections or decayed ends of members. Profiles can be duplicated using hand molds, which are created by pressing a ball of patching compound over a sound section of the profile which has been rubbed with butcher's wax. This can be a very efficient technique where there are many typical repairs to be done. Technical Preservation Services has published *Epoxies for Wood Repairs in Historic Buildings* (see Additional Reading section at end), which discusses the theory and techniques of epoxy repairs. The process has been widely used and proven in marine applications; and proprietary products are available at hardware and marine supply stores. Although epoxy materials may be comparatively expensive, they hold the promise of being among the most durable and long lasting materials available for wood repair.

Any of the three techniques discussed can stabilize and restore the appearance of the window unit. There are times, however, when the degree of deterioration is so advanced that stabilization is impractical, and the only way to retain some of the original fabric is to replace damaged parts.

**Repair Class III: Splices and Parts Replacement**

When parts of the frame or sash are so badly deteriorated that they cannot be stabilized there are methods which permit the retention of some of the existing or original fabric. These methods involve replacing the deteriorated parts with new matching pieces, or splicing new wood into existing members. The techniques require more skill and are more expensive than any of the previously discussed alternatives. It is necessary to remove the sash and/or the affected parts of the frame and have a carpenter or woodworking mill reproduce the damaged or missing parts. Most millwork firms can duplicate parts, such as muntins, bottom rails, or sills, which can then be incorporated into the existing window, but it may be necessary to shop around because there are several factors controlling the practicality of this approach. Some woodworking mills do not like to repair old sash because nails or foreign objects in the sash can damage expensive knives (which cost far more than their profits on small repair jobs); others do not have cutting knives to duplicate muntin profiles. Some firms prefer to concentrate on larger jobs with more profit potential, and some may not have a craftsman who can duplicate the parts. A little searching should locate a firm which will do the job, and at a reasonable price. If such a firm does not exist locally, there are firms which undertake this kind of repair and ship nationwide. It is possible, however, for the advanced do-it-yourselfer or craftsman with a table saw to duplicate moulding profiles using techniques discussed by Gordie Whittington in "Simplified Methods for Reproducing Wood Mouldings," *Bulletin of the Association for Preservation Technology*, Vol. III, No. 4, 1971, or illustrated more recently in *The Old House*, Time-Life Books, Alexandria, Virginia, 1979.

The repairs discussed in this section involve window frames which may be in very deteriorated condition, possibly requiring removal; therefore, caution is in order. The actual construction of wooden window frames and sash is not complicated. Pegged mortise and tenon units can be disassembled easily, if the units are out of the building. The installation or connection of some frames to the surrounding structure, especially masonry walls, can complicate the work immeasurably, and may even require dismantling of the wall. It may be useful, therefore, to take the following approach to frame repair: 1) conduct regular maintenance of sound frames to achieve the longest life possible, 2) make necessary repairs in place whenever possible, using stabilization and splicing techniques, and 3) if removal is necessary, thoroughly investigate the structural detailing and seek appropriate professional consultation.

Another alternative may be considered if parts replacement is required, and that is sash replacement. If extensive replacement of parts is necessary and the job becomes prohibitively expensive it may be more practical to purchase new sash which can be installed into the existing frames. Such sash are available as exact custom reproductions, reasonable facsimiles (custom windows with similar profiles), and contemporary wooden sash which are similar in appearance. There are companies which still manufacture high quality wooden sash which would duplicate most historic sash. A few calls to local building suppliers may provide a source of appropriate replacement sash, but if not, check with local historical associations, the state historic preservation office, or preservation related magazines and supply catalogs for information.

If a rehabilitation project has a large number of windows such as a commercial building or an industrial complex, there may be less of a problem arriving at a solution. Once the evaluation of the windows is completed and the scope of the work is known, there may be a potential economy of scale. Woodworking mills may be interested in the work from a large project; new sash in volume may be considerably less expensive per unit; crews can be assembled and trained on site to perform all of the window repairs; and a few extensive repairs can be absorbed (without undue burden) into the total budget for a large number of sound windows. While it may be expensive for the average historic home owner to pay seventy dollars or more for a mill to grind a custom knife to duplicate four or five bad muntins, that cost becomes negligible on large commercial projects which may have several hundred windows.

Most windows should not require the extensive repairs discussed in this section. The ones which do are usually in buildings which have been abandoned for long periods or have totally lacked maintenance for years. It is necessary to thoroughly investigate the alternatives for windows which do require extensive repairs to arrive at a solution which retains historic significance and is also economically feasible. Even for projects requiring repairs identified in this section, if the percentage of parts replacement per window is low, or the number of windows requiring repair is small, repair can still be a cost effective solution.

**Weatherization**

A window which is repaired should be made as energy efficient as possible by the use of appropriate weatherstripping to reduce air infiltration. A wide variety of products are available to assist in this task. Felt may be fastened to the top, bottom, and meeting rails, but may have the disadvantage of absorbing and holding moisture, particularly at the bottom rail. Rolled vinyl strips may also be tacked into place in appropriate locations to reduce infiltration. Metal strips or new plastic spring strips may be used on the rails and, if space permits, in
the channels between the sash and jamb. Weatherstripping
is a historic treatment, but old weatherstripping (felt) is
not likely to perform very satisfactorily. Appropriate con-
temporary weatherstripping should be considered an in-
tegral part of the repair process for windows. The use of
sash locks installed on the meeting rail will insure that the
sash are kept tightly closed so that the weatherstripping
will function more effectively to reduce infiltration.
Although such locks will not always be historically accu-
rate, they will usually be viewed as an acceptable con-
temporary modification in the interest of improved thermal
performance.
Many styles of storm windows are available to improve
the thermal performance of existing windows. The use of
exterior storm windows should be investigated whenever
feasible because they are thermally efficient, cost-effective,
reversible, and allow the retention of original windows
(see "Preservation Briefs: 3"). Storm window frames may
be made of wood, aluminum, vinyl, or plastic; however,
the use of unfinished aluminum storms should be
avoided. The visual impact of storms may be minimized
by selecting colors which match existing trim color.
Arched top storms are available for windows with special
shapes. Although interior storm windows appear to offer
an attractive option for achieving double glazing with
minimal visual impact, the potential for damaging con-
densation problems must be addressed. Moisture which
becomes trapped between the layers of glazing can con-
dense on the colder, outer prime window, potentially
leading to deterioration. The correct approach to using
interior storms is to create a seal on the interior storm while
allowing some ventilation around the prime window. In
actual practice, the creation of such a durable, airtight
seal is difficult.

Window Replacement

Although the retention of original or existing windows is
always desirable and this Brief is intended to encourage
that goal, there is a point when the condition of a win-
dow may clearly indicate replacement. The decision pro-
cess for selecting replacement windows should not begin
with a survey of contemporary window products which
are available as replacements, but should begin with a
look at the windows which are being replaced. Attempt to
understand the contribution of the window(s) to the ap-
pearance of the facade including: 1) the pattern of the
openings and their size; 2) proportions of the frame and
sash; 3) configuration of window panes; 4) muntin pro-
files; 5) type of wood; 6) paint color; 7) characteristics of
the glass; and 8) associated details such as arched tops,
hoods, or other decorative elements. Develop an under-
standing of how the window reflects the period, style, or
regional characteristics of the building, or represents tech-
nological development.

Armed with an awareness of the significance of the exis-
ting window, begin to search for a replacement which
retains as much of the character of the historic window as
possible. There are many sources of suitable new win-
dows. Continue looking until an acceptable replacement
can be found. Check building supply firms, local wood-
working mills, carpenters, preservation oriented maga-
zines, or catalogs or suppliers of old building materials,
for product information. Local historical associations and
state historic preservation offices may be good sources of
information on products which have been used success-
fully in preservation projects.

Consider energy efficiency as one of the factors for
replacements, but do not let it dominate the issue. Energy
conservation is no excuse for the wholesale destruction
of historic windows which can be made thermally efficient
by historically and aesthetically acceptable means. In fact,
a historic wooden window with a high quality storm win-
dow added should thermally outperform a new double-
glazed metal window which does not have thermal
breaks (insulation between the inner and outer frames in-
tended to break the path of heat flow). This occurs
because the wood has far better insulating value than the
metal, and in addition many historic windows have high
ratios of wood to glass, thus reducing the area of highest
heat transfer. One measure of heat transfer is the U-value,
the number of Btu’s per hour transferred through a square
foot of material. When comparing thermal performance,
the lower the U-value the better the performance. Accord-
ing to ASHRAE 1977 Fundamentals, the U-values for
single glazed wooden windows range from 0.88 to 0.99.
The addition of a storm window should reduce these
figures to a range of 0.44 to 0.49. A non-thermal break,
double-glazed metal window has a U-value of about 0.6.

Conclusion

Technical Preservation Services recommends the retention
and repair of original windows whenever possible. We
believe that the repair and weatherization of existing
wooden windows is more practical than most people
realize, and that many windows are unfortunately re-
placed because of a lack of awareness of techniques for
evaluation, repair, and weatherization. Wooden windows
which are repaired and properly maintained will have
greatly extended service lives while contributing to the
historic character of the building. Thus, an important ele-
ment of a building’s significance will have been preserved
for the future.

Additional Reading

of Heating, Refrigerating and Air-conditioning Engineers, 1978
(chapter 20).

Ferro, Maximillian. Preservation: Present Pathway to Fall River’s Future.
Fall River, Massachusetts: City of Fall River, 1979 (chapter 7).


Look, David W. “Preservation Briefs: 10 Paint Removal from Historic
Woodwork.” Washington, DC: Technical Preservation Services,

University Press, 1952.

Phillips, Morgan, and Selwyn, Judith. Epitaphs for Wood Repairs in
Historic Buildings. Washington, DC: Technical Preservation Ser-
vice, U.S. Department of the Interior (Government Printing Office,

Rehab Right. Oakland, California: City of Oakland Planning Depart-
ment, 1978 (pp. 78-83).


Smith, Baird M. “Preservation Briefs: 3 Conserving Energy in Historic

1981
The Repair and Thermal Upgrading of Historic Steel Windows

Sharon C. Park, AIA

Technical Preservation Services  Preservation Assistance Division
National Park Service  U.S. Department of the Interior

The Secretary of the Interior's "Standards for Rehabilitation" require that where historic windows are individually significant features, or where they contribute to the character of significant facades, their distinguishing visual qualities must not be destroyed. Further, the rehabilitation guidelines recommend against changing the historic appearance of windows through the use of inappropriate designs, materials, finishes, or colors which radically change the sash, depth of reveal, and muntin configuration; the reflectivity and color of the glazing; or the appearance of the frame.

Windows are among the most vulnerable features of historic buildings undergoing rehabilitation. This is especially the case with rolled steel windows, which are often mistakenly not deemed worthy of preservation in the conversion of old buildings to new uses. The case with which they can be replaced and the mistaken assumption that they cannot be made energy efficient except at great expense are factors that typically lead to the decision to remove them. In many cases, however, repair and retrofit of the historic windows are more economical than wholesale replacement, and all too often, replacement units are unlike the originals in design and appearance. If the windows are important in establishing the historic character of the building (see fig. 1), insensitively designed replacement windows may diminish—or destroy—the building's historic character.

This Brief identifies various types of historic steel windows that dominated the metal window market from 1890-1950. It then gives criteria for evaluating deterioration and for determining appropriate treatment, ranging from routine maintenance and weatherization to extensive repairs, so that replacement may be avoided where possible. This information applies to do-it-yourself jobs and to large rehabilitations where the volume of work warrants the removal of all window units for complete overhaul by professional contractors.

This Brief is not intended to promote the repair of ferrous metal windows in every case, but rather to insure that preservation is always the first consideration in a rehabilitation project. Some windows are not important elements in defining a building's historic character; others are highly significant, but so deteriorated that repair is impossible. In such cases, the Brief offers guidance in evaluating appropriate replacement windows.

Fig. 1  Often highly distinctive in design and craftsmanship, rolled steel windows play an important role in defining the architectural character of many later nineteenth and early twentieth century buildings. Art Deco, Art Moderne, the International Style, and Post World War II Modernism depended on the slim profiles and streamlined appearance of metal windows for much of their impact. Photo: William G. Johnson.

*The technical information given in this brief is intended for most ferrous (or magnetic) metals, particularly rolled steel. While stainless steel is a ferrous metal, the cleaning and repair techniques outlined here must not be used on it as the finish will be damaged. For information on cleaning stainless steel and non-ferrous metals, such as bronze, Monel, or aluminum, refer to Metals in America's Historic Buildings (see bibliography).*
HISTORICAL DEVELOPMENT

Although metal windows were available as early as 1860 from catalogues published by architectural supply firms, they did not become popular until after 1890. Two factors combined to account for the shift from wooden to metal windows about that time. Technology borrowed from the rolling industry permitted the mass production of rolled steel windows. This technology made metal windows cost competitive with conventional wooden windows. In addition, a series of devastating urban fires in Boston, Baltimore, Philadelphia, and San Francisco led to the enactment of strict fire codes for industrial and multi-story commercial and office buildings.

As in the process of making rails for railroads, rolled steel windows were made by passing hot bars of steel through progressively smaller, shaped rollers until the appropriate angled configuration was achieved (see fig. 2). The rolled steel sections, generally 1/8" thick and 1" - 1 1/2" wide, were used for all the components of the windows: sash, frame, and subframe (see fig. 3). With the addition of wire glass, a fire-resistant window resulted. These rolled steel windows are almost exclusively found in masonry or concrete buildings.

A byproduct of the fire-resistant window was the strong metal frame that permitted the installation of larger windows and windows in series. The ability to have expansive amounts of glass and increased ventilation dramatically changed the designs of late 19th and early 20th century industrial and commercial buildings.

The newly available, reasonably priced steel windows soon became popular for more than just their fire-resistant qualities. They were standardized, extremely durable, and easily transported. These qualities led to the use of steel windows in every type of construction, from simple industrial and institutional buildings to luxury commercial and apartment buildings. Case ment, double-hung, pivot, projecting, austral, and continuous windows differed in operating and ventilating capacities. Figure 4 outlines the kinds and properties of metal windows available then and now. In addition, the thin profiles of metal windows contributed to the streamlined appearance of the Art Deco, Art Moderne, and International Styles, among others.

The extensive use of rolled steel metal windows continued until after World War II when cheaper, non-corroding aluminum windows became increasingly popular. While aluminum windows dominate the market today, steel windows are still fabricated. Should replacement of original windows become necessary, replacement windows may be available from the manufacturers of some of the earliest steel windows. Before an informed decision can be made whether to repair or replace metal windows, however, the significance of the windows must be determined and their physical condition assessed.

---


Fig. 2. The process of rolling a steel bar into an angled section is illustrated above. The shape and size of the rolled section will vary slightly depending on the overall strength needed for the window opening and the location of the section in the assembly: subframe, frame, or sash. The 1/8" thickness of the metal section is generally standard. Drawing: A Metal Window Dictionary. Used with permission.

Fig. 3 A typical section through the top and bottom of a metal window shows the three component parts of the window assembly: subframe, frame, and sash. Drawings: Catalogue No. 15, January 1931; International Casement Co., Inc., presently Hope's Architectural Products, Inc., Jamestown, NY. Used with permission.
EVALUATION

Historic and Architectural Considerations

An assessment of the significance of the windows should begin with a consideration of their function in relation to the building’s historic use and its historic character. Windows that help define the building’s historic character should be preserved even if the building is being converted to a new use. For example, projecting steel windows used to introduce light and an effect of spaciousness to a warehouse or industrial plant can be retained in the conversion of such a building to offices or residences.

Other elements in assessing the relative importance of the historic windows include the design of the windows and their relationship to the scale, proportion, detailing and architectural style of the building. While it may be easy to determine the aesthetic value of highly ornamented windows, or to recognize the importance of streamlined windows as an element of a style, less elaborate windows can also provide strong visual interest by their small panes or projecting planes when open, particularly in simple, unadorned industrial buildings (see fig. 5).

One test of the importance of windows to a building is to ask if the overall appearance of the building would be changed noticeably if the windows were to be removed or radically altered. If so, the windows are important in defining the building’s historic character, and should be repaired if their physical condition permits.

Physical Evaluation

Steel window repair should begin with a careful evaluation of the physical condition of each unit. Either drawings or photographs, liberally annotated, may be used to record the location of each window, the type of operability, the condition of all three parts—sash, frame and sub-frame—and the repairs essential to its continued use.

Specifically, the evaluation should include: presence and degree of corrosion; condition of paint; deterioration of the metal sections, including bowing, misalignment of the sash, or bent sections; condition of the glass and glazing compound; presence and condition of all hardware, screws, bolts, and hinges; and condition of the masonry or concrete surrounds, including need for caulking or resetting of improperly sloped sills.

Corrosion, principally rusting in the case of steel windows, is the controlling factor in window repair; therefore, the evaluator should first test for its presence. Corrosion can be light, medium, or heavy, depending on how much the rust has penetrated the metal sections. If the rusting is merely a surface accumulation or flaking, then the corrosion is light. If the rusting has penetrated the metal (indicated by a bubbling texture), but has not caused any structural damage, then the corrosion is medium. If the rust has penetrated deep into the metal, the corrosion is heavy. Heavy corrosion generally results in some form of structural damage, through delamination, to the metal section, which must then be patched or spliced. A sharp probe or tool, such as an ice pick, can be used to determine the extent of corrosion in the metal. If the probe can penetrate the surface of the metal and brittle strands can be dug out, then a high degree of corrosive deterioration is present.

In addition to corrosion, the condition of the paint, the presence of bowing or misalignment of metal sections, the amount of glass needing replacement, and the condition of the masonry or concrete surrounds must be assessed in the evaluation process. These are key factors in determining whether or not the windows can be repaired in place. The more complete the inventory of existing conditions, the easier it will be to determine whether repair is feasible or whether replacement is warranted.

Rehabilitation Work Plan

Following inspection and analysis, a plan for the rehabilitation can be formulated. The actions necessary to return windows to an efficient and effective working condition will fall into one or more of the following categories: routine maintenance, repair, and weatherization. The routine maintenance and weatherization measures described here are generally within the range of do-it-yourselfers. Other repairs, both moderate and major, require a professional contractor. Major repairs normally require the removal of the window units to a workshop, but even in the case of moderate repairs, the number of windows involved might warrant the removal of all the deteriorated units to a workshop in order to realize a more economical repair price. Replacement of windows should be considered only as a last resort.

Since moisture is the primary cause of corrosion in steel windows, it is essential that excess moisture be eliminated and that the building be made as weathertight as possible before any other work is undertaken. Moisture can accumulate from cracks in the masonry, from spalling mortar, from leaking gutters, from air conditioning condensation runoff, and from poorly ventilated interior spaces.

Finally, before beginning any work, it is important to be aware of health and safety risks involved. Steel windows have historically been coated with lead paint. The removal of such paint by abrasive methods will produce toxic dust. Therefore, safety goggles, a toxic dust respirator, and protective clothing should be worn. Similar protective measures should be taken when acid compounds are used. Local codes may govern the methods of removing lead paints and proper disposal of toxic residue.

ROUTINE MAINTENANCE

A preliminary step in the routine maintenance of steel windows is to remove surface dirt and grease in order to ascertain the degree of deterioration, if any. Such minor cleaning can be accomplished using a brush or vacuum followed by wiping with a cloth dampened with mineral spirits or denatured alcohol.
Double-hung industrial windows duplicated the look of traditional wooden windows. Metal double-hung windows were early examples of a building product adapted to meet stringent new fire code requirements for manufacturing and high-rise buildings in urban areas. Soon supplanted in industrial buildings by less expensive pivot windows, double-hung metal windows regained popularity in the 1940s for use in speculative suburban housing.

Austral windows were also a product of the 1920s. They combined the appearance of the double-hung window with the increased ventilation and ease of operation of the projected window. (When fully opened, they provided 70% ventilation as compared to 50% ventilation for double-hung windows.) Austral windows were often used in schools, libraries and other public buildings.

Pivot windows were an early type of industrial window that combined inexpensive first cost and low maintenance. Pivot windows became standard for warehouses and power plants where the lack of screens was not a problem. The window shown here is a horizontal pivot. Windows that turned about a vertical axis were also manufactured (often of iron). Such vertical pivots are rare today.

Casement windows adapted the English tradition of using wrought iron casements with leaded cames for residential use. Rolled steel casements (either single, as shown, or paired) were popular in the 1920s for cottage style residences and Gothic style campus architecture. More streamlined casements were popular in the 1930s for institutional and small industrial buildings.

Projecting windows, sometimes called awning or hopper windows, were perfected in the 1920s for industrial and institutional buildings. They were often used in "combination" windows, in which upper panels opened out and lower panels opened in. Since each movable panel projected to one side of the frame only, unlike pivot windows, for example, screens could be introduced.

Continuous windows were almost exclusively used for industrial buildings requiring high overhead lighting. Long runs of clerestory windows operated by mechanical tension rod gears were typical. Long banks of continuous windows were possible because the frames for such windows were often structural elements of the building.

If it is determined that the windows are in basically sound condition, the following steps can be taken: 1) removal of light rust, flaking and excessive paint; 2) priming of exposed metal with a rust-inhibiting primer; 3) replacement of cracked or broken glass and glazing compound; 4) replacement of missing screws or fasteners; 5) cleaning and lubrication of hinges; 6) repainting of all steel sections with two coats of finish paint compatible with the primer; and 7) caulking the masonry surrounds with a high quality elastomeric caulk.

Recommended methods for removing light rust include manual and mechanical abrasion or the application of chemicals. Burning off rust with an oxy-acetylene or propane torch, or an inert gas welding gun, should never be attempted because the heat can distort the metal. In addition, such intense heat (often as high as 3800°F) vaporizes the lead in old paint, resulting in highly toxic fumes. Furthermore, such heat will likely result in broken glass. Rust can best be removed using a wire brush, an aluminum oxide sandpaper, or a variety of power tools.

Fig. 4 Typical rolled steel windows available from 1890 to the present. The various operating and ventilating capacities in combination with the aesthetics of the window style were important considerations in the selection of one window type over another. Drawings: Sharon C. Park, AIA.

Fig. 5 Windows often provide a strong visual element to relatively simple or unadorned industrial or commercial buildings. This design element should be taken into consideration when evaluating the significance of the windows. Photo: Michael Auer.
adapted for abrasive cleaning such as an electric drill with a wire brush or a rotary whip attachment. Adjacent sills and window jambs may need protective shielding.

Rust can also be removed from ferrous metals by using a number of commercially prepared anti-corrosive acid compounds. Effective on light and medium corrosion, these compounds can be purchased either as liquids or gels. Several bases are available, including phosphoric acid, ammonium citrate, oxalic acid and hydrochloric acid. Hydrochloric acid is generally not recommended; it can leave chloride deposits, which cause future corrosion. Phosphoric acid-based compounds do not leave such deposits, and are therefore safer for steel windows. However, any chemical residue should be wiped off with damp cloths, then dried immediately. Industrial blow-dryers work well for thorough drying. The use of running water to remove chemical residue is never recommended because the water may spread the chemicals to adjacent surfaces, and drying of these surfaces may be more difficult. Acid cleaning compounds will stain masonry; therefore plastic sheets should be taped to the edge of the metal sections to protect the masonry surrounds. The same measure should be followed to protect the glazing from etching because of acid contact.

Measures that remove rust will ordinarily remove flaking paint as well. Remaining loose or flaking paint can be removed with a chemical paint remover or with a pneumatic needle scaler or gun, which comes with a series of chisel blades and has proven effective in removing flaking paint from metal windows. Well-bonded paint may serve to protect the metal further from corrosion, and need not be removed unless paint buildup prevents the window from closing tightly. The edges should be feathered by sanding to give a good surface for repainting.

Next, any bare metal should be wiped with a cleaning solvent such as denatured alcohol, and dried immediately in preparation for the application of an anti-corrosive primer. Since corrosion can recur very soon after metal has been exposed to the air, the metal should be primed immediately after cleaning. Spot priming may be required periodically as other repairs are undertaken. Anti-corrosive primers generally consist of oil-alkyd based paints rich in zinc or zinc chromate. Red lead is no longer available because of its toxicity. All metal primers, however, are toxic to some degree and should be handled carefully. Two coats of primer are recommended. Manufacturer's recommendations should be followed concerning application of primers.

REPAIR

RePAIR in Place

The maintenance procedures described above will be insufficient when corrosion is extensive, or when metal window sections are misaligned. Medium to heavy corrosion that has not done any structural damage to the metal sections can be removed either by using the chemical cleaning process described under "Routine Maintenance" or by sandblasting. Since sandblasting can damage the masonry surrounds and crack or cloud the glass, metal or plywood shields should be used to protect these materials. The sandblasting pressure should be low, 80-100 pounds per square inch, and the grit size should be in the range of #10-#45. Glass peening beads (glass pellets) have also been successfully used in cleaning steel sections. While sandblasting equipment comes with various nozzle sizes, pencil-point blasters are most useful because they give the operator more effective control over the direction of the spray. The small aperture of the pencil-point blaster is also useful in removing dried putty from the metal sections that hold the glass. With any cleaning technique, once the bare metal is exposed to air, it should be primed as soon as possible. This includes the inside rabbeted section of sash where glazing putty has been removed. To reduce the dust, some local codes allow only wet blasting. In this case, the metal must be dried immediately, generally with a blow-drier (a step that the owner should consider when calculating the time and expense involved). Either form of sandblasting metal covered with lead paints produces toxic dust. Proper precautionary measures should be taken against toxic dust and silica particles.

Bent or bowed metal sections may be the result of damage to the window through an impact or corrosive expansion. If the distortion is not too great, it is possible to realign the metal sections without removing the window to a metal fabricator's shop. The glazing is generally removed and pressure is applied to the bent or bowed section. In the case of a muntin, a protective 2 × 4 wooden bracing can be placed behind the bent portion and a wire cable with a winch can apply progressively more pressure over several days until the section is realigned. The 2 × 4 bracing is necessary to distribute the pressure evenly over the damaged section. Sometimes a section, such as the bottom of the frame, will bow out as a result of pressure exerted by corrosion and it is often necessary to cut the metal section to relieve this pressure prior to pressing the section back into shape and making a welded repair.

Once the metal sections have been cleaned of all corrosion and straightened, small holes and uneven areas resulting from rusting should be filled with a patching material and sanded smooth to eliminate pockets where water can accumulate. A patching material of steel fibers and an epoxy binder may be the easiest to apply. This steel-based epoxy is available for industrial steel repair; it can also be found in auto body patching compounds or in plumber's epoxy. As with any product, it is important to follow the manufacturer's instructions for proper use and best results. The traditional patching technique—melting steel welding rods to fill holes in the metal sections—may be difficult to apply in some situations; moreover, the window glass must be removed during the repair process, or it will crack from the expansion of the heated metal sections. After these repairs, glass replacement, hinge lubrication, painting, and other cosmetic repairs can be undertaken as necessary.

*Refer to Table IV: "Types of Paint Used for Painting Metal in Metals in America's Historic Buildings," p. 139. (See bibliography).*
To complete the checklist for routine maintenance, cracked glass, deteriorated glazing compound, missing screws, and broken fasteners will have to be replaced; hinges cleaned and lubricated; the metal windows painted, and the masonry surrounds caulked. If the glazing must be replaced, all clips, glazing beads, and other fasteners that hold the glass to the sash should be retained, if possible, although replacements for these parts are still being fabricated. When bedding glass, use only glazing compound formulated for metal windows. To clean the hinges (generally brass or bronze), a cleaning solvent and fine bronze wool should be used. The hinges should then be lubricated with a non-greasy lubricant specially formulated for metals and with an anti-corrosive agent. These lubricants are available in a spray form and should be used periodically on frequently opened windows.

Final painting of the windows with a paint compatible with the anti-corrosive primer should proceed on a dry day. (Paint and primer from the same manufacturer should be used.) Two coats of finish paint are recommended if the sections have been cleaned to bare metal. The paint should overlap the glass slightly to insure weathertightness at that connection. Once the paint dries thoroughly, a flexible exterior caulk can be applied to eliminate air and moisture infiltration where the window and the surrounding masonry meet.

Caulking is generally undertaken after the windows have received at least one coat of finish paint. The perimeter of the masonry surround should be caulked with a flexible elastomeric compound that will adhere well to both metal and masonry. The caulking used should be a type intended for exterior application, have a high tolerance for material movement, be resistant to ultraviolet light, and have a minimum durability of 10 years. Three effective compounds (taking price and other factors into consideration) are polyurethane, vinyl acrylic, and butyl rubber. In selecting a caulking material for a window retrofit, it is important to remember that the caulking compound may be covering other materials in a substrate. In this case, some compounds, such as silicone, may not adhere well. Almost all modern caulking compounds can be painted after curing completely. Many come in a range of colors, which eliminates the need to paint. If colored caulking is used, the windows should have been given two coats of finish paint prior to caulking.

As part of the orderly removal of windows, each window should be numbered and the parts labelled. The operable metal sash should be dismantled by removing the hinges; the fixed sash and, if necessary, the frame can then be unbolted or unscrewed. (The subframe is usually left in place. Built into the masonry surrounds, it can only be cut out with a torch.) Hardware and hinges should be labelled and stored together.

The two major choices for removing flaking paint and corrosion from severely deteriorated windows are dipping in a chemical bath or sandblasting. Both treatments require removal of the glass. If the windows are to be dipped, a phosphoric acid solution is preferred, as mentioned earlier. While the dip tank method is good for fairly evenly distributed rust, deep set rust may remain after dipping. For that reason, sandblasting is more effective for heavy and uneven corrosion. Both methods leave the metal sections clean of residual paint. As already noted, after cleaning has exposed the metal to the air, it should be primed immediately after drying with an anti-corrosive primer to prevent rust from recurring.

Sections that are seriously bent or bowed must be straightened with heat and applied pressure in a workshop. Structurally weakened sections must be cut out, generally with an oxy-acetylene torch, and replaced with sections welded in place and the welds ground smooth. Finding replacement metal sections, however, may be difficult. While most rolling mills are producing modern sections suitable for total replacement, it may be difficult to find an exact profile match for a splicing repair. The best source of rolled metal sections is from salvaged windows, preferably from the same building. If no salvaged windows are available, two options remain. Either an ornamental metal fabricator can weld flat plates into a built-up section, or a steel plant can mill bar steel into the desired profile.

While the sash and frame are removed for repair, the subframe and masonry surrounds should be inspected. This is also the time to reset sills or to remove corrosion from the subframe, taking care to protect the masonry surrounds from damage.

Missing or broken hardware and hinges should be replaced on all windows that will be operable. Salvaged windows, again, are the best source of replacement parts. If matching parts cannot be found, it may be possible to adapt ready-made items. Such a substitution may require filling existing holes with steel epoxy or with plug welds and tapping in new screw holes. However, if the hardware is a highly significant element of the historic window, it may be worth having reproductions made.

Following are illustrations of the repair and thermal upgrading of the rolled steel windows in a National Historic Landmark (fig. 6). Many of the techniques described above were used during this extensive rehabilitation. The complete range of repair techniques is then summarized in the chart titled Steps for Cleaning and Repairing Historic Steel Windows (see fig. 7).
Fig. 6 a. View of the flanking wing of the State Capitol where the rolled steel casement windows are being removed for repair.

Fig. 6 b. View from the exterior showing the deteriorated condition of the lower corner of a window prior to repair. While the sash was in relatively good condition, the frame behind was rusted to the point of inhibiting operation.

Fig. 6 c. View of the rusted frame which was unscrewed from the subframe and removed from the window opening and taken to a workshop for sandblasting. In some cases, severely deteriorated sections of the frame were replaced with new sections of milled bar steel.

Fig. 6 d. View looking down towards the sill. The subframes appeared very rusted, but were in good condition once debris was vacuumed and surface rust was removed, in place, with chemical compounds. Where necessary, epoxy and steel filler was used to patch depressions in order to make the subframe serviceable again.

Fig. 6 e. View looking down towards the sill. The cleaned frame was reset in the window opening. The frame was screwed to the refurbished subframe at the jamb and the head only. The screw holes at the sill, which had been the cause of much of the earlier rusting, were infilled. Vinyl weatherstripping was added to the frame.

Fig. 6 f. View from the outside of the completely refurbished window. In addition to the steel repair and the installation of vinyl weatherstripping, the exterior was caulked with polyurethane and the single glass was replaced with individual lights of thermal glass. The repaired and upgraded windows have comparable energy efficiency ratings to new replacement units while retaining the historic steel sash, frames and subframes.

Fig. 6. The repair and thermal upgrading of the historic steel windows at the State Capitol, Lincoln, Nebraska. This early twentieth century building, designed by Bertram Goodhue, is a National Historic Landmark. Photos: All photos in this series were provided by the State Building Division.
## STEPS FOR CLEANING AND REPAIRING HISTORIC STEEL WINDOWS

<table>
<thead>
<tr>
<th>Work Item</th>
<th>Recommended Techniques</th>
<th>Tools, Products and Procedures</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Removing dirt and grease from metal</td>
<td><em>(Must be done in a workshop)</em></td>
<td>Vacuum and bristle brushes to remove dust and dirt; solvents (denatured alcohol, mineral spirits), and clean cloths to remove grease.</td>
<td>Solvents can cause eye and skin irritation. Operator should wear protective gear and work in ventilated area. Solvents should not contact masonry. Do not flush with water.</td>
</tr>
<tr>
<td>2. Removing Rust/Corrosion</td>
<td><strong>Light</strong>&lt;br&gt;Manual and mechanical abrasion</td>
<td>Wire brushes, steel wool, rotary attachments to electric drill, sanding blocks and disks.</td>
<td>Handsanding will probably be necessary for corners. Safety goggles and masks should be worn.</td>
</tr>
<tr>
<td></td>
<td>Chemical cleaning</td>
<td>Anti-corrosive jellies and liquids (phosphoric acid preferred); clean damp cloths.</td>
<td>Protect glass and metal with plastic sheets attached with tape. Do not flush with water. Work in ventilated area.</td>
</tr>
<tr>
<td></td>
<td><strong>Medium</strong>&lt;br&gt;Sandblasting/abrasive cleaning</td>
<td>Low pressure (80-100 psi) and small grit (#10-#45); glass peening beads. Pencil blaster gives good control.</td>
<td>Removes both paint and rust. Codes should be checked for environmental compliance. Prime exposed metal promptly. Shield glass and masonry. Operator should wear safety gear.</td>
</tr>
<tr>
<td></td>
<td><strong>Heavy</strong>&lt;br&gt;*Chemical dip tank</td>
<td>Metal sections dipped into chemical tank (phosphoric acid preferred) from several hours to 24 hours.</td>
<td>Glass and hardware should be removed. Protect operator. Deepset rust may remain, but paint will be removed.</td>
</tr>
<tr>
<td></td>
<td>*Sandblasting/abrasive cleaning</td>
<td>Low pressure (80-100 psi) and small grit (#10-#45).</td>
<td>Excellent for heavy rust. Remove or protect glass. Prime exposed metal promptly. Check codes for environmental compliance. Operator should wear safety gear.</td>
</tr>
<tr>
<td>3. Removing flaking paint.</td>
<td><strong>Chemical method</strong></td>
<td>Chemical paint strippers suitable for ferrous metals. Clean cloths.</td>
<td>Protect glass and masonry. Do not flush with water. Have good ventilation and protection for operator.</td>
</tr>
<tr>
<td></td>
<td>Mechanical abrasion</td>
<td>Pneumatic needle gun chisels, sanding disks.</td>
<td>Protect operator; have good ventilation. Well-bonded paint need not be removed if window closes properly.</td>
</tr>
<tr>
<td>4. Aligning bent, bowed metal sections</td>
<td><strong>Applied pressure</strong>&lt;br&gt;<em>Heat and pressure</em></td>
<td>Wooden frame as a brace for cables and winch mechanism. Remove to a workshop. Apply heat and pressure to bend back.</td>
<td>Remove glass in affected area. Realignment may take several days. Care should be taken that heat does not deform slender sections.</td>
</tr>
<tr>
<td>Work Item</td>
<td>Recommended Techniques</td>
<td>Tools, Products and Procedures</td>
<td>Notes</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>5. Patching depressions</td>
<td><em>(Must be done in a workshop)</em></td>
<td>Epoxy fillers with high content of steel fibers; plumber's epoxy or autobody patching compound.</td>
<td>Epoxy patches generally are easy to apply, and can be sanded smooth. Patches should be primed.</td>
</tr>
<tr>
<td></td>
<td>Welded patches</td>
<td>Weld in patches using steel rods and oxy-acetylene torch or arc welder.</td>
<td>Prime welded sections after grinding connections smooth.</td>
</tr>
<tr>
<td>6. Splicing in new metal</td>
<td><em>Cut out decayed sections and weld in new or salvaged sections</em></td>
<td>Torch to cut out bad sections back to 45° joint. Weld in new pieces and grind smooth.</td>
<td>Prime welded sections after grinding connection smooth.</td>
</tr>
<tr>
<td>sections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Priming metal sections</td>
<td>Brush or spray application</td>
<td>At least one coat of anti-corrosive primer on bare metal. Zinc-rich primers are generally recommended.</td>
<td>Metal should be primed as soon as it is exposed. If cleaned metal will be repaired another day, spot prime to protect exposed metal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Replacing missing</td>
<td>Routine maintenance</td>
<td>Pliers to pull out or shear off rusted heads. Replace screws and bolts with similar ones, readily available.</td>
<td>If new holes have to be tapped into the metal sections, the rusted holes should be cleaned, filled and primed prior to redrilling.</td>
</tr>
<tr>
<td>screws and bolts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Cleaning, lubricating</td>
<td>Routine maintenance, solvent cleaning</td>
<td>Most hinges and closure hardware are bronze. Use solvents (mineral spirits), bronze wool and clean cloths. Spray with non-greasy lubricant containing anti-corrosive agent.</td>
<td>Replacement hinges and fasteners may not match the original exactly. If new holes are necessary, old ones should be filled.</td>
</tr>
<tr>
<td>or replacing hinges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and other hardware</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Replacing glass and</td>
<td>Standard method for application</td>
<td>Pliers and chisels to remove old glass, scrape putty out of glazing rabbet, save all clips and beads for reuse. Use only glazing compound formulated for metal windows.</td>
<td>Heavy gloves and other protective gear needed for the operator. All parts saved should be cleaned prior to reinstallation.</td>
</tr>
<tr>
<td>glazing compound</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Caulking masonry</td>
<td>Standard method for application</td>
<td>Good quality (10 year or better) elastomeric caulking compound suitable for metal.</td>
<td>The gap between the metal frame and the masonry opening should be caulked; keep weepholes in metal for condensation run-off clear of caulk.</td>
</tr>
<tr>
<td>surrounds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Repainting metal</td>
<td>Spray or brush</td>
<td>At least 2 coats of paint compatible with the anti-corrosive primer. Paint should lap the glass about 1/8&quot; to form a seal over the glazing compound.</td>
<td>The final coats of paint and the primer should be from the same manufacturer to ensure compatibility. If spraying is used, the glass and masonry should be protected.</td>
</tr>
<tr>
<td>windows</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
WEATHERIZATION

Historic metal windows are generally not energy efficient; this has often led to their wholesale replacement. Metal windows can, however, be made more energy efficient in several ways, varying in complexity and cost. Caulking around the masonry openings and adding weatherstripping, for example, can be do-it-yourself projects and are important first steps in reducing air infiltration around the windows. They usually have a rapid payback period. Other treatments include applying fixed layers of glazing over the historic windows, adding operable storm windows, or installing thermal glass in place of the existing glass. In combination with caulking and weatherstripping, these treatments can produce energy ratings rivaling those achieved by new units.

Weatherstripping

The first step in any weatherization program, caulking, has been discussed above under “Routine Maintenance.” The second step is the installation of weatherstripping where the operable portion of the sash, often called the vent, and the fixed frame come together to reduce perimeter air infiltration (see fig. 8). Four types of weatherstripping appropriate for metal windows are spring-metal, vinyl strips, compressible foam tapes, and sealant beads. The spring-metal, with an integral friction fit mounting clip, is recommended for steel windows in good condition. The clip eliminates the need for an applied glue; the thinness of the material insures a tight closure. The weatherstripping is clipped to the inside channel of the rolled metal section of the fixed frame. To assure against galvanic corrosion between the weatherstripping (often bronze or brass), and the steel window, the window must be painted prior to the installation of the weatherstripping. This weatherstripping is usually applied to the entire perimeter of the window opening, but in some cases, such as casement windows, it may be best to avoid weatherstripping the hinge side. The natural wedging action of the weatherstripping on the three sides of the window often creates an adequate seal.

Vinyl weatherstripping can also be applied to metal windows. Folded into a “V” configuration, the material forms a barrier against the wind. Vinyl weatherstripping is usually glued to the frame, and although some brands have an adhesive backing, as the vinyl material and the applied glue are relatively thick, this form of weatherstripping may not be appropriate for all situations.

Compressible foam tape weatherstripping is often best for large windows where there is a slight bending or distortion of the sash. In some very tall windows having closure hardware at the sash mid-point, the thin sections

*One measure of energy efficiency is the U-value (the number of BTUs per hour transferred through a square foot of material). The lower the U-value, the better the performance. According to ASHRAE HANDBOOK-1977 Fundamentals, the U-value of historic rolled steel sash with single glazing is 1.5. Adding storm windows to the existing units or replacing with 5/8" insulating glass produces a U-value of .69. These methods of weatherizing historic steel windows compare favorably with rolled steel replacement alternatives: with factory installed 1" insulating glass (.67 U-value); with added thermal-break construction and factory finish coatings (.62 U-value).

of the metal window will bow away from the frame near the top. If the gap is not more than 1/4", foam weatherstripping can normally fill the space. If the gap exceeds this, the window may need to be realigned to close more tightly. The foam weatherstripping comes either with an adhesive or plain back; the latter variety requires application with glue. Compressible foam requires more frequent replacement than either spring-metal or vinyl weatherstripping.

A fourth type of successful weatherstripping involves the use of a caulking or sealant bead and a polyethylene bond breaker tape. After the window frame has been thoroughly cleaned with solvent, permitted to dry, and primed, a neat bead of low modulus (firm setting) caulk, such as silicone, is applied. A bond breaker tape is then applied to the operable sash covering the metal section where contact will occur. The window is then closed until the sealant has set (2-7 days, depending on temperature and humidity). When the window is opened, the bead will have taken the shape of the air infiltration gap and the bond breaker tape can be removed. This weatherstripping method appears to be successful for all types of metal windows with varying degrees of air infiltration.

Since the several types of weatherstripping are appropriate for different circumstances, it may be necessary to use more than one type on any given building. Successful weatherstripping depends upon using the thinnest material adequate to fill the space through which air enters. Weatherstripping that is too thick can spring the hinges, thereby resulting in more gaps.

Fig. 8 APPROPRIATE TYPES OF WEATHERSTRIPPING FOR METAL WINDOWS. Weatherstripping is an important part of upgrading the thermal efficiency of historic steel windows. The chart above shows the jamb section of the window with the weatherstripping in place. Drawings: Sharon C. Park, AIA.
Thermal Glazing

The third weatherization treatment is to install an additional layer of glazing to improve the thermal efficiency of the existing window. The decision to pursue this treatment should proceed from careful analysis. Each of the most common techniques for adding a layer of glazing will effect approximately the same energy savings (approximately double the original insulating value of the window); therefore, cost and aesthetic considerations usually determine the choice of method. Methods of adding a layer of glazing to improve thermal efficiency include adding a new layer of transparent material to the window; adding a separate storm window; and replacing the single layer of glass in the window with thermal glass.

The least expensive of these options is to install a clear material (usually rigid sheets of acrylic or glass) over the original window. The choice between acrylic and glass is generally based on cost, ability of the window to support the material, and long-term maintenance outlook. If the material is placed over the entire window and secured to the frame, the sash will be inoperable. If the continued use of the window is important (for ventilation or for fire exits), separate panels should be affixed to the sash without obstructing operability (see fig. 9). Glass or acrylic panels set in frames can be attached using magnetized gaskets, interlocking material strips, screws or adhesives. Acrylic panels can be screwed directly to the metal windows, but the holes in the acrylic panels should allow for the expansion and contraction of this material. A compressible gasket between the prime sash and the storm panel can be very effective in establishing a thermal cavity between glazing layers. To avoid condensation, 1/8" cuts in a top corner and diagonally opposite bottom corner of the gasket will provide vapor bleed, through which moisture can evaporate. (Such cuts, however, reduce thermal performance slightly.) If condensation does occur, however, the panels should be easily removable in order to wipe away moisture before it causes corrosion.

The second method of adding a layer of glazing is to have independent storm windows fabricated. (Pivot and austral windows, however, which project on either side of the window frame when open, cannot easily be fitted with storm windows and remain operational.) The storm window should be compatible with the original sash configuration. For example, in paired casement windows, either specially fabricated storm casement windows or sliding units in which the vertical meeting rail of the slider reflects the configuration of the original window should be installed. The decision to place storm windows on the inside or outside of the window depends on whether the historic window opens in or out, and on the visual impact the addition of storm windows will have on the building. Exterior storm windows, however, can serve another purpose besides saving energy: they add a layer of protection against air pollutants and vandals, although they will partially obscure the prime window. For highly ornamental windows this protection can determine the choice of exterior rather than interior storm windows.

The third method of installing an added layer of glazing is to replace the original single glazing with thermal glass. Except in rare instances in which the original glass is of special interest (as with stained or figured glass), the glass can be replaced if the hinges can tolerate the weight of the additional glass. The rolled metal sections for steel windows are generally from 1" - 1 1/2" thick. Sash of this thickness can normally tolerate thermal glass, which ranges from 3/8" - 5/8". (Metal glazing beads, readily available, are used to reinforce the muntins, which hold the glass.) This treatment leaves the window fully operational while preserving the historic appearance. It is, however, the most expensive of the treatments discussed here. (See fig. 6f.)

Fig. 9 Two examples of adding a second layer of glazing in order to improve the thermal performance of historic steel windows. Scheme A (showing jamb detail) is of a 1/4" acrylic panel with a closed cell foam gasket attached with self-tapping stainless steel screws directly to the exterior of the outwardly opening sash. Scheme B (showing jamb detail) is of a glass panel in a magnetized frame affixed directly to the interior of the historic steel sash. The choice of using glass or acrylic mounted on the inside or outside will depend on the ability of the window to tolerate additional weight, the location and size of the window, the cost, and the long-term maintenance outlook. Drawing: Sharon C. Park, AIA.

WINDOW REPLACEMENT

Repair of historic windows is always preferred within a rehabilitation project. Replacement should be considered only as a last resort. However, when the extent of deterioration or the unavailability of replacement sections renders repair impossible, replacement of the entire window may be justified. In the case of significant windows, replacement in kind is essential in order to maintain the historic character of the building. However, for less significant windows, replacement with compatible new windows may be acceptable. In selecting compatible replacement windows, the material, configuration, color, operability, number and size of panes, profile and proportion of metal sections, and reflectivity of the original glass should be duplicated as closely as possible.

A number of metal window manufacturing companies produce rolled steel windows. While stock modern window designs do not share the multi-pane configuration of
historic windows, most of these manufacturers can reproduce the historic configuration if requested, and the cost is not excessive for large orders (see figs. 10a and 10b). Some manufacturers still carry the standard pre-World War II multi-light windows using the traditional 12” x 18” or 14” x 20” glass sizes in industrial, commercial, security, and residential configurations. In addition, many of the modern steel windows have integral weatherstripping, thermal break construction, durable vinyl coatings, insulating glass, and other desirable features.

For product information on replacement windows, the owner, architect, or contractor should consult manufacturers’ catalogues, building trade journals, or the Steel Window Institute, 1230 Keith Building, Cleveland, Ohio 44115.

**SUMMARY**

The National Park Service recommends the retention of significant historic metal windows whenever possible. Such windows, which can be a character-defining feature of a historic building, are too often replaced with inappropriate units that impair rather than complement the overall historic appearance. The repair and thermal upgrading of historic steel windows is more practicable than most people realize. Repaired and properly maintained metal windows have greatly extended service lives. They can be made energy efficient while maintaining their contribution to the historic character of the building.

**BIBLIOGRAPHY**


Windows manufactured from other materials generally cannot match the thin profiles of the rolled steel sections. Aluminum, for example, is three times weaker than steel and must be extruded into a box-like configuration that does not reflect the thin historic profiles of most steel windows. Wooden and vinyl replacement windows generally are not fabricated in the industrial style, nor can they reproduce the thin profiles of the rolled steel sections, and consequently are generally not acceptable replacements.

The author gratefully acknowledges the invaluable assistance of co-worker Michael Auer in preparing this brief for publication. This publication is an extension of research initiated by Frederec E. Kleye. Special thanks are given to Hope’s Architectural Products, Inc., Jamestown, NY, for their generous contribution of historic metal window catalogues which were an invaluable source of information. The following individuals are also to be thanked for reviewing the manuscript and making suggestions: Hugh Miller, Chief, Park Historic Architecture Division, National Park Service; Barclay L. Rogers, Museum Services, National Park Service; Susan M. Young, Steel Window Institute, and Danny Schlichenmaier, State Building Division, Lincoln, Nebraska. Finally, thanks go to Technical Preservation Services Branch staff and to cultural resources staff of the National Park Service Regional Offices, whose valuable comments were incorporated into the final text and who contributed to the publication of this brief.

This publication has been prepared pursuant to the Economic Recovery Tax Act of 1981, which directs the Secretary of the Interior to certify rehabilitations of historic buildings that are consistent with their historic character; the guidance provided in this brief will assist property owners in complying with the requirements of this law.

Preservation Briefs: 13 has been developed under the technical editorship of Lee H. Nelson, AIA, Chief, Preservation Assistance Division, National Park Service, U.S. Department of the Interior, Washington, D.C. 20240. Comments on the usefulness of this information are welcomed and can be sent to Mr. Nelson at the above address.
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D: Second Floor, South Elev. S218</td>
<td>Replace molding. Replace with mortar. Replace with nine light sash to match upper.</td>
</tr>
</tbody>
</table>
MARQUETTE BUILDING
Chicago, Illinois

The Marquette Building, constructed in 1895, is one of Chicago's finest commercial buildings. Individually listed in the National Register of Historic Places, the building incorporated the then-recent structural innovation of the steel frame with a design that brought much acclaim to the architectural firm of Holabird and Roche. Though the site was slated for redevelopment in the 1970's and the occupancy rate fell to ten percent, a decision was made in 1978 to renovate the building for prime office and retail space in Chicago's Loop.

The modified Chicago-style windows, which fill the bays between the structural piers, are one of the most prominent features of the building's facade. The large glazed area in each bay consists of two narrow double-hung sash flanking either a large central fixed light or a pair of fixed lights. Careful evaluation of the window repair and replacement options showed that preserving the historic windows was the most cost-effective treatment. The project demonstrated that proper planning can control rehabilitation costs - as well as lead to the preservation of historic windows.

Rehabilitation Planning

The Marquette Building is a 16 story building with 290,000 square feet of net rentable floor space and fronts on Dearborn and Adams Streets. While the building has nearly 350 double-hung windows principally on the upper three floors and throughout the northern facade fac-
ing on an alley, the 182 Chicago style windows are of greatest interest here because of their style, prominence, and large size. Although the windows vary in size, most measure about 12' wide by 8' high (see figure ).

Constructed out of good quality mahogany, the windows were still in sound physical condition despite over ninety years of exposure to Chicago's winter weather and years of neglect due to deferred maintenance (see figure ). While some of the sills needed repair, the windows primarily needed to be repainted and to have some interior trim replaced. Recaulking around the frames was necessary, but otherwise there was very little air infiltration. The windows had already proven to be very durable and, except for periodic painting, long-term maintenance was expected to be minor. The project architect, Walker C. Johnson, AIA, of Holabird and Root, estimated the life of the windows to be in excess of another ninety years. Even with this information, the architect and owner still had other factors to consider in examining alternatives for the repair or replacement of the windows.

Related HVAC Study One added consideration for the proposed window work was an outgrowth of the energy analysis done for the building. The new heating and cooling system (HVAC) chosen as a result of the study consisted of a variable volume air system for cooling and a hot water radiation system using perimeter finned tube units.

Based on current operating expenditures and projected energy costs supplied by the local power company, it was determined that by having the windows closed all the time, savings could have been achieved as a result of purchasing smaller capacity HVAC units and having lowered operational costs.

Window Evaluation Criteria In conjunction with the HVAC analysis, three window alternatives were considered:

- repairing the existing windows and fixing them closed;
- modifying the existing windows by installing insulated glazing for improved thermal performance; or
- replacing the existing windows with high-quality, aluminum units with insulating glass that matched the appearance of the original.

Criteria for evaluating the three alternatives related to aesthetics, window performance and economics:

1. The historic character of the large office windows had to be preserved;
2. Only high quality materials and

(4) While specific requirements were not established at the outset for the energy efficiency of the windows, a project goal was to have the overall building meet the energy utilization and building performance standards established by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE); and

(5) Any changes to the windows in order to improve energy performance needed to be cost-effective.

With these criteria established, the three window treatments were then examined in detail.

![Figure 1. The Marquette Building has both Chicago-style windows, as shown above on the second floor, and a modified Chicago-style window consisting of two fixed lights in the center section. Photo: Charles E. Fisher](image)

![Figure 2. The window sash were well-constructed of mahogany and the frames were faced on the outside with cast iron trim. Drawing: Martha L. Werenfels](image)
First Alternative—Window Repair Repairs needed on the large windows consisted of: (1) repairing ten units where the vertical mullion dividing the two large fixed panes had been changed to accommodate interior partition alterations; (2) installing a fiberglass wrap on approximately 5% of the wood sills where deterioration was a problem; (3) installing approximately 1000 linear feet of new casing trim on the interior to match original trim that was damaged or that had been removed as a result of later partition alterations; (4) repainting the exterior and interior woodwork; and (5) reconditioning the chains, pulleys, sash weights, and hardware in case the windows ever needed to be opened. The estimated cost of this work was $65,000, including the repair and reinstallation of fixed frames and glass in 28 windows where a material hoist and trash chutes were located during the rehabilitation.

Second Alternative—Modifying Existing Sash A new estimate was made of the cost-effectiveness of installing insulated glass in both the existing fixed panes and the double-hung sash throughout the building. The insulating glass would be installed by cutting back the interior stops. Such a window system would lighten the load on the mechanical system by reducing seasonal heat losses and gains. This window work would achieve further savings by reducing energy consumption and permitting installation of a smaller HVAC system. Construction costs, however, were estimated to be $860,000.

Third Alternative—Aluminum Replacement Only good quality, high-performance replacement windows were considered because the architect sought to avoid some of the recurring problems associated with hangers, connectors, and weather stripping. The estimated cost of aluminum replacement windows that matched the appearance, size and configuration of the existing windows was nearly $1,600,000. This estimate included the cost of removing the existing windows and installing metal substitutes that had a thermal break and insulating glass.

Planning Results

The windows in the Marquette Building at first glance would seem prime targets for alteration or replacement in order to improve their energy performance. Installing matching replacement units with thermal glass or adding interior storm glazing both could have been

Figure 3. Approximately 1000 linear feet of matching window casing trim had to be installed. In many cases, damage had occurred where later partitions had intersected the windows. Lighter color wood shown in the photograph is the new trim prior to painting. Photo: Charles E. Fisher

undertaken without significant alteration to the visual appearance of the windows, yet the historic windows would have been lost.

After an in-depth study of the repair, modifications, and replacement alternatives in which such factors as energy costs, construction costs, and finance charges were considered, the architect determined that the most cost-effective solution was to repair the existing windows.

Figure 4. The only modification made to the windows was the addition of a screw through the decorative end of the sash stile to fix closed the operable portions. This decision grew out of the recommendations by the mechanical engineers. Photo: Charles E. Fisher

Double glazing, achieved either through adding insulated glazing or as a result of new replacement units, would have improved the energy efficiency of the windows and the building, yet would have been expensive and, in this case, unnecessary. Assuming the worst conditions for infiltration, insulating glass would have resulted at best in energy savings of 10% in heating costs and 15% reduction in cooling costs. Building management decided to save the money since there was no pay back. Furthermore, even without additional glazing being added to the windows, the overall building exceeds the energy utilization and building performance standards of ASHRAE. In the future, if conditions change, the addition of insulating glass could be accomplished with little problem.

Repair work on the windows was conducted at the site, working one floor at a time. Wood stops were removed, and the windows taken out of those frames needing repair. The hardware was cleaned and repaired, or replaced where missing. Only about 7% of the windows and trim required any major work. Most of the required work was due to the use during rehabilitation of two fixed windows per floor for trash removal and the material hoist or where later partitions intersecting the windows had damaged the wooden trim (see figure 3). The wood stops were then reattached using screws in order to facilitate future window work that might arise.

To prevent tenants from opening the windows, a screw was secured through the decorative extension on the stiles of both upper and lower sash (see figure
The work was done on schedule and within the original cost estimates.

Project Evaluation

In many rehabilitation projects involving historic buildings, the original windows are mistakenly identified as obsolete and, as a result, are needlessly replaced. Too often the replacements do not satisfactorily suit the intent of the original design and thus severely alter the historic character of the structure. Where this occurs, substantial Federal tax incentives for historic preservation may be jeopardized.

Figure 5. Careful planning and evaluation led to the conclusion that the most cost-effective approach was merely to repair the windows rather than undertake measures to upgrade their performance. Photo: Charles E. Fisher

This and other rehabilitation projects have shown the value of careful and objective evaluation of existing window conditions (see figure 5). Sound planning can result in window decisions that take into account good preservation decisions and the realities of the marketplace.

This PRESERVATION TECH NOTE was prepared by the National Park Service in cooperation with the Center for Architectural Conservation, Georgia Institute of Technology. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Coordinator for the TECH NOTES. Special thanks go to Walker C. Johnson, AIA, for his time and generous assistance in providing information concerning the window work at the Marquette Building. Thanks also go to the following people who contributed to the production of this TECH NOTE: John H. Myers and Laura A. Muckenfuss, Center for Architectural Conservation, and Preservation Assistance Division staff, particularly Kay D. Weeks, Michael J. Auer, Martha L. Werenfels, Martha A. Gutrick, and Mae Simon. Cover, Marquette Building Photo: Courtesy, Commission on Chicago Historical and Architectural Landmarks.

This and many of the TECH NOTES on windows are included in "The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings" (available late 1984), a joint publication of the Preservation Assistance Division, National Park Service and the Center for Architectural Conservation, Georgia Institute of Technology. For information write to The Center for Architectural Conservation, P.O. Box 93402, Atlanta, Georgia 30377.

This PRESERVATION TECH NOTES are designed to provide practical information on innovative techniques and practices for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards. This TECH NOTE was prepared pursuant to Federal tax laws which direct the Secretary of the Interior to certify rehabilitations of historic buildings that are consistent with their historic character; the advice and guidance provided in this TECH NOTE will assist property owners in complying with Federal tax requirements.

Comments on the usefulness of this information are welcomed and should be addressed to TECH NOTES, Preservation Assistance Division, National Park Service, Washington, D.C. 20240. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the author and the National Park Service are appreciated.

ISSN: 0741-9023
PTN-1 January 1984
WORTHINGTON HOUSE
Monocacy National Battlefield
Frederick County, Maryland

Located on the grounds of the Monocacy National Battlefield, the Worthington House is a mid-19th century ell-shaped brick farmhouse. Judging from the modest exterior, it is rather surprising to find that the building contains noteworthy interior stenciling. The two front rooms on either side of the center stair hall and the stair hall itself all have remarkably intact examples of trompe l'oeil stencilled panelling combined with an egg and dart motif frieze border.

The National Park Service acquired the 282 acre Worthington property in 1982, principally to protect this detached portion of the battlefield from intensive development. At the time of acquisition, the farmhouse was vacant and severely deteriorated with extensive water damage occurring as a result of major roof leaks and a predominance of broken and missing windows. Vines and saplings were growing up through the building and root, destroying the mortar and displacing the bricks. The one-story porch across the front had collapsed, causing noticeable dislocation of the front masonry wall. In several areas large numbers of the handmade brick had been scavenged from the exterior, leaving gaping holes in the bearing walls.

With no immediate use planned for the building, it was necessary to repair and stabilize the structure or lose it to deterioration. Work was undertaken using limited funds to make the building structurally sound, weathertight, and less vulnerable to vandalism. Rather than using traditional mothballing techniques, which rely heavily on temporary measures and the introduction of non-historic elements, the project team utilized high quality but cost-effective stabilization measures whenever possible to ensure the long-term preservation of the historic building. Temporary features, such as window vents, were designed and installed in such a manner as to be reversible and to cause little additional loss of historic fabric.

Preservation Problem

Situated on a very windy knoll, the Worthington House had several immediate preservation problems. The interior was waterlogged. Rain entered through broken and missing windows and through the deteriorated slate roof. At the time of acquisition, the structure had been occupied sporadically for approximately 10 years by vagrants and had received no upkeep at all. Rodent and insect infestation was also contributing to the deterioration of the structure.

Early work focused on the need to make the building as weathertight as possible, yet allow for adequate ventilation. Consideration was given to devising a solution that would incorporate the window work with a passive ventilation system. It was recognized that if the house was tightly sealed with insufficient ventilation, the building would be particularly susceptible to condensation and moisture damage. Another factor to consider was that the building would remain unheated and unoccupied for an undetermined length of time.

Neither boarding over the openings nor installing full sash throughout would provide optimum ventilation on the interior. This would be required to deter fungal decay of the wood and to avoid condensation damage to plaster walls and to their decorative surface.

Special care should be taken to provide sufficient ventilation in unoccupied historic buildings to deter fungal decay and condensation damage.
stencil work. Hot daytime temperatures followed by cold nights in the spring and early fall could result in significant condensation damage to the plaster and stencil work. Damage would be particularly acute when nighttime temperatures fell below freezing. Furthermore, the hot moist air of the long Maryland summer would create problems, since high humidity can present a favorable condition for fungal growth. This is particularly true when the drying effect of air movement, normally induced in an occupied building, is not present. The potential for damage in these circumstances was great. Once wood absorbs enough moisture from the hot humid air and if fungal attack begins, the process of wood decay would enable the fungi to maintain the wood in a wet condition since fungi reduces wood to water and carbon dioxide. While such moisture problems could arise throughout the house, the basement was particularly susceptible to such damage due to moisture infiltration through the dirt floor, the below grade location, and seepage through the walls and basement doors.

**Preservation Solution**

Since the stabilization plan did not call for the installation of either a heating or a mechanical ventilation system, the solution to the air circulation needs was to install vent windows. The basic “rule-of-thumb” used by the project staff for determining the amount of open air needed for good air circulation in this building is to use 50 percent of the sash units for ventilation. This approach has been successfully used by the Williamsport Preservation Training Center in previous projects. Depending upon individual conditions, some adjustment needs to be made based on the layout of rooms, interior walls, door locations, and number and location of stair shafts and windows.

Because cross-room ventilation was desirable, the location of the ventilating louvers was critical. With proper planning, natural ventilation could be induced through the “chimney” or “updraft effect” within the building by which warm air raises and escapes through higher level vents, to be replaced with cooler air entering at lower levels.

Good air movement would also tend to equalize interior and exterior temperatures, thus lessening condensation problems within the brick walls and on interior painted plaster surfaces.

The window louvers had to be located so as to promote cross-room ventilation and avoid stagnant air pockets in the rooms. Furthermore, improvements to the appearance of the exterior of this long neglected building were desired. Efforts were taken, therefore, to locate as many of the louvers as possible on side and rear elevations, thereby minimizing the visual impact on the front elevation. Full double-sash vents could be placed in some side and rear windows to permit more glass on the front elevation. Even the glazing in the reconditioned or replacement windows would help to facilitate air movement within the building, since the sunlight passing through the glass would heat inside air and cause it to rise out through upper floor level vents. Cooler air entering through the basement windows would replace the warmer air.

A survey of the building’s 31 window openings established that on the first floor all but one sash were either missing or beyond repair. Altogether, only about one-third of the individual sash units were repairable. Most of those that were reconditioned required muntin replacement. In order to save on the final production costs involved in repairing or constructing the 52 individual sash units, all sash work was completed in one shop operation. The louvers vents were temporarily installed in lieu of the glazed sash on the bottom half of most window openings as part of the “mothballing” and stabilization efforts.

**Louvered Window Vents**

Wooden fixed louvered vents were custom-made and installed. The easily fabricated louvers were sized to fit the lower sash opening — 34 1/2" wide by 34 1/2" high on the first floor, while those for the smaller second floor windows were only 25 1/4" high. Full units were installed in all single-sash basement windows, since the window area was much less and the moisture problems more severe (see figure 1). At the same time, the three attic windows were also replaced with full louvered to encourage thorough multi-level ventilation.

Custom-built wooden louvers were selected over stock, pre-fabricated metal vents for the following reasons: most pre-fabricated vent systems would require modifications of the historic jamb in order to get a secure fit; a single style metal unit could not be found to fit the variety of opening sizes and the depth of the jamb; costs would be greater than making the custom units; and most important, it was felt that the thin gauge metal units offered little or no deterrent to unlawful entry. The wooden units presented a more secure system.

---

Figure 1. Full louvered vents were installed in all single-sash openings in the basement because of the more severe moisture problems present in that location. Photo: Charles Fisher
The louver frame was designed to fit snugly into the existing sash tracks and simultaneously to secure the glazed upper sash. An added benefit of the 6" stock width is that it provided a fairly rigid — and thus secure — louver frame. The louver frame was constructed of 1" × 6" shelf grade northeastern white pine; the louver slats were made from 1" × 8" pine (see figure 2). The spacing of the louver slats did not exceed 4" in order to provide additional lateral strength (and security) to the frame. The relative closeness of the slats also would make it more difficult to kick out the grade level units. The slats were set into the frame at a 45 degree angle by routing a 1/2" deep dado cut into the jamb of the louver. The exposed edges of the slats were plumb cut in order to create a water drip on the exterior.

Prior to assembly, the louver members were primed using an alcohol base paint in order to get at least one protective coat on all surfaces. After assembly, they were given one shop coat of oil base exterior house paint. A final coat was applied after installation. For aesthetic reasons, the paint color used on the sash and trim was selected for the final coat on the louvers (see figure 3).

In order to secure the vents in place, common 6d galvanized box nails were driven through the louver jambss into the sash tracks of the historic window jambss. To keep the jamb and stops from being damaged by the louver installation, temporary blocking was set between the parting bead and the inner and outer stops (see figure 4). By attaching the vents in this location, little damage was done as the nails were driven into the sash track rather than an exposed portion of the jamb. Once the building is returned to use, the lower sash will be installed and the nail holes will be filled with wood putty. Since the nails were driven in on the interior of the building, nearly 3' from the exterior wall, adequate security was achieved without driving the nails all the way in. Thus it will be relatively easy to grab onto the nail heads and back them out when the vents are eventually removed.

Figure 3. The exposed edges of the louver slats were plumb cut in order to create a water drip on the exterior. For aesthetic reasons, the louvers were painted the same color as the sash and trim. Photo: Charles Fisher
Figure 4. The lower sash (Figure 4a) were removed to permit installation of the louvers. To minimize damage to historic fabric in installing the louvers, temporary blocking was set between the parting bead and stops prior to nailing the units in place (Figure 4b). Drawings: Thomas Vitanza and Christina Henry.

After the louvers were secured in place, $\frac{3}{16}$" mesh copper wire screening was installed on the interior of the louver frame using a $\frac{1}{2}$" square wood frame. The screening is an integral part of the louver design. This seemingly minor detail was necessary to prevent the recurrence of insect, bird, and rodent infestation (see figure 5). The $\frac{3}{16}$" mesh was specified to keep out the ever-present mud-dauber wasp, whose hive-building instincts have no regard for historic plaster or paint.

The cost of constructing and installing the louvers in 27 window openings was around $1,800, including 17 full size louvers, 7 basement and 3 attic units. This work was undertaken concurrently with the construction and installation of the reconstructed window sash and repairs to the frames, sills, jambs, and surrounding brickwork. The total cost of the window work was less than $9,000, involving 31 window openings.

Figure 5. Screening was attached to the back side of the louvers to prevent the recurrence of insect, bird, and rodent infestation. Photo: Charles Fisher
Project Evaluation

The window louvers installed in the Worthington House have proven effective over the past two years in providing the necessary ventilation for the building (see figure 6). Neither fungal attack nor condensation damage has recurred, and the interior air lacks even the typically humid, musty odor typically found in many older buildings. The louvers provide for good air movement within the building and a greater equilibrium between interior and exterior humidity levels and air temperatures, thus helping to protect the historic plaster and the significant interior finishes. The installation of the louver system in conjunction with the other sash work, and the overall exterior stabilization work has stimulated an interest in finding a use for the structure. As a temporary solution to a complex set of problems, the louver vents in the Worthington House have resolved a variety of issues. When used together with additional weatherproofing measures, this venting solution can be adopted for use in other buildings being mothballed.

Figure 6. The window louvers installed in the Worthington House have proven effective over the past two years in providing the necessary ventilation for the building. Photo: Tom Vitanza.
**Project Data**

**Building:**
Worthington House
Monocacy National Battlefield
Frederick County, Maryland

**Owner:**
National Park Service
Antietam National Battlefield
Sharpsburg, Maryland

**Project Date:** January-June 1983

**Project Staff:**
Williamsport Preservation Training Center
National Park Service
Williamsport, Maryland

- Douglas C. Hicks
  - Project Supervisor
  - Supervisory Exhibit Specialist
- Thomas A. Vitanza
  -Project Leader
  - Historical Architect Trainee
- William Hose
  - Exhibit Specialist Trainee
- Bruce Martin
  - Woodworking Specialist

**Project Cost:**
Material and labor for construction of the 17 full size, 7 basement and 3 attic louvers was approximately $1,800. The material and labor cost for reconstruction of the sash, including glazing, painting, sizing and installation was around $5,200 (roughly $100 per sash unit), involving 21 pairs of double-hung sash and 7 basement and 3 attic windows. All other related work for the 31 openings, including sizing and installation of the louvers, repair to window openings (repair/replacement of sills and jambs and related masonry work), painting, and installation of screening and blocking cost between $1,000 and $2,000. Total window costs for complete sash and the louvers as well as installation and finish work was between $8,000 and $9,000.

---

This PRESERVATION TECH NOTE was prepared by the National Park Service. Charles E. Fisher, Preservation Assistance Division, National Park Service serves as Technical Coordinator for the PRESERVATION TECH NOTES. Special thanks go to James S. Akins, Branch Chief, Williamsport Preservation Training Center, for his time and generous assistance in providing information concerning the ventilation problems of mothballed historic buildings. Thanks also go to Doug Hicks, Project Supervisor, Williamsport Preservation Training Center, for his contributions to this Tech Note. The following Preservation Assistance Division staff contributed to the production of this Tech Note: Michael J. Auer, Brenda Johnson, Christina Henry, Janet L. Thomas, Theresa Robinson, and Alicia Hardison.

Cover Photo: Tom Vitanza.

This and many of the PRESERVATION TECH NOTES on windows are included in “The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings,” a joint publication of the Preservation Assistance Division, National Park Service, and the Center for Architectural Conservation, Georgia Institute of Technology. For information write to The Center for Architectural Conservation, P.O. Box 93402, Atlanta, Georgia 30377.

PRESERVATION TECH NOTES are designed to provide practical information on practices and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures, and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act Amendments of 1980 which directs the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Preservation Assistance Division, P.O. Box 37127, Washington, D.C. 20013-7127.

ISSN:0741-9023 PTN-11 August 1985
D: Second Floor, South Elev.  S218

- Replace molding
- Sash - repair with mordant
- Replace with nine light sash to match upper

E: Second Floor, North Elev.  N221

- Replace rail or consolidate with epoxy
- Sash weights missing - install new to match, replace all sash cord using sash chain
- Interior - consolidate apron using epoxy

---

D: Second Floor, East Elev.  E208

- Replace outer tracks and parting stops
- Replace molding
- Install new glass
- Interior - replace soffit of head

E: Second Floor, South Elev.  S211

- Transom missing
- Weatherstripping missing - install new to match
- Interior - fill open joints, repair transom mechanism
- Right transom missing - install new wood transom to match
CHALMERS UNITED CHURCH

Kingston, Ontario

Erected in 1889-91 for a United Church of Canada congregation, the Chalmers United Church is a handsome structure, designed by Gillen and Gillen, and constructed from local limestone. Among its most striking features are the stained glass windows (artist unknown) on the north and south facades. Each set of tripartite windows consist of a 9' x 24' center portion, flanked by 5' x 20' wing sections on both sides. The center portion depicts scenes from the New Testament; the side windows feature geometric designs. All of the windows were fabricated at the time the church was built.

Repair Problem

Over time the windows had suffered severely on the southern facade of the church, which is exposed to sun and constant strong winds blowing in from nearby Lake Ontario (see figure 1). This wind not only carries dust and dirt, but also has a high moisture content. Because of weathering and the lack of regular maintenance, the wooden frames which secured the stain glass panels had gradually deteriorated. The decay finally became so acute that by 1982 the windows were in imminent danger of collapsing. The parishioners at that point had no choice but to arrange for the urgent repair of the windows.

The original plan formulated by the parish was to remove the large windows from the openings, frame and all, and ship them to a stained glass manufacturer's plant for repairs. There the leaded stained glass panels would have been removed from the deteriorated wood frame; then new mullions would have been fabricated and the glass reset in this new frame.

To design and supervise the work, the church hired architect Wilfred B. Sorenson. After reviewing the situation, the architect realized that following the usual repair procedures, as proposed by the parish, would not be the best way to tackle this job. Not only was the cost estimate quite high, but also there was a very real danger that the fragile stained glass panels would be damaged during removal and transportation. In addition, the large openings left on the wall while the windows were away for repair would have presented another major problem; costly temporary closures would have been required to withstand winter weather.

Repair Solution

After studying the options available, the architect decided to restore the windows, in situ, thereby avoiding the risk of Historic wooden windows should be repaired rather than replaced whenever possible.
of damage during removal and transportation. Instead of making new mullions, the decayed frame was reinforced in an unusual manner, using a method developed by Paul Stumes, the consulting engineer for the project. The method involved the use of epoxy consolidants along with steel reinforcement rods (see figure 2). To permit the work to take place undisturbed by the weather, a "cocoon" formed out of vinyl sheet was attached to the temporary bracing installed to stabilize the windows while the restoration work was underway (see figure 3).

Sash Repair

The first step in the restoration process was the careful removal of the remains of old paint on the wood frame. This exposed the true extent of the deterioration. In some areas, as much as 40-50% of the wood had been lost. The wooden parts of the window frame that were found to be crumbling were saturated and consolidated with a commercially available liquid epoxy.

Next, a 1/2" wide groove was cut into the mullions on opposite faces to receive a steel reinforcement rod. The depth of this groove ranged from 3/4" to 1 1/4", depending on the location. This delicate exercise was carried out with utmost care. After some experimentation was carried out on scrap wood, a hand-held electric router was adapted for the job. Special rollers were installed to guide the rotating cut-
ting bit (see figure 4). Notwithstanding the usefulness of this apparatus, the real success of the operation can be attributed to the skill of the craftsman who guided the tool. The wooden mullions varied in size; on a typical 3 1/4" wide mullion, the outer edge where the groove was cut was 1 1/2" wide. In cutting a 1/2" groove on the outer edge, only 1/2" of wood remained on either side. A slight deviation of the tool could have seriously damaged the mullions.

After the grooves were cut, the wood was treated with a wood preservative on all exposed sides to prevent possible decay. The wood preservative had to be selected with special care because most such products are not compatible with the epoxy resins which were used for the stabilization work. Wood samples were treated with different types of preservatives and tested for compatibility with the epoxies selected for the project. A relatively inexpensive, locally available product was found to be most suitable, and all exposed wood was saturated with it.

For reinforcement, 1/4" diameter steel bars (the same type used to reinforce concrete) were painstakingly bent to match the curves of the mullions. The shape of the bars had to be accurate, within a tolerance of 1/8" in any direction, in order to fit comfortably in the 1/2" wide grooves which followed the complex curves of the windows (see figure 5). Because of the deteriorated condition of the wood, the steel bars could not be forced into the grooves without the danger of splitting the frames apart. In a few instances where the steel rods could not be suitably shaped, braided fiberglass strands were used instead.

With the reinforcement in place, the grooves were filled with an epoxy compound, thus completely embedding the steel in epoxy. The epoxy used for this project — the high-modulus, thixotropic Sikadur gel in which some Union Carbide phenolic microballoons had been added for more firmness and improved workability — had the consistency of a stiff paste. This mixture had the advantage of remaining in position and retaining its shape wherever it was placed. If a fluid epoxy had been used on these vertical windows, special molds would have had to be fabricated and positioned to prevent the liquid from spilling out before it hardened. After this paste epoxy cured, it achieved a strong adhesive bond with the wood of the mullions and the reinforcing steel bars, creating a sturdy composite window frame.

In many places, due to the advanced decay, the fine details of the mullions crumbled into unrecognizable shapes. In these areas, the original form was recreated using the epoxy.
paste like modeling clay. Skillful hands of the craftman sculpted fill-ins which blended perfectly into the curvature of the wooden mullions. After the epoxy paste hardened, only the color was different from the wood; the shape and the texture were the same. To complete the work, the windows were then primed and painted (see figure 6).

Evaluation

This method not only restored the church windows without any breakage of the precious stained glass, but also retained as much of the original fabric of the wooden frame as possible. Fortunately the frames were wide enough to permit the installation of reinforcing rods. Problems associated with placing a new frame into a usually deformed old opening were avoided. In addition to preserving the original architectural components, this method was successful in terms of church operations and budget. Since the windows were not removed, the functioning of the church was not disturbed during restoration, and the repair of the windows in situ was achieved at a cost 25% less than that of just fabricating a new frame.

Figure 6. Repairing the historic frames resulted in a 25% savings over fabrication of new ones. The work included paint removal, reinforcing of the mullions, consolidation of the deteriorated wood, and repainting.

PROJECT DATA:

Building:
Chalmers United Church
Kingston, Ontario
Canada

Project Date: 1983

Architect:
Wilfred B. Sorensen
Kingston, Ontario
Canada

Consulting Engineer:
Paul Stumes, P.Eng.
Parks Canada
Ottawa, Ontario
Canada

Contractor:
Whitby Gather
Kingston, Ontario
Canada

Materials:
Epoxy Paste: high-modulus, thixotropic Sikadur Gel with Union Carbide’s phenolic microballoons added

Epoxy Consolidant: Sika’s liquidColma-Dur epoxy
Sika Chemical of Canada, Ltd., Point Claire, Quebec, Canada or Sika Chemical Corp.
P.O. Box 297
Lyndhurst, New York

Project Cost: $11,000.00

This PRESERVATION TECH NOTES was prepared by the National Park Service. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Coordinator for the PRESERVATION TECH NOTES. Substantial portions of the text have been reprinted from an article entitled “A Fitting Solution...For Onsite Window Restoration,” which appeared in the Fall 1983 issue of Technology & Conservation. We would like to thank its publisher, Susan E. Schur, for her kind permission to use the copyrighted material. Special thanks also go to Peter Charles, Center for Architectural Conservation, Georgia Tech, and to the following Preservation Assistance Division staff who contributed to the production of this Tech Note: Michael J. Auer, H. Ward Jandi, Theresa Robinson, and Brenda Siler.

PRESERVATION TECH NOTES are designed to provide practical information on practice and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to the established National Park Service policies, procedures, and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act Amendments of 1980, which direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to Tech Notes, Preservation Assistance Division, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127. The material in this publication is protected under copyright laws and cannot be reproduced without the permission of the publisher of Technology & Conservation.

ISSN: 0741-9023
PTN-19
November 1986
SAWYER MILLS
Dover, New Hampshire

Sawyer Woolen Mills, built between 1864 and 1892 and operated by the Sawyer family, produced uniforms for the Union Navy and, later, high-quality worsted cloth and cashmeres. In 1899 Sawyer Mills went bankrupt and was absorbed as one of the eight original mills that formed the American Woolen Company. This national textile giant dominated the domestic woolen industry for half a century and, in 1954, became part of Textron Corporation. The complex consists of 22 interconnected structures, comprising a quarter of a million square feet of space.

Eleven hundred multi-light double-hung wooden windows provided maximum natural light and ventilation for the buildings, while strongly defining the architectural appearance, function and scale of this nineteenth-century workplace.

Problem

Architectural planning for the rehabilitation of Sawyer Mills for use as apartments began in mid-1983. The developer recognized early in the planning process the importance of the design characteristics of the original wooden windows and their critical role in preserving the historic character of the mills.

Remarkably, nearly all of the original window sash remained in 1983, having survived more than a century in the harsh New England climate and changing corporate ownership. After undertaking a survey of existing window conditions, and exploring alternative windows in wood, vinyl, and aluminum, the developer was convinced that repair was both feasible and economically realistic. With so many windows involved, thorough planning of the window repair work well in advance of construction was crucial.

Cost, technical capability and window performance were the key considerations in developing the repair approach. The window survey enabled the general contractor to estimate the number of new window sash needed and to form an overall view of the repair work required for sash, frames and sills. To facilitate this aspect of planning, a window and millwork consultant was retained to analyze survey data and to develop shop drawings and specifications for subcontractor’s bids.

The general contractor evaluated staff capability to direct and execute such a large task and concluded the job could be done effectively. Fortunately, the general contractor owned a complete, mobile millwork shop managed by a master craftsman and staffed with several highly-skilled tradesmen.

The performance that could be

Christopher W. Closs
Closs Planners Inc.

With proper planning, many late 19th and early 20th century wooden mill windows can be repaired and upgraded in performance in a cost-effective manner.
anticipated from the repaired windows was of paramount concern to the architect and owner. Two hundred twenty-two apartments were planned, each with central heating and air conditioning. Easily operable primary window sash combined with storm window units were essential in order for the complex to be operated economically. To meet the New Hampshire Energy Code, respectable U and R values would have to be achieved from both windows and exterior walls, which were uninsulated.

The window survey concluded that 800 of 1100 windows were considered repairable. Eight different configurations of sash were found, including several sizes of each configuration.

Solution

Following a close evaluation of typical deterioration problems in a random selection of sash, repair criteria were established. In cases where more than one frame member or where more than two joints were deteriorated beyond repair, the sash was discarded. Salvaged components were used for repair on other units. Muntins were retained if at least half of the grid remained serviceable.

A significant number of window frames and especially sills were found to be in unserviceable condition and required replacement. Some frames had bowed, impairing operability, while many sills were so deeply checked or split that an adequate water-shedding surface could not be recreated. Panning the sills with aluminum was rejected as an alternative to replacement because of the difficulty in achieving a proper flashing detail without further damage to frames and brickmolding.

Several types of interior storm windows were evaluated, including a new style with vinyl frames and Lexan glazing. The type selected was a standard triple track, aluminum, one-light-over-one unit, with special narrow frame profile and a half screen. A key design constraint imposed on the supplier was the requirement that the interior perimeter of the storm window could not visually encroach from behind the glass area of the primary sash, which would create an obtrusive appearance from outside.

The considerable tasks of removing glazing and paint, repairing sash frames, sanding, priming, re-glazing and painting eight hundred windows required organizing the work flow and labor force in a logical sequence (see figure 1). The decision was made to undertake the work on the site and to establish a mobile millwork shop adjacent to the window repair shop so that the former could continuously supply the latter (see figure 2). The shops had to be relocated only once during construction. A key factor making the on-site window repair approach feasible was that the millwork shop’s variable workload from window repairs was supplemented by specialty orders from outside contracts, eliminating costly downtime.

The repair crews consisted of three groups: a millwork shop foreman and assistant; a team of four window repairers (who were trained at the beginning of the project); and a two-person window removal and re-installation crew. Except for the shop foreman, these groups were rotated routinely to avoid monotony and enhance safety, and to build skills within the crews, so that reserves were available in the event of illness or injury. The window consultant and millwork foreman provided skills training for the repair and installation crews and ensured quality control of the repair work.

High quality materials were used in repairing sash and milling new sills and window frames. Canadian eastern white pine, grades #1 and #2, was used exclusively. Canadian #1 white pine was the most cost-effective material that could be procured knot-free and that has proven to wear well in window construction.

Considerable money was saved by re-using original materials wherever possible. All glass from the old sash was carefully removed and stacked for re-use; approximately 60 percent of the original glass was reused in the repaired sash. Cleaning the glass was labor-intensive and not entirely successful, since some surfaces remained a little cloudy as a result of etching over the years. An effort was made not to mix new glass with the old in repaired sash in order to minimize differential reflectivity outside. Existing sash cord pulleys were removed, cleaned and lubricated, and reinstalled with new sash cord in each window opening. Cast iron counter weights were found in their pockets for the most part, and were also re-used.

Sash Repair Procedure

Original sash were removed from their openings in groups of 20 to 30 units by the installation crew, who carefully checked that both frames and sash were marked with the corresponding window survey number. Once delivered to the repair shop, individual sash were de-glazed, the glass stacked by size, and residual dirt, putty and paint removed from the frames at the first work station (see figure 3). If simple repairs only were needed (e.g., muntin replacement, filling holes or gluing a cracked muntin), they were done and the window sent on for sanding and priming. If more substantial repair was needed, the sash was sent to a work station where milled bars and rails, a whole muntin assembly, or mortise and tenon parts could be fitted. Wherever possible, whole
Figure 2. Drawing shows the plan of the window repair shop set up within Sawyer Mill during renovation work. The mobile millwork site was located in a room immediately to the left of the repair shop. Drawing: Christopher Closs

Muntins were saved from otherwise deteriorated sash and used for spare parts during repairs, resulting in additional savings in milling costs. The repair shop had 4 full-time employees.

The most typical problem encountered was loose or failed mortise and tenon joints; this was remedied by drilling out the old pegs with a slightly oversize bit and then drawing the sash frame together tightly with pipe clamps (see figure 4). Fluted,

Figure 3. Electric deglazing irons were used to remove hardened putty so glass could be removed and the sash frames repaired. Photo: Christopher Closs

Figure 4. The basic repair: cleaning sash frame and drilling out pegs to tighten corner joints. Glue purchased in bulk was transferred to squeeze-bottles for ease of application. Oversize bit and new hardwood dowel shown ready for use. Glazing has not yet been completely removed. Photo: Christopher Closs
hardwood cabinet dowels, liberally coated with waterproof glue, were then driven in to secure the joints. To allow for natural movement, the mortise and tenon joints were not glued. In some instances, deteriorated tenons were cut off and bored out, and new tenons installed, using glue to secure the tenons in their seats but not inside the joints. This worked well providing the receiving mortises were sound. If muntins required selective replacement, this was done before clamping. It was critically important to “true” each sash square before re-pinning the corner joints.

Common tools used through this stage of the operation included an electric de-glazing iron, propane torch with both narrow orifice and flame spreader for putty removal, wire brushes and several types of paint scrapers with varying profiles. Standard ¼” or ½” (chuck size) hand-held electric drills, were used for joint repair.

It was not necessary to remove all the paint from the wood sash frames, but only enough to sand smooth and create a fresh bondable surface to which paint could be successfully applied. In practice, roughly 50-60 percent of the paint was removed.

Once the sash for a complete window were made structurally sound, frames were hand-sanded and fully primed with a shellac-based sealer. Sash were then reglazed in conventional manner and stacked to await final finish with two coats of exterior-grade, oil-based paint (see figure 5). The wood edges of the sash were left unpainted to avoid interfering with hand-planing during fitting in final installation.

**Onsite Millwork Shop**

All repair and milling of replacement frames, sills, and brickmolds, and components for such special features as the wooden belltower finial and interior louvered office blinds, was performed on-site. The mobile millwork shop was located in a room adjacent to the repair shop and occupied an area 35’ x 45’. The basic equipment of the millwork shop included: 18” bandsaw, 10” tablesaw, 36” lathe, a jointer, 12” planer, a molder/shaper machine, several routers, and a floor-model drill press with mortising attachments.

Profile gauges were used to create molding machine knives ground specially to match the historic brickmold that trimmed the window openings. Templates were made of the arc of each type of segmental arch window head, so that reproduction of deteriorated features would be precise. Because the white pine stock available was of insufficient dimension to replicate the width of the original arch head, a bandsaw was used to cut segments which were laminated in three pieces to form replacement arched window frame heads. Replacement window sills were laminated similarly.

To maintain production and minimize waste, the millwork shop continuously supplied the repair and reinstallation operations with common components such as muntins, bars and rails, frames, sills and brickmold. Approximately one-third of the frames and brickmolding required replacement. Where complete new frames were required, these were produced and assembled by the millwork shop, ready for priming.

**Reinstallation and Storm Windows**

New matching wood sash, manufactured in Springfield, Massachusetts, were required to fill three hundred openings where the originals were missing or beyond repair (see figure 6). Deliveries of the new sash were scheduled to match the installation capacity of the project crews with the
output of the millwork shop. The new sash were delivered pre-primed. A second re-installation crew was trained and put in service during the peak production period in early 1985.

The re-installation crew was responsible for repairing or installing new frames, mounting brickmolds and installing repaired and new sash. Two "gun carriages" were constructed to facilitate frame installation and to ensure safety for the crews (see figure 7). Each carriage served as a cantilevered work platform (if fitted with dolly wheels they would have resembled a naval gun carriage). They permitted the installation crew to work safely on the exterior of the window opening without staging (much of this work had to be done over the river). The carriages had stops on the interior, were counter balanced, and were moved from opening to opening as frame repairs and brickmold work proceeded.

Re-installation of the sash was done in batches of 20 to 30 pairs of sash, which although indexed to the original openings, often required planning of the edges of stiles to achieve smooth operability. For this a handheld, 3½" power planer was employed.

The installation of the aluminum interior storms occurred after the primary windows were in place (see figure 8). Installation of the storm windows was monitored carefully to ensure that aluminum frames were set in a continuous bead of silicone caulk to provide a tight weather seal. This was made easier by the absence of decorative casing on all of the windows; storms were simply screwed fast to the flat, three-inch weight pocket covers (see figure 9). A new beveled 1" wooden strip was applied around the outside perimeter of the weight pocket covers and the heads, and caulked forming an uninterrupted seal with the brick masonry wall. Weight pockets were not insulated since the counterweights remained operable.

To reduce the chances of moisture being trapped between the storm unit and the primary window, the repaired wooden sash were fitted somewhat loosely, thus allowing for adequate venting. In practice, this approach worked well. The first units installed were checked during the winter of 1984 and exhibited no excess moisture or frost build-up.

**Figure 7.** "Gun carriage" (scaffolding) in use by the window re-installation crew who are preparing to replace missing brickmold with replacement made by the millwork shop. Note saw kerfs used to create are in molding for use in the window head (same method as used in the original molding). Photo: Christopher Closs

**Figure 8.** Typical interior aluminum combination storm window unit with insect screen shown at top. Beveled stops around the perimeter were added and the windows were caulked to provide for a good energy seal. Photo: Christopher Closs

**Figure 9.** Drawing showing installation of the interior storm window. Drawing: Christopher Closs
Evaluation

In an energy-conscious era, this project shows that the repair of historic wooden windows in mill buildings can be cost-effective and energy-efficient with proper planning. The following measures need to be considered in the design solution:

1) Proper and detailed survey evaluation is made of the existing window stock
2) Repair procedures are designed and integrated into the overall schedule and work flow of the rehabilitation project
3) Skilled and semi-skilled personnel are available, and provisions are made for any necessary training
4) Modern methods for upgrading the energy performance of existing windows are integrated into the design.

The rehabilitation of the original wooden windows at Sawyer Mills was successful in meeting historic preservation standards, aesthetic considerations and window performance objectives. Seventy-three percent of the original windows were preserved. The actual costs only slightly exceeded the original budget allowance of $440 per opening, excluding the new storm windows. The thermal performance of the windows was upgraded and ease of operability restored for the new residential use; both were accomplished with little difficulty and at minimum cost. Moreover, the introduction of interior storm windows was an entirely reversible solution that caused no change or alteration to historic material and was expected to reduce maintenance cleaning costs.

PROJECT DATA

Property:
Sawyer Mills
Dover, New Hampshire

Owner:
Sawyer - Bellamy Mill Associates
Dover, New Hampshire

Project Duration: 1983-1985

Architects:
Keyes Associates
Providence, Rhode Island
Paul Mirski, AIA
Enfield, New Hampshire

Preservation Consultant:
Christopher W. Closs, MNRP
Closs Planners, Inc.
Concord, New Hampshire

Window/Millwork Consultant:
Arthur L. Pepperman II
Heritage Preservation, Inc.
Laconia, New Hampshire

General Contractor:
Bonnie Brae Construction
East Waterboro, Maine

Project Costs:
The rehabilitation of Sawyer Mill cost approximately $12,000,000. The window work cost about $616,000, or an average of $555 per window including the $90 per window cost for the fabrication and installation of the interior storm windows.

800 Windows (Sash Repair)
Sash repair $300 per window
Sill and frame work (repair & replacement) $100
New wooden brick molding $20
Reinstallation $50
Painting (included in overall painting contract) $150
Total $470 per window

300 Windows (Sash Replacement)
Sash Replacement $250 per window
All other costs the same as the repair work
Total $420 per window

Miscellaneous Window Cost: $15,000

1100 Interior Storms
Fabrication and Installation $90 per window.

Materials:
Grade #1 and #2 eastern white pine
(Canadian)
DAP Glazing Compound

This PRESERVATION TECH NOTE was published by the National Park Service and the Center for Architectural Conservation, Georgia Institute of Technology. Charles E. Fisher, Preservation Assistance Division, National Park Service serves as Technical Coordinator for the PRESERVATION TECH NOTES. Special thanks go to Christopher Closs for writing this Tech Note at the request of the National Park Service. Thanks also go to John Ponzetti, Construction Manager, Bonnie Brae Construction, for his assistance in providing cost data. The following Preservation Assistance Division staff contributed to the production of this Tech Note: Michael J. Auier, Brenda Siler, and Theresa Robinson. Cover Photo: Christopher Closs

This and many of the PRESERVATION TECH NOTES on windows are included in “The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings,” a joint publication of the Preservation Assistance Division, National Park Service, and the Center for Architectural Conservation, Georgia Institute of Technology. For information write to the Center for Architectural Conservation, P.O. Box 93402, Atlanta, Georgia 30377.

PRESERVATION TECH NOTES are designed to provide practical information on practices and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures, and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act Amendments of 1980 which directs the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Preservation Assistance Division, 424, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127.

ISSN:0741-9023 PTN-21 December 1986
LIPPINCOTT PRESS BUILDING
Philadelphia, Pennsylvania

Located along Philadelphia's Schuylkill River, the Lippincott Press Building is a prominent early twentieth-century industrial structure contributing to the Schuylkill National Register Historic District. Designed by Mahlon H. Dickinson and constructed in 1915, it is a six-story, 118,000 square foot structure of reinforced concrete with brick infill. The tripartite industrial steel windows, each with a central pivoting sash, were the dominant architectural feature of the building.

Constructed for the A.H. and F.H. Lippincott Company, the building served as a printing plant until the 1940's, at which time the U.S. Navy converted the building into offices. In the 1960s the University of Pennsylvania leased portions of the structure for offices and laboratory space.

In 1985 the Lippincott Building was purchased by Historic Landmarks for Living, a Philadelphia-based development firm that specialized in the rehabilitation of historic properties. Their proposal was to convert the building into 105 apartments. The treatment of the windows needed to meet current residential and energy code requirements. In addition, the rehabilitation had to comply with the Secretary of the Interior's Standards for Rehabilitation in order to qualify for the historic preservation tax credits.

Historic steel windows should be repaired rather than replaced whenever possible.
Problem
Since the Lippincott Building was used for a long time as a storage facility, the windows had not been painted, oiled, reglazed, or caulked, nor had missing or damaged parts been replaced in well over twenty years (see figure 1). Naturally, many of the windows exhibited problems typically found on inadequately maintained steel windows, including corrosion, bent and bowed metal sections, non-operable ventilators, missing or non-functional hardware and broken glazing. Furthermore, some of the original windows had been removed and replaced with double-hung aluminum windows, and other window openings had been infilled with glass and concrete block, metal louvered air vents, ductwork and other mechanical equipment (see cover photo).

Solution
To ascertain the feasibility of repairing the existing steel windows, the project architects conducted a preliminary window condition survey. With this preliminary survey, each window opening was assigned a number and a physical inspection was undertaken window-by-window (see figure 2). The results of the inspection were recorded on a survey sheet that typically listed six window openings per page and included the following information:

1. The type of window present and the overall condition of the unit, evaluated on a scale of one to five, five being the poorest condition.
2. Whether the window in its current condition met the Pennsylvania State Energy Code requirements for heat loss, air infiltration, and other energy/comfort criteria.
3. Whether the window met the City of Philadelphia Code, Section 809.4, which requires that operable windows with sill heights no greater than 44” above finished floor level be provided for all habitable apartment spaces below the fourth floor level.
4. Comments on the type and location of deterioration or structural problem found on the window.

From this preliminary condition survey conducted in June, 1986, the following results were obtained. Of the building’s 415 windows contained within 193 window openings:

- 6% of the historic windows on all elevations were missing. These windows had been removed and replaced over the years with incompatible windows, or had been enclosed with concrete block and/or mechanical equipment.
- 58% of the historic windows were in poor or nonrepairable condition. The windows designated as being in poor condition contained some heavily corroded sections, primarily in the jamb and sill areas. However, it was considered possible to bring these windows back to a weather-tight, structurally sound state. The nonrepairable windows were those with substantial warping or heavy corrosion on over fifty-percent of the steel members or were irreparably damaged by duct/mechanical equipment.
- 36% of the historic windows were in fair condition. These units had minor sill deterioration and slight warping and were clearly repairable.

Anticipating that full replacement of the historic windows was necessary, the project architects prepared detailed drawings of the fifteen existing window types as well as the proposed replacement window options (see figure 3). The new replacement window options considered were:

1. An industrial steel sash with double-glazing manufactured by A and S Steel Company—exterior bars would have a cavetto rather than a bullnose shape.
2. A “Landmark Series” steel window, also with double-glazing, manufactured by Hope’s Architectural Products, Inc.—exterior bars would be flat.

<table>
<thead>
<tr>
<th>WINDOW DESIGNATION</th>
<th>WINDOW TYPE</th>
<th>WINDOW CONDITION</th>
<th>ENERGY COMPLIANCE</th>
<th>CODE COMPLIANCE</th>
<th>REMARKS</th>
<th>RECOMMENDATIONS</th>
<th>WINDOW DESIGNATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>116a</td>
<td></td>
<td></td>
<td>S. PASS FAIL</td>
<td>NOT APPL.</td>
<td></td>
<td></td>
<td>116</td>
</tr>
<tr>
<td>116b</td>
<td></td>
<td></td>
<td>S. PASS FAIL</td>
<td>NOT APPL.</td>
<td></td>
<td></td>
<td>116</td>
</tr>
<tr>
<td>216</td>
<td></td>
<td></td>
<td>S. PASS FAIL</td>
<td>NOT APPL.</td>
<td></td>
<td></td>
<td>216</td>
</tr>
<tr>
<td>616</td>
<td></td>
<td></td>
<td>S. PASS FAIL</td>
<td>NOT APPL.</td>
<td></td>
<td></td>
<td>616</td>
</tr>
</tbody>
</table>

Figure 1. Typical multi-light steel window with ventilator as seen from the interior. This window exhibits typical pre-rehab conditions including sill corrosion, missing hardware and a poorly operating ventilator. Photo: Clio Group.

Figure 2. Window survey form. Prepared by H2L2 Architects.
3. An EFCO, non-thermally broken aluminum sash with double-glazing—exterior pieces would be extruded with a bullnose shape.

In addition to the comparative drawings, mock-ups of the windows manufactured by Hope's and EFCO were installed on the third floor of the south elevation to evaluate how closely the replacements matched the historic windows.

As seen in the comparative drawings and as evident from the mock-ups, the new double-glazed windows did not match the proportions, dimensions, thin profiles and sight lines of the historic steel windows due to the increased dimensions of the new window members. Thus, although the new proposed windows promised increased energy performance, the installation of these non-matching windows would not have been in keeping with the building's historic character.

Recognizing the visual problems with the proposed replacement windows, the project team decided to examine further the feasibility of repairing and retrofitting the existing windows. Since the preliminary window survey indicated that 58% of the historic windows were in either poor or non-repairable condition, a second and more detailed analysis of these windows was undertaken by the architectural firm and historical consultants. Particular emphasis was placed on distinguishing between windows categorized as poor-but-repairable and those considered non-repairable.

From this more detailed analysis it was concluded that in 85–90% of the windows originally categorized as poor or unreparable condition, heavy corrosion was confined to the jamb and sill areas and that these units were in fact repairable. Of all the windows within the building, only 10–15% of the existing historic windows were in a non-repairable condition according to the second, more indepth survey, and 6% were missing, leaving 80–85% of all the windows in arguably repairable condition.

The project team decided to rehabilitate the majority of the existing windows after taking into account the following factors: the majority of the existing windows were repairable; the proposed replacement windows installed as mock-ups did not adequately match the existing windows; and the entire rehabilitation project was on a fast-track work schedule that could not allow for delays in the manufacturing and delivery of a new design for custom-made windows.
The rehabilitation included replacing the deteriorated steel sections, particularly in the sill areas, and replacing the missing and nonrepairable windows with new single-glazed steel windows similar in profile and configuration to the existing windows. As part of the repair process, the existing ventilator windows would be modified from center pivoting sash to projecting sash (to meet Philadelphia code for emergency egress), and both the repaired and new steel windows would receive interior storm windows to bring the windows into compliance with the Pennsylvania State Energy Code requirements for heat loss, air infiltration, and other energy/comfort criteria.

To accommodate the first floor lobby and parking garage, the decision was made to repair and reglaze with frosted glass the existing steel windows in the garage area, and to install new windows in the newly created lobby area where no windows previously existed. The garage windows retained their operable pivoting sash, since compliance with energy requirements was not applicable. To provide for adequate garage ventilation, glazing was omitted from a number of the ventilators (see figure 4).

**Work Description**

The new steel windows were ordered immediately so that their installation would be concurrent with the repair of the historic windows. All the other windows were to be repaired.

Working directly with the project’s general contractor, a number of specialized subcontractors were chosen for the window work:

1. Two contractors for the repair and replacement work of the steel components;
2. A contractor who worked directly with a steel window company and supplied all the replacement window parts, including entire windows for those locations that required new windows and stock lengths of steel window sections for replacement pieces for deteriorated members;
3. A glazing contractor who removed all the old glazing and putty, cleaned the steel sections and glazed the windows; and
4. A painting contractor who caulked and painted the windows.

The repair work on the historic steel windows began in November 1986, under the direction of the general contractor.

**Glazing Removal**

The first step in the repair process was the removal of all the wire glass and other types of more recent glazing. The glazing contractor with a team of eight to twelve men, usually in two-man crews, began breaking out the glass, commencing on the top floor and completing all of the elevations on one entire floor at a time. As much of the glass as possible was removed at this time, but there was no attempt made to remove all of the putty.

**Steel Repair and Ventilator Retrofitting**

Immediately after the glazing contractor had removed the glazing from an entire floor, the contractors for the metal work began. Since this rehabilitation was on such a tight completion schedule, and given the labor-intense nature of the repair work, two metal working contractors were utilized. Each contractor was responsible for
the repair/replacement of windows on three floors of the building. Although most of the seriously deteriorated windows were identified as part of the window surveys, the general rule for the contractors was that if, after close examination, more than 50% of the window unit exhibited severe deterioration, then the entire unit could be replaced. The remaining usable members would be salvaged for use as replacement pieces on other windows.

Generally employing three crews of three to four men, each contractor began by cutting out all the severely corroded and/or heavily bent metal sections from each window. Severe corrosion occurred primarily in the sill areas where the original steel sill section was embedded in concrete—a condition existing in approximately 95% of the window sills to be repaired (see figure 5). The spalled concrete and the corroded metal sill sections were chopped out with a portable band saw. In addition to the corrosion in the sill areas, extensive deterioration typically extended up the window muntins approximately three to six inches. These members were cut at a 45 degree angle with a five-inch grinding wheel using a five-inch disk, usually at a point four to seven inches from the sill or where the steel was no longer corroded.

Concurrent with the cutting out of the window's corroded steel members, each of the existing pivot window ventilators on floors two through six were cut from their jambs, labeled and brought to an on-site work station. At the work station, the pivotizing ventilators were modified to operate as projecting windows (see figure 6). This was accomplished by cutting off the bullnose outside face of the side and bottom rails on the sash and riveting a new water-shed steel angle at the same locations. To allow the ventilators to swing out, two 16" heavy-duty, 6 bar, zinc chromate plated steel, TRUTH hinges were screwed to each ventilator (see figure 7). New right-hand, cast iron, bronze lacquered, locking handles were installed on the bottom rail by face-mounting and screwing to each ventilator.

In addition to the retrofitting of the ventilators, many of the window muntins and structural mullions needed to be straightened, patched and repaired (see figure 8). Members that were seriously bowed and could not be adequately straightened were cut off using grinding wheels and salvaged; replacement members were welded into place. Two relatively simple techniques were used to straighten the less seriously bent and bowed steel members. With mullions, a wooden brace (usually a two-by-four) was attached to the mullion; a wire cable was wrapped around the wooden brace and the mullion; and slowly the cable was pulled with a "come-along" winch hooked to the ceiling of the building. Since the mullions had typically bowed toward the exterior, the member was pulled in the direction opposite its bowing, towards the inside of the building. To straighten out bent and bowed muntins, the contractor applied constant pressure through the use of 14" bar-type clamps on the muntin. All indentations and gouges left in the steel members were filled with an auto-body patching compound containing steel fibers and an epoxy binder, sanded smooth and primed with a rust-inhibiting primer.

Once the muntins and mullions were set plumb, the final steps in the steel repair process began. In most of the sill areas, lengths of new steel sections were installed to replace the original corroded members. The new cavetto-shaped steel sections did not match exactly the bullnose profile of the historic windows (see figures 9 and 10). However, the original profile was no longer available and the new profile was close enough so that the overall proportions, profile, and shadow lines were compatible with the historic window appearance. The new steel sections at the sill and the lengths...
extending up into the muntins were welded together, installed in the appropriate location and then clamped and welded to the remaining original window. All welds were ground smooth and primed immediately with a rust-inhibiting primer. The concrete sills were then patched. Concurrent with the splicing-in of the new members, the ventilator jambs were also retrofitted to accept the new projecting ventilator. Similar to the work on the ventilators, the bullnose trim piece on the upper portion of the exterior side rails was cut off and a new steel angle was installed on the interior of the side and bottom rails and the hinges were attached.

**Cleaning of the Steel, Glazing and Painting**

After the metalworkers had cut out the deteriorated pieces, spliced in new steel sections, retrofitted the ventilators and ventilator jambs, and straightened out all the bent and bowed muntins and Mullions, the glazing contractor began preparing the steel windows for the installation of new glass. A formidable task in re-glazing the windows was the removal of the old glazing putty still left in the glazing rabbet. Two basic techniques were employed. Hammer-guns with chisel-ends were used extensively, although care had to be taken to prevent damage to the steel sections. Slower and less effective, acetylene torches were also used to remove the putty. The torches softened the putty to the point where it could be removed with a scraper.

After the putty was removed, remaining flaking and loose paint and light surface corrosion were removed by rotary wire brushes attached to electric drills or by hand-scrapping and sanding. No attempt was made to remove sound paint from the steel windows since the paint did not interfere with the effective operation of the windows.

The windows were then backglazed and new double-strength glass was installed in the bed of compound. Fortunately most of the original clips that helped secure the glass in place remained in good condition and were reinstalled wherever possible. New glazing clips were used as needed. The same compound was used for the finish glazing.

The final step in the repair of the historic steel windows was painting. Operating from swing-staging, which extended the width of an entire three-window opening, the painting contractor lightly sanded and primed with a rust-inhibiting primer all the surfaces that had not been previously primed. All of the windows were then given two coats of a dark green, alkyd-based paint. Prior to the final paint coat, all of the window perimeters were caulked with a vinyl acrylic caulking compound that was also given a coat of finish paint.

**Weatherization**

An essential component of the rehabilitation project was the upgrading of the steel windows to meet current residential and energy code requirements. The repair and retrofitting of the existing steel windows in and of itself was not sufficient in bringing the windows up to code. The development of an interior storm window system provided the additional thermal performance for code compliance. The system involved an aluminum, triple-track, interior storm unit with flanking, fixed “sidelites” (see figure 11). A major consideration in the development of this storm system was the desire to minimize the outside visibility of the storm unit by aligning as closely as possible the meeting rails and other aluminum members with the steel window members (see figure 12). The exterior face of the storm windows was painted the same color as the steel windows so as to be as inobtrusive as possible (see figure 13). Although, the aluminum members do not match exactly the width of the opposite steel members, the storm windows were not readily visible from the exterior.

**Project Evaluation**

Whether to repair or replace historic windows is a complex issue often facing building owners, contractors, architects and others involved in the rehabilitation field. In this case, the various options available to the development team—from full replacement with a new insulated window system to repairing the existing windows—
were explored with the ultimate decision made to repair the significant historic steel windows. This decision was based on the assumption that repair of the windows was both a practical and cost-effective undertaking. The end product was a practical, cost-effective and ultimately successful solution to a difficult rehabilitation problem. The prominence of the thinly profiled, multi-light, industrial steel windows has been retained while current residential and energy code requirements as well as the Secretary of the Interior's Standards for Rehabilitation have been met.

There were, however, some aspects of this project that could be modified in future rehabilitations involving the repair of steel windows. First and foremost would be hiring skilled metal workers experienced to undertake the intricate steel work. Since most of the metal workers on the job had little or no experience in this type of work, considerable time was spent training
and supervising the workers. For optimum paint performance and long-term maintenance, the repaired steel windows should have been sandblasted to fully remove the remaining paint and rust and to ensure a long-lasting bond between the steel and the new coats of paint. The additional cost would undoubtedly be justified by the more effective paint finish. Finally, although the storm window installed met the energy and overall visibility criteria established for the project, alternative schemes could have been developed that more closely reflected the operational and structural design of the historic steel window.

PROJECT DATA

Building:
Lippincott Press Building (Locust Point)
25th and Locust Streets
Philadelphia, Pennsylvania

Owner:
Lippincott Penn Historic Associates
c/o Historic Landmarks for Living
30 South Front Street
Philadelphia, Pennsylvania

Project Dates:
November, 1986—April, 1987
(Window work)

Architects:
H2L2 Architects/Planners
714 Market Street
Philadelphia, Pennsylvania

Historic Consultants:
Clio Group
Lancaster Avenue
Philadelphia, Pennsylvania

Contractors:
J.J. DeLuca, Inc. (General)
Chester, Pennsylvania

Metal:
Colory Metal, Inc.
Bensalem, Pennsylvania
Ornamental Security and Maintenance Company
Moorstown, New Jersey

Windows:
Winderco, Inc.
Mt. Laurel, New Jersey
A and S Windows
Glendale, New York

Glazing:
H. Perilstein Glass Division
Philadelphia, Pennsylvania

Painting:
Murphy Painting
Trevose, Pennsylvania

Project Costs:
$12,100,000 (Total project rehabilitation costs)
$708,800 (Total window rehabilitation costs)
$41,800 (Window repair work, material)
$351,000 (Window repair work, labor)
$116,000 (Window demolition, glass and glazing)
$130,000 (Storm windows)
$70,000 (Painting)
Total of units rehabilitated:
191 window openings
408 windows
8,964 total lights

This PRESERVATION TECH NOTE was prepared by the National Park Service. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as the Technical Coordinator for the PRESERVATION TECH NOTES. Information on the steel window repair work described here was supplied by Tim Noble of the Clio Group, Jeffrey L. Matthews AIA, of H2L2 Architects, Greg Mason of Colony Metal, Inc., Edward J. McCourt of Winderco, Inc., Neil Goldberg of H. Perilstein Glass Division and Sam Marabella and Terry Adams of J.J. DeLuca, Inc., the General Contractor for the project. Special thanks go to the following National Park Service staff who contributed to the production of this Tech Note: William Bolger, John Hnedak, Cynthia MacLeod and Martha Raymond of the Mid-Atlantic Regional Office. Cover photo: Clio Group, Inc.

This and many of the PRESERVATION TECH NOTES on windows are included in “The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings.”

For information write to the Historic Preservation Education Foundation, P.O. Box 27080, Central Station, Washington, D.C. 20038.

PRESERVATION TECH NOTES are designed to provide practical information on practices and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards. This Tech Note was prepared pursuant to the National Historic Preservation Amendments of 1980 which direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Preservation Assistance Division-424, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127.

ISSN: 0741-9023
PTN 29
August 1989
9 ROXBURY ROAD
SCARSDALE, NEW YORK

Introduction

Durable, versatile and functional, steel casements were a popular window type throughout the first half of the twentieth century. They were simultaneously modern and traditional, easily adapted to fit the variety of eclectic architectural styles that appeared during the period. Benefiting from steel’s strength, casements featured slender profiles that provided a lightness and delicacy unmatched by other window forms. They also admitted large amounts of sunlight and ventilation to the interior. Steel casements were widely distributed by a number of manufacturers including Fenestra, David S. Lupton & Sons, and Hope’s of Jamestown (the latter of which is still in business), until the windows fell out of favor in the years after World War II. High quality steel, combined with the window’s simplicity and solid construction, helped many survive three quarters of a century of use, wear, and often, neglect.

Casement windows are an important design element of the Tudor Revival house at 9 Roxbury Road. Built in the early 1920s, it is a common house type found within the neighborhood and among other suburban communities that date to this era. The sixty-five steel windows are placed individually, in pairs or in bands of three or four along the masonry and stucco exterior (see figure 1). Each of the Fenestra brand windows contains six lights in two vertical rows with the panes putty-glazed on the outside. The historic glazing was double-strength glass with noticeable, though not prominent, distortions (see figure 2). Hardware, consisting of a locking handle and sliding “lift and stay” operator with brass pin, was both functional and decorative, providing subtle embellishment along the inside of the window (see figure 3).

Problem

The windows on 9 Roxbury Road showed deterioration and damage typical of historic steel casements. In the course of over seventy-five years, corrosion, wear and some distortion of the sash and frame had occurred. Rust was particularly prevalent along the lower parts of the sash and frame where water had penetrated the distorted opening and the cracked perimeter.

Steel casement windows should be repaired rather than replaced whenever possible.
Exterior glazing putty that helped secure and seal the glass in the window sash was deteriorated in many areas. Furthermore, some of the horizontal muntins along the room side of the sash were missing back putty that had cracked and fallen out. As expected with windows of this age, most sash showed signs of repeated patch attempts at reglazing and repainting. Resulting profiles lacked the crisp bevel that is characteristic of steel casement windows. Successive reglazing and repainting efforts had crept further out onto the glass (especially along the inside surface), increasing sightlines well beyond the 3/4” width of the historic glazing bars.

Solution

The owner had purchased the house at 9 Roxbury Road, in part, because of its historic appearance. As an architect interested in older buildings, the owner recognized the importance of steel casement windows in helping to define the building's historic character (see “Steel Windows and Historic Character” sidebar).

When the windows deteriorated to the point where major repairs were required, the owner sought the least intrusive solution. Having seen other houses where casements had been replaced, it was clear that new aluminum, wood or vinyl units would not share the same dimensions, profiles and craftsmen-ship of the historic windows. While replacement with new steel casements was an alternative, saving most or all of the historic windows, if possible, was the preferred preservation solution.

The owner contacted a window repair company that had over twenty years of experience repairing and servicing steel casement windows. After an initial inspection of the windows, a plan was drawn up for their complete rehabilitation. Much of the work would consist of realigning the bent sash and frame, thus returning them to their original tight fit. All the hardware would be serviced to make locks secure and to allow the hinges and other mechanisms to move without resistance. Additionally, broken parts were to be replaced with like materials from the repair company’s stock. The

caulk (see figure 4). Originally tight fitting, all of the sash were bent out of alignment with resulting gaps from 1/16” inch to 3/4” inch between sash and frame. Hardware was corroded, stiff, and in some windows, seized shut. Prior attempts to force the distorted windows closed had also bent some of the locking handles and other hardware.

Ten windows were completely inoperable either because they were so far out of alignment that they could not be opened and closed or because successive layers of paint had sealed them shut. When a previous owner installed window-mounted air conditioners not designed for steel sash, four additional windows were modified and made inoperable.

Figure 3. The window hardware at 9 Roxbury Road included a two-part “lift and stay” operator (right) and a common locking handle (disassembled at left). The hinged portion of the lift and stay (upper right) is attached to the sash while the perforated length is connected to the frame. To open the window, the pin is lifted from the hole on the far right, the sash is pushed open and the pin reset in one of the adjacent holes.

Figure 4. The sash and frame were most severely corroded along lower horizontal members. A vertical glazing bar had previously been removed from the sash above to fit a window air conditioning unit (1). A replacement “T”-shaped length of steel that will be spliced in can be seen on the right (2).
Steel Windows and Historic Character

Whether Tudor Revival or International Style, Collegiate Gothic, Mission or Art Deco, steel casement windows had a place in many of the stylistic trends prominent in the years prior to World War II. Buildings based on medieval forms used steel casements to recreate traditional European windows. Modern architects, already partial to steel, found that ribbons of single-light casements matched their industrial aesthetic. The adaptability of steel casements also extended to a variety of building types and sizes, including small cottages and ostentatious mansions, schools, hospitals and apartment buildings. Frank Lloyd Wright’s Fallingwater and the thirty-story Drake Tower in Philadelphia, though very different in scale and style, both featured steel casement windows as an important design element.

Regardless of a building’s style or function, steel casement windows are often a crucial, “character-defining” feature. The muntin patterns of steel casements complement both the orientation of the window openings and the arrangement of windows in multiple groups or bands. Thin profiles form a pleasing contrast to the heavy masonry, brick or stucco walls in which they were often set. The aesthetic appeal and functional value of casements is enhanced when the units are opened, allowing maximum ventilation, and in those units with divided lights, emphasizing variations in the individual windowpanes.

Because casement windows figure prominently in a building’s visual appearance and contribute to its historical character, any rehabilitation project should first attempt to repair the existing units. Unfortunately, replacement windows often do not match the historic windows. Replacements may be incompatible in material, dimensions, muntin arrangement or color. Any one of these changes can have a negative effect, and may compromise the historic value of the entire structure. This Preservation Tech Note suggests methods that can be successfully used to repair steel casements. In rare cases where the historic units are beyond repair, replacement windows should match as closely as possible the design and appearance of the original casements.

Inappropriate replacement windows dramatically affect the appearance of a historic home that once featured steel casement windows.

Historic steel casement windows are in the process of being replaced with new units that compromise the character of this building facade.

decided that after the windows were repaired and serviced, the company would strip existing paint and built-up rust, replace cracked or severely scratched glass panes, reputty as needed, and then repaint the windows.

Window Repair

Each window presented a different set of repair challenges depending on where it was located on the house, how often it was used, and whether it had previously been altered. All required some degree of realignment and servicing. Unless a sash was severely corroded or replacement steel sections required, glass was not removed from the sash for any part of the repair process.

A two-person team undertook repairs one room at a time, usually from the inside of the house. To protect interior spaces and furnishings from paint chips, dust, lubricating oil and primer, the crew taped plastic sheathing along the affected areas. When necessary, workers also...

window-mounted units were to be removed from the four affected windows and the damaged areas of the sash and frame rebuilt with lengths of steel that matched the existing profiles.

A separate painting company with extensive experience in painting historic steel windows would remove corrosion and repaint and reglaze the windows. As part of the planning, the paint contractor visited the site to evaluate the condition of the windows and discuss the work schedule.
rately determined and the repairman could tell when a correct fit was achieved. Using metal shims of varying thickness placed between sash and frame, the worker then began the realignment process by gently applying pressure to the sash. With the shims acting as levers, one location was pushed in while another was pulled, to bring racked corners and warped planes back into alignment. Where the sash was bent outward on either the top or bottom, it was gently twisted back into shape. On single windows, where there was little room to reach out and manipulate the sash from the inside, various pull bars custom-made of notched aluminum rods were used (see figure 6). When the sash was aligned, bent locking pieces and other hardware were similarly returned to their original shape or, where broken, replaced with identical pieces.

The fit of sash against frame and the ease of movement in the hardware was tested throughout the process by opening and closing the window. Frequently gauging the progress prevented over-adjustment. Care also had to be taken not to break hinges, handles or glass. The experienced repair team’s understanding of the characteristics and tolerances of steel windows prevented such mishaps on this project.

When a close fit had been achieved and the window opened and closed freely, servicing began. Paint was scraped from hardware joints and contact points. Locking handles that did not function smoothly were disassembled, cleaned, adjusted and reinstalled. Loose handles were tightened. Dirt was removed from hinges and operators and then all working parts were lubricated. After repair and servicing were completed, areas of the window that had been stripped of paint were coated with an oil-based primer. This protected the bare metal from corrosion until the entire window could be repainted in the next phase.

Fortunately, most of the hardware at 9 Roxbury Road was generally in working order. Window repair projects that encounter broken hardware have several options. Minor damage, such as bent sliders or hinges, can often be repaired either in place or after removing the pieces to a workshop. If these working parts are damaged beyond repair (or missing), replacements can be obtained from dealers in salvaged,

Figure 5. Before realigning the window, paint, caulk, weatherstripping and rust were stripped from all surfaces where the sash and frame were in contact.

accessed the windows from the outside, either on the ground or by a ladder scaffold. In this case, plastic sheeting was hung vertically in the interior. The work was undertaken during the day, while the homeowner was away. Before evening, work areas were cleaned up and protective sheeting was removed so that the process had little impact on the owner’s household routine.

After protecting the work area, layers of paint, rust, caulk and weatherstripping were scraped from all contact surfaces where the sash meets the frame and where locking pieces meet (see figure 5). Such extraneous material had to be removed before attempting to realign the window, so that the severity of distortion could be accu-

Figure 6. Pull bars were used to realign the sash from the inside. These custom made tools were especially useful on single sash units where the worker was unable to reach through an adjacent opening to apply pressure from the outside.

Figure 7. New steel sections were brazed into the historic sash and frame where the windows had previously been altered to fit air conditioning units. Because the replacement pieces came from a stock of salvaged window materials, they matched perfectly the profiles and dimensions of the missing sections.
or new, replicated hardware. See http://www2.epa.gov/tps/pmm45/material.htm for a list of possible replacement material sources.

In order to repair the four windows previously altered for air conditioning at 9 Roxbury Road, it was necessary to replace missing metal sections along the lower third of the sash and frame. Lengths of replacement steel with the typical "Z" and "T"-shaped profiles were obtained from a stock of salvage material maintained by the repair company. Exact matches were easily achieved because replacement pieces came from identical Fenestra casement windows of the same period. To rebuild the sash, replacement steel bars were held to the existing sash with clamps and brazed together with an oxyacetylene torch (see figure 7). After cooling, the brass seam was ground down with a sander so that it was flush with the existing surface. Though not necessary in this project, a similar treatment can be used when portions of the frame or sash are corroded beyond repair. In such a case, damage is usually limited to the frame, sill and lower portions of the sash, where unattended water problems lead to severe oxidation. The deteriorated section can usually be cut out and new pieces from salvaged stock brazed into place.

When the steel windows were properly aligned, the "Z"-shaped bars of the sash and frame fit together in a near weathertight configuration. As a result, weatherstripping was deemed unnecessary. In the past, however, as casement windows on the house had become misaligned and air and moisture infiltration increased, previous owners did add a variety of weatherstrips. Placed along the hinge side, the additional material acted as a shim, putting stress on the locking handle and hinges by holding the sash open on the locking side. A damaging cycle ensued as thicker weatherstrip was added in an attempt to close the widening gap, and the windows became increasingly distorted as the owner tried to force them shut. Eventually, problematic windows were simply never opened.

If weatherstrip is used on rehabilitated casement windows, care should be given to its placement in relation to the window's operation. The thinnest possible material that does not retain water or spring the hinges should be selected. One weatherstrip that has been used successfully with casements is a sealant bead. In this system, a silicone bead is applied to the frame and the sash contact surface covered with a non-stick tape. The sash is then closed and the bead allowed to set in the shape of the space between sash and frame. More information about weatherstripping and steel windows is contained in Preservation Brief 13. “The

### Health Considerations

As with many old and new building materials, potential hazards exist in historic steel windows that require careful handling. Lead-based paint is likely among the built-up paint layers found on casements, while some glazing putty manufactured after 1930 for a time contained asbestos fibers. At a minimum, removing these materials requires the use of HEPA-filtered half-face respirators by workers, as well as covering the affected area with six mill polyethylene sheeting, and vacuuming dust and chips with a HEPA-filtered vacuum. The degree of protection required is determined by the manner in which potentially hazardous materials are removed; techniques that limit the spread of dust and do not make asbestos friable present fewer risks. Depending upon the type of work being done, the size of the project, and the jurisdiction of differing state laws and local ordinances, a certified contractor may be required to remove and dispose of these materials. Preservation Brief 37, “Appropriate Methods of Reducing Lead Paint Hazards in Historic Housing,” as well as local environmental offices, the EPA and OSHA can provide additional information.
Repair and Thermal Upgrading of Historic Steel Windows.*

**Stripping, Reglazing, Painting**

Arriving after the windows have been completely repaired, adjusted and serviced, the paint contractor stripped old layers of paint from the windows, replaced deteriorated glazing putty and broken glass and reglazed and repainted each of the windows. Before any work was undertaken, plastic sheets were placed below the windows on the exterior and hung vertically along adjacent interior spaces. The sheets captured paint, rust chips and old putty so that they could be safely discarded (see "Health Concerns" sidebar).

Deteriorated putty was removed with a utility knife and small chisel. Back putty that had crumbled or lost its adhesion was removed from the inside face of the sash using a small chisel and vacuum. Because individual panes were not removed unless previously broken, extreme care was required to clear old putty from the sash without damaging the historic glass. Removing the pane would have required prying it free of the remaining putty, a process that is extremely difficult to achieve without breakage. Having been protected by the glass and putty, the glazing bar beneath this area was usually in good condition; any minor rust patches were sanded by hand and then primed.

Initial paint and rust removal was done with a pneumatic needlegun. When set to a standard air pressure, the needlegun neither pitted the steel, nor damaged adjacent glass (see figure 8). Occasionally an air hammer with a blunt end attachment was also used. The needlegun was followed by a sander with wire wheel attachments. Run the length of each steel member, this tool removed almost all of the remaining paint and most of the rust. It was especially useful in clearing pockets of rust from crevices and gently grinding down the more severely pitted surfaces. Removing rust with a sander was preferred over sandblasting because a sander is less messy, does not require shielding the glass and masonry surround, and is less likely to damage the steel. Finally, a small hand chisel and sandpaper were used in corners, on the inside edges of the hinges and in other tight locations not reachable with larger tools. Because they were used as guides for the application of the new putty bevel, it was essential that the edges of the muntins were free from nicks or bumps that would have resulted in an uneven profile.

After the sash and frame were stripped, a primer coat was immediate-ly applied to the steel to prevent oxidation of the bare metal. The reglazing process then began. Approximately six percent of the historic glass panes were cracked or severely scratched prior to the beginning of the project. Damaged panes were replaced with standard double strength (1/8" thick) window glass. Alternately, the owner could have used a reproduction glass with a slightly distorted appearance that resembled the historic panes. However, the small number of new panes required meant that replacement flat glass would not be overly noticeable among the historic material.

The glazing contractor used natural, oil-based (linseed or soybean) putty that remains relatively soft. Putty was repacked along the interior face first. In keeping with the historic appearance of the windows, all putty lines on the inside were run flush with the muntin, so that no bevel profile was present. This brought sightlines back to the narrow appearance that is so characteristic of historic steel windows, while creating a watertight seal that keeps condensation from entering the joint. Putty was then applied along the exterior in a beveled profile that helps shed water (see figure 9). Finally, the glass was carefully cleaned with a four-inch razor blade followed by a standard glass cleaner.

Although the manufacturer states that the putty can be painted the day after application, the painting contractor preferred to allow two weeks for the putty to cure sufficiently. Two finish coats were applied to the frame, sash and glazing putty. The industrial paint, a brand commonly used on steel bridges, was custom mixed a taupe color to match the exterior wood trim. To form a moisture resistant seal, paint was extended a small amount beyond the putty and onto the glass face – a standard practice, both past and present.

**Evaluation**

Steel casement windows that are in good working order tend to stay that way. If they function without resistance, excessive (and often damaging) force is not required to operate them. When windows are used and receive attention, eventual repair needs are more quickly identified, before they grow severe. While sound windows remain sound, steel windows that are in poor condition usually deteriorate at an accelerated rate. Problems often
begin with lack of maintenance. If the hinges or locking hardware become stiff and the window resists opening or closing, owners try to force the window, causing it to bend out of alignment. As alignment problems are aggravated, the window becomes harder to operate and the space between the sash and the frame widens, allowing unacceptable levels of air and moisture infiltration.

Repairing the historic steel casement windows at 9 Roxbury Street preserved a significant feature of the house, one that is important to the exterior appearance as well as the interior. With the removal of deteriorated paint and putty and a return to original narrow sightlines, the historic look of the windows was enhanced rather than diminished (see figures 10 and 11). Window performance was increased through servicing and realignment, as the tight manufacturing tolerances between sash and frame were restored. The work was done in a timely manner, with no effect on surrounding historic materials. Of equal importance, the sixty-five windows were repaired and replazed for less than the cost of comparable steel or aluminum replacement windows.

Due to the high structural strength of steel, replacement sash of other materials (wood, aluminum, vinyl), rarely, if ever, can match the narrow members of the original sash. Additionally, installing replacement windows may require removal of the historic steel subframe and cause damage to plasterwork and exterior masonry. If replacement windows are set within the existing subframes, the glazed area of the window may need to be reduced by up to twenty percent, greatly altering the appearance of the opening and reducing the amount of light reaching the interior.

Furthermore, modern glass that accompanies replacement units will not replicate the slight variation that exists between the original panes of a historic window.

Even when historic steel windows are not severely deteriorated, they are often targeted for replacement because of the desire to increase energy efficiency. Though good double glazed replacement windows will provide better thermal performance and lower energy costs than historic steel windows alone, any energy or cost saving calculation must include other factors not usually acknowledged. True replacement costs should include the expense and inconvenience of removing the historic units, the need to repair resulting damage to the window surrounds and the cost of the replacement units themselves. Such considerations are particularly relevant in light of the fact that homes are often owned for increasingly short time periods before being resold. Additionally, a shorter lifespan should be assumed for the replacement units, as the insulating glass units that accompany new windows will eventually fog and require costly replacement.

Assemblies have been developed that increase thermal efficiency while allowing the preservation of significant historic windows. The most common approach is to install storm windows. Because casements swing outward, the storms are almost always placed on the interior. Where casements are paired, inexpensive horizontally sliding storm windows can be installed on the inside. This arrangement allows full access to each sash so that they can be operated and maintained. Although full ventilation for which casements are prized is partially restricted, the level of airflow is still comparable to a typical double hung window. Storm windows can be extremely cost effective and can have little visual impact when they are installed properly and given an appropriate (typically dark color) finish. For a more detailed discussion of how storm windows can be applied to casements, consult Preservation Tech Note, "Windows Number 15. Interior Storms for Steel Casement Windows."

Another alternative to wholesale replacement of steel windows is the
use of laminated glass in place of the historic double-strength glass. Quarter-inch laminated glass, available through most glass suppliers, consists of a thin sheet of plastic film sandwiched between two sheets of standard glass, or a combination of standard and restoration glass. Reglazing casement windows with laminated glass provides improved thermal qualities and avoids the eventual fogging that occurs with insulating glass. The main drawback is, of course, the need to remove historic glass panes.

Conclusion

The historic steel windows at 9 Roxbury Street survived over seventy-five years of weather and wear. Their longevity attests to the strength of the material and the quality of their construction. Though significantly deteriorated, the owner chose to repair the historic windows rather than replace them. After realignment, reglazing, cleaning and repainting, the windows offer a continued lifespan that is hard for any replacement window to match. The benefits are doubly visible. On the outside, the house retains its historic look with appropriate windows with appropriate muntin divisions and profiles. On the inside, the narrow sightlines permit a large amount of light to enter the room, and the beauty of the window’s craftsmanship is apparent.

Project Data:

Building:
9 Roxbury Road
Scarsdale, New York

Owner:
Chris Keeny

Project Date:
Fall 2001

Window Repair:
Seekircher Steel Window Repair
Scarsdale, New York

Window Stripping, Reglazing and Repainting:
Patriot Restorations
Scarsdale, New York

Project Cost:
The total cost for rehabilitating the sixty-five steel windows at 9 Roxbury Road came to approximately $23,500 total or $360 per window. This included approximately $4,000 for realigning and servicing, rebuilding missing sash sections, and replacing hardware. The remainder included stripping, reglazing and repainting all of the windows, as well as the necessary replacement glass.

Photos in “Steel Windows and Historic Character” sidebar are NPS file photos. All other photos are by the author.
Introduction

In historic preservation, aluminum windows are generally thought of as replacement windows, common since the 1970s. Many people are surprised to learn that aluminum windows in buildings have been around since the 1930s and that numerous landmark buildings in the 1930s and 1940s prominently featured them in their design. After World War II, aluminum windows gained more widespread use in the construction industry and soon surpassed steel window sales. By the 1970s, they rivaled the dominant wood window industry, particularly in commercial and institutional construction. The historic significance of early aluminum windows is now being recognized and efforts are being taken to preserve and rehabilitate them.

Aluminum windows actually appeared as early as 1912 for use in railroad cars, streetcars, and buses. The Union Pacific Railroad touted them in their modern streamlined trains for their “high efficiency as to weather tightness, great ease of operation, low upkeep costs, great strength and beauty.”

It was the modern look and appeal of aluminum that helped generate a market in the 1930s for aluminum windows in buildings, particularly in signature buildings and high-end projects. By 1932, the Aluminum Company of America (ALCOA) was running separate full-page advertisements in *Architectural Record* proudly featuring buildings such as the Cities Services Building in New York City with its 2,652 double-hung aluminum windows and the Medical Center Building at Louisiana State University School of Medicine in New Orleans with its 570 windows (see Figure 1).

Leaving no opportunity to chance, manufacturers began offering aluminum windows that mimicked Colonial-style wood windows with true divided lights, and also casement, projecting, and accordion windows to compete against a thriving steel window industry. A 1932 advertisement for residential aluminum windows that appeared in the *Architectural Record* read: “It isn’t a fad — it’s just plain thrift to use building materials of Alcoa Aluminum. ..Take casements for instance. Because window frames, sashes and sills made by Alcoa Aluminum are non-rusting, they won’t drip stain and leave unsightly streaks on adjoining surfaces. ..” (see illustration above). Over time, aluminum windows even took on their own design, in contrast to the appearance of wood and steel windows.
Whether a distinctive part of a major architect-designed building or representative of an early use on a vernacular building type, aluminum windows from the 1930s to the 1950s have earned their place in the history of building construction in the United States. Today, they merit consideration for preservation and repair when dealing with historic buildings.

**Early Fabrication**

Most early aluminum windows were designed either to look like wood or steel windows. Their fabrication borrowed heavily from both manufacturing processes. In fact, a number of the early steel and wood window manufacturers began offering aluminum windows as an additional product line.

Early aluminum windows can be generally characterized as either residential grade or commercial grade, with the latter designed particularly for larger window openings and non-residential applications. Early aluminum windows employed much heavier gauge aluminum than is used today, particularly with commercial and better quality residential windows. Some of the commercial grade aluminum windows also utilized steel for the sub-frame or for the connection to the wall opening, because of its greater strength. The steel sub-frame usually had welded corner joints to provide a continuous frame. Windows with steel sub-frames also commonly featured steel sills and/or mullions.

Manufacturers either prescribed panning over all or part of the exposed steel components with aluminum or simply painting the steel and leaving it exposed. Although some residential grade windows came with similar steel components, most utilized an all aluminum sub-frame, sill, and mullion, often made with a thicker gauge of aluminum than the sash.

Extruded aluminum was used to fabricate the frame and the sash. In cross-section, the aluminum frame for a hung window would usually consist of two or more extruded pieces, interlocked and secured with screws. Window sashes designed to look like wood double-hung or casement windows were often described as tubular or of hollow-metal construction by their early manufacturers. This distinction characterized the sash as a rectangular hollow construction, different from most steel window construction. Typically, the mitered corners of both the sash and aluminum frames were welded. Mulltins were integral to the sash frame and duplicated the appearance of either wood muntins or steel glazing bars, depending upon the look of the window.

Aluminum window sash tended to operate much in the same way as traditional wood or steel windows. For example, hung windows were set into either extruded channels similar to those used in some of today’s aluminum windows or they were installed in guide strips similar to the stops and parting beads used in wood windows.

Like steel windows of the time, many manufacturers of aluminum windows relied on the manner of construction and fit of operable units to minimize air leakage.
infiltration and did not rely on weatherstripping. However, a number of early aluminum window companies did place considerable attention on well-designed weatherstripping features. Stainless steel or zinc weatherstripping was used along with wool felt, pile woven fabric, and other materials. Measures were also taken to reduce friction between the sash and frame, including the use of “bumpers” to cushion against jarring metal when operating the sash. Wool felt and rubber were used for ease of operation, along with newer synthetic materials such as Duprene, a rubber-like material manufactured by Dupont. Continuous fins or receptors for the weatherstripping and bumpers were often included as part of the extruded sections of the sash and frame.

Hardware for aluminum windows drew heavily on that which was available for wood and steel windows. Spring balances and metal tape balances were popular for hung windows and placed in the frame, either at the head or jamb. For a sleek modern appearance, sash locks and lifts were available in white metal and chromed bronze to compliment the color of natural aluminum.

Glazing depended on the type of window. Traditional outside putty glazing was common. Integral muntins were standard for divided lights. As with steel windows, some aluminum windows featured inside putty glazing, which was particularly desirable in factories. Some commercial grade windows with inside glazing included the option of using glazing beads for a more finished appearance.

Various manufacturers also offered exterior insect screens with full-length tracks integral to the window frame. Others had full or half screens as separate attachments as well as full-length, removable, exterior aluminum storms.

**Early Finishes**

Aluminum windows came in a variety of surface treatments, including nonfinished, anodized, chemical conversion coatings, and painted (or lacquered). The most common finish used between 1920 and 1950 was a “nonfinish,” also called a “mill finish.” These terms are used for a bare aluminum surface with only its natural oxide patina, which forms upon exposure to air. This natural film was thin, transparent, tough, and to a considerable extent, protective. Nonfinish aluminum varied in appearance, depending on the fabrication technique. The surface could be smooth, highly polished, or brushed. It could have a patterned texture as well, created by casting, extruding, or machining. With time, the unfinished surface darkened and discolored, eventually turning a darker color, typically gray.

An anodized finish consisted of an extra thick coating of oxide film (from 0.05 to over 1.5 mils) produced in an acid bath by passing an electric current through the aluminum. The thickness of the coating was determined by the strength of the current and the duration of the treatment. The coating could be clear or integrally colored by adding pigments or dyes before it was sealed. Anodizing increased the resistance of the metal to corrosion and wear, and prepared the surface for other processes and coatings including paint. Although exceptionally resilient, anodized aluminum could still be damaged by harsh chemicals, abrasion, and abuse.

Such conditions usually affected only the surface finish and did not reduce the service life of the aluminum. In the 1930s and 1940s, this finish was used most extensively on naval aircraft, in particular on seaplanes, and was not readily available on architectural elements until the 1950s.

A third type of finish was a chemical conversion coating which consisted of a thin oxide, phosphate, or chromate film formed by chemical reaction on the bare surfaces of aluminum and aluminum alloys. The coating could be dipped, sprayed, or brushed on, its thickness varying by the dwell time. This finish was thinner and less abraison resistant than anodic coatings and was often used as shop preparation before painting. When a conversion coating was the final finish (without paint), it was typically clear or colored gold, gray, golden brown, green, or blue-green.
Unless the windows have been regularly maintained, excessive air leakage may be a problem. It can be accompanied by water leakage as well. Leakage is commonly caused by cracked perimeter caulking, missing or cracked glazing putty, cracked or broken glass, and worn, ill-fitting, or missing hardware. Such conditions are typical of long-term use and deferred maintenance. If the windows originally incorporated weatherstripping, most of this material would have exceeded its life expectancy and would now be worn, cracked, deformed, or even missing altogether.

Misaligned or deformed window sections can also cause air and water leakage. In investigating water infiltration around window openings, it is important to ascertain the actual source. Problems with the exterior wall rather than the window may manifest itself as moisture on the interior walls around window openings. Where windows have become misaligned over the years, it is common to find stopgap measures being used to reduce air and water infiltration, such as retrofitted weatherstripping or caulk. Such measures often only aggravate the problem and lead to further misalignment.

Moisture problems with the exterior wall also may affect the window subframe. Both steel and aluminum subframes may prematurely corrode where in contact with damp, porous brickwork and stonework. It is thus important to insure that the connections of the subframe to the wall and to the window frame are secure.

As with wood or steel windows, the most serious problems with the aluminum window frame and sash tend to occur where the units were originally undersized for the opening, have been subjected to intensive use and abuse or were of poor quality construction. Under such conditions, the windows may be racked or bowed and sections may even be bent or otherwise damaged.

continued on page 8
The U.S. Department of Justice Building, Washington, DC

Located within the 70-acre Federal Triangle complex in Washington, DC, the U.S. Department of Justice Building is a monumental structure spanning an entire city block. Constructed of limestone, the seven-story building includes five separate courtyards of varying sizes. The large windows along the outside perimeter and in these courtyards provide natural light and ventilation to the offices as well as help define the architectural character of the building.

Designed by the Philadelphia architectural firm Zantzinger, Borie and Medary, and completed in 1935, this classical revival style building reflected the architecture of existing buildings in the Federal Triangle complex. In a distinct departure, however, the extensive use of aluminum throughout the building, as both a utilitarian and a decorative metal, provided a showcase for federal architecture in the variable new uses of aluminum. Besides the 20-foot decorative entrance doors, aluminum was used for the interior stair railing, grills, doors, light fixtures, elevator cabs, and decorative artwork. In contrast to the steel windows commonly used in the federal complex, the 1,908 windows in the Justice Building were fabricated from aluminum. While it was $100,000 more expensive to use aluminum for features throughout the building, the architect justified the extra expense in terms of projected maintenance savings.

Nearly 65 years after construction, the Justice Building underwent major renovation work, starting in 1999, to update systems original to the building. During the renovation, offices were relocated within the building to accommodate the work. The project included the restoration of the original 1930s aluminum windows, which was undertaken in three phases and spanned a period of six years.

The predominant window type consists of a pair of outward swinging casements centered above a hopper that opens inward. A single row of fixed lights flank the operable hopper and paired casement windows. Depending on the floor level and location, the individual windows had either a single or double row of fixed lights above the casement or none at all (Figure a). Windows with a single row of fixed lights at the top measured approximately 10'-2" by 5'-5". Overall, the aluminum windows emulate the appearance of traditional steel windows and include true divided lights. The aluminum sash and frame have a mill finish that has weathered on the outside to a gray color.

Window Survey

A window survey was first undertaken to record the condition of each window and to inventory the hardware, fasteners, and missing frame pieces. Although the windows retained a high degree of historic integrity, some changes had been made over the years. To allow for the installation of ventilation louvers or window-mounted air conditioning units, over 400 of the hoppers below the casements had either been removed or had been rendered inoperable and the wide vertical muntin removed. Although the historic windows were not designed for weatherstripping, some of the windows had been retrofitted with weatherstripping to reduce air infiltration as a result of worn hardware or deflections in the operable units. At various times, caulk had been applied to set in replacement glass or to fill in unwanted gaps. Areas of surface deterioration were also evident including discoloration and varying degrees of corrosion and pitting.

Figure b. The panes of glass were secured into the frame with aluminum glazing stops, each individually cut, drilled, and fixed in place from the inside. Here the vertical stop is in place while the horizontal is missing.
The renovation plan called for cleaning the aluminum window parts, replacing the existing glass and any missing or damaged parts, and making the historic windows fully operable again. Mock-ups of all phases of the work were required early on to establish the work standard to which the finished job would be held. It was anticipated that most of the work could be done in place, with work on the interior and exterior portions of each window done simultaneously.

**Abatement**

Early testing of the original glazing compound showed varying levels of asbestos. As a result, an abatement team was brought in to remove the metal glazing stops which secured the glass in place, dislodge and dispose of the glazing compound and existing glass, temporarily reinstall the glazing stops, and provide temporary protection over the unglazed window openings. Since each of the original metal glazing stops had been individually cut, drilled, and fixed in place when the glass was installed and were not interchangeable, it was important that each stop be returned to its original location. Thus, as each pane was abated, it was specified that the glass stops were to be put back in the same location and secured with mechanical fasteners (see Figure b). For the duration of the removal, 6-8 crews worked at once. Each crew was to complete one window bay each day.

**Cleaning**

After the glass was removed, the aluminum frames and muntins were thoroughly cleaned on the inside with an aluminum jelly cleaner, pumice, and scouring pads, when needed. The aluminum was then rinsed to remove the cleaner residue (Figure c). For the exterior surfaces of windows that were more heavily corroded, the aluminum restoration company proposed a more aggressive chemical cleaner be used. This necessitated that the surrounding limestone surfaces around each window be well protected. During a mockup cleaning exercise, this chemical cleaner proved too acidic, difficult to control, and damaging to the adjacent stone. After testing some alternate products, the team found that a diamond abrasive pad used in combination with the Duro Aluminum Cleaner in jelly form, worked the best. Special care was still necessary to protect the surrounding limestone.

Some of the windows had areas of surface delamination. In such cases, the deteriorated surfaces were first ground down to remove the delamination and then cleaned as described earlier.

**Hardware**

The hardware used on the aluminum windows was similar or the same as used on comparable steel windows of the time. The hardware consisted of nickel bronze, brass, steel, or a combination thereof. Each of the individual casements was attached to the mullion with three hinges along the side. Fastened to each casement along the bottom rail and at the frame, casement adjusters permitted each unit to be fixed in various open positions. To secure the casements closed, a cremorne bolt extended vertically at the intersection of the two casements.

To permit the hopper to be opened inward for ventilation, it had a handle attached to the center of the top rail with a corresponding keeper at the frame, matching hinge arms that secured the side of each rail, and pivot hinges along either side at the bottom.

Each piece of hardware was inspected for wear or damage. A number of the casement hinges were cracked or broken, which contributed to the malfunctioning of the operable sash. Deficient ones were replaced with new, matching hinges.

Handles, adjusters, and cremorne bolts were cleaned, repaired, and lubricated as needed. Worn or redundant screw holes were filled in. Where hardware was missing or damaged beyond repair, original parts were salvaged from less significant areas, such as the basement and attic, for use on windows in more significant areas.

It was also necessary to reproduce some of the missing hardware for use on the primary floor levels. For secondary locations, it was possible
to purchase currently available new pieces that were similar but not exact matches. Some of the original hardware finishes were difficult to match but satin sanding and tumbling often brought the reproduction hardware closer to the historic appearance.

It was decided early on that the mechanical fasteners, which included primarily aluminum but also some brass screws, would largely be replaced because of their age and condition. Some were unique in size and shape, and had to be specially made.

**Extrusions**

Sections of the window frames had been removed or cut away to allow for various alterations over time, including the installation of window air conditioner units and ventilation louvers. Some original pieces were found in the attic of the building and were subsequently reused.

An aluminum company reproduced the vertical muntin that historically existed in the hopper unit but was missing from numerous units. After the muntins were cut to size, each was slotted at the end and fitted into the hopper frame, and then welded at the tip. The same company also made custom extrusions for the rails and stiles of the hopper units for use in fabricating entire hoppers where missing (Figure d).

**Additional Repairs**

Most of the repair work was done on site. Units that needed to be completely reconstructed (less than 5%) were moved to a welders shop. Where areas of severe corrosion on the exterior of the windows were encountered, Lab-Metal, a high temperature repair epoxy, was used to fill voids and to build-up surfaces to their original outside dimensions. Because the windows were generally in good condition, the use of epoxy fillers was not widespread.

In very limited areas on the exterior where severe delamination had occurred, the flaking aluminum was removed, epoxy applied to even the surface, and then an aluminum flat bar was attached with stainless steel screws to re-establish the original profile.

**Replacement Glass**

After the windows had been cleaned and repaired, new glass was installed from the inside. Unlike the original glass, 6.4 mm laminated glass was used as a replacement, providing the additional qualities of shatter resistance and enhanced energy performance. The laminated glass consisted of an outer layer of clear, heat-strengthened glass with a Low-E coating and an inner layer of fully tempered glass. A contemporary glazing tape was used instead of glazing compound to seal the glass and the aluminum glazing beads were affixed to the inside with screws to secure the glass. It was necessary to purchase additional aluminum glazing bead to augment historic beads that could not be reused.

**PROJECT DATA**

**Owner:**
General Services Administration

**Project Manager:**
Gilbane Building Company, Washington, DC

**Window Contractor:**
Clyde McHenry, Inc., Hyattsville, MD

**Aluminum Cleaning and Finishing:**
Atlantic Refinishing & Restoration, Inc., Waldorf, MD

**Hardware Supplier:**
Blaine Hardware Inc., Hagerstown, MD

**Glass Supplier:**
Northwestern Industries, Inc., Seattle, WA

**Project Date:**
1999-2005
Factory windows and residential windows of very lightweight construction were most prone to such problems. On many buildings, however, such conditions are uncommon or are limited to only some windows.

More common are instances where sash have been damaged as a result of previous retrofits of either mechanical vents or window air conditioning units. Such installations may also have resulted in the removal of one or more muntins to accommodate these units.

While interlocking seams were found on some early aluminum windows, units were normally assembled using mechanical fasteners and welded joints. Operable units that were primarily welded together tend to have been higher quality windows and are generally found in better condition than windows that were mostly fastened together with screws, bolts, or rivets. Machine screws may have a tendency to loosen over time, which can contribute to various problems that require remedial work.

In assessing the condition of the sash and frame, any flanges and receptors for weatherstripping that were extruded as part of the sash or frame should be examined, as some sections may have been damaged over time. Aluminum glides or stops for operable sash also need to be checked to determine whether they are bent, gouged, corroded, or painted. These conditions could impede the ease of operation of the sash.

Other problems that can affect the operability of the window include broken balances, corroded and broken hardware, misaligned or loose hardware, and windows that have been later sealed or painted shut.

While aluminum is resistant to most types of corrosion, it is affected by certain agents such as alkalis, hydrochloric acid, and lead-based paints.

While considered a durable building material, aluminum does deteriorate. It is subject to corrosion when wet and in contact with certain alkalines, such

built in 1966 by the Chicago Housing Authority, the Raymond M. Hilliard Center was originally a public housing complex of five buildings with 710 apartments located south of Chicago's downtown loop. Designed by Bertrand Goldberg, it is acclaimed for both its mixture of elderly and family housing and its modern "new-expressionist" architecture. Of special note are the 2,300 window openings of a modified ellipse shape with the bottom and top curved segments compressed into straight parallel edges, set into the concrete walls of the tower buildings. These openings have been described as "television sets," "beehives," and "airplane windows" (Figure b). The windows are a combination of two rectangular aluminum horizontal slider sash with flanking radial fixed panes. Each flanker is set back at an approximate 22.5-degree angle to the outer face of the center units, conforming to the curved outer wall (Figure a).

Problem

Early on, the private developer, Holsten Real Estate Development Corporation, committed to rehabilitating the Hilliard Center for continued use as mixed-income housing. They recognized the importance of the original aluminum windows and sought to preserve as many as possible. Distinctive in their configuration and form, the windows, however, were light residential units manufactured with affordability in mind. They had thin aluminum members, lacked drip edge or weeps to direct water away from the openings, and, typical of the time, were only single glazed. There were provisions for insect screens but not for storm windows.

Nearly all of the original windows had survived 40 years of Chicago's harsh winters and numerous abuses from high-density occupation. The architect completed a condition survey of 120 typical windows and found that 61% of the windows lacked the original glazing (replaced with Plexiglas or similar material), 31% had damaged operating sash, 29% were boarded up with damage to the frame, 25% were missing their original operating glazing sash, and 71% were missing screens. Only 15% of the windows had no visible defects.
Solution

The decision was made to save the historic windows for the first four floors of the towers, since they would be most visible from the ground. Units on the first four floors in bad condition were to be replaced by windows in better condition relocated from above floors. Matching aluminum replacement windows were to be installed on the upper floors.

The window survey provided an overall view of the necessary repair work to the historic units. There were standard components within each of the different window types and the aluminum had proved durable where not abused. Thus it would not be necessary to replace large numbers of the entire window assembly within each bay on the lower floors. The windows could be repaired, utilizing parts easily salvaged from other units within a building to replace worn-out or missing ones. In the total project, 336 original windows were to be repaired and 2,016 to be replaced.

Figure d. Both the interior and exterior faces of the window are set back on a slight reveal in the wall. The curved portions of the windows are fixed while the central rectangular section is fitted with sliding sash. Rivets secured the flanking to the window assembly. (Drawing: Holsten Real Estate Development Corp.)

Disassembly and Salvage

Windows on the upper floors that were in good condition were marked for salvage and then taken to the repair shop in the basement. There they were sorted and stacked by size and by their original inside or outside position in the window track.

For the window repair work on the lower four stories, a portable shop area was created on each floor. Here the crew assembled a gang box of their tools to be used: 6" metal bender, reciprocating saw, chisels, screwdrivers, scrapers, wire brushes, drills, acetylene torches, caulk, and caulking guns.

Most of the frames could be repaired in place. In areas where the frames were to be removed and replaced, a reciprocating saw was used to cut the rivets holding them in place. A 1/8" space adjacent to the frame was needed to accommodate the blade to cut the rivets. When the frame was too tight against the concrete, a 6" bender was used. This work was done from the inside of the window both for convenience and also not to damage the exterior finish of the unit. The mastic that held the window frame to the continuous aluminum closure piece was also cut away. Once loose, the frames could be grabbed on both ends and lifted out of the opening.

One of the more time consuming aspects of the project involved the radial flankers. Many of these historic window units were broken and had been caulked together in a repair effort. Due to age and stiffness, it was necessary to first heat the sealing gasket for the glass with a small acetylene torch. The gasket could then be removed from around the frame, thus freeing the broken glass for disposal. Typically this involved the handling of a number of broken pieces of glass and subsequently took a great deal of time to clean it down to the raw opening.

If the frame for the flanker unit was to be removed, rivets securing the unit were cut at both ends and the unit lifted out (Figure d). At this point, the only remaining window piece in the opening was the aluminum subframe to which the window frame was attached. Set within the concrete walls, the subframe was left undisturbed.

Salvaging parts from upper level windows saved considerable money. This was particularly the case where entire operable units were taken intact and reused from upper floor units. As a result of salvaging parts, no new parts were needed other than items such as rivets and weatherstripping. Even latch mechanisms and locks were salvaged by first removing the old rivets and then cleaning and reattaching them as needed.

Cleaning Procedure

Over the years many attempts had been made to make the windows
operate better. As units became worn, loose, or deflected, pieces of weather-stripping were added between the sash and sash tracks to better seal out the cold. Metal plates were added to the bottom of the operable sash to enable it to better slide in the channel and caulk was applied to close up unwanted openings between the glass and the frame, as well as to repair broken pieces of glass. Residual dirt, putty, grease, and paint coated many of the window units.

The aluminum surfaces needed to be cleaned and taken back closer to their original appearance. Because of the effect of weathering and use, it was considered acceptable in this project to use certain cleaning techniques not normally recommended for more ornamental architectural aluminum. A common chemical cleaner and/or denatured alcohol were used to remove the general residue on the aluminum. Wearing rubber gloves, the crew wiped on the cleaner with a damp cloth, allowed it to stand for 3-5 minutes, and then wiped it off with a clean damp cloth. Scouring pads and scrapers were sometimes used on more encrusted areas, as needed. The removable sash units were cleaned in the basement shop, while any frames that remained in situ were cleaned in place (Figure e).

**Repair and Reinstallation**

Some window units were in such good condition that they only needed to be cleaned, with any minor repairs being made at the same time. Others required more substantial work and were sent to a separate workstation after cleaning. Repairs varied from replacing or resecuring any loose screws holding the sash frame together, to realigning pieces by bending or reforming. All the sash hardware was cleaned, lubricated, and then reattached.

There were a sufficient number of operable sash with existing glazing and frames in serviceable condition that they could be used for the entire lower four floors. Such was not the case with the flankers where 50 pieces of glass costing a total of $1,300 had to be ordered to augment what existed. Before the new glass for the flankers could be installed, a template in the shape of the radial opening was made and then taken around to various openings where glass was to be replaced. Adjustments to the shape were made as needed in an effort to get the best-standardized shape. The new glass was custom ordered and delivered to the on-site shop for installation.

When reinstalling window units, care was taken to ensure correct alignment. This was particularly important with the operable units to guarantee a good weather tight seal when closed (Figure f). New screen windows were installed as part of the final completion work.

**PROJECT DATA**

**Owner:**
Holsten Real Estate Development Corporation, Chicago, IL

**Project Date:**
2001-2004

**Architect:**
Liseck & Biederman, Ltd., Architects and Planners, Chicago, IL

**General Contractor:**
Linn-Mathes Inc., Chicago, IL

**Glass Contractor:**
Tortensen Glass, Chicago, IL

**Window Screen Supplier:**
Commons Manufacturing, Chicago, IL

**Project Cost:**
The cost for window repair, including both labor and materials, totaled $1,486 per window. The cost for a new aluminum unit ran $1,700 per window.
as concrete, mortar, and plaster. Some forms of wood, wallboard, lead-based paints, and insulation materials may also attack aluminum. Particularly important, acid-based chemicals used to clean masonry surfaces can also corrode aluminum.

Aluminum is also subject to damage by galvanic action when in contact with certain dissimilar metals such as copper and steel. Nonconductive materials like paint or mastics are needed to electrolytically insulate the metal. This was a common procedure where steel was used as the subframe for aluminum windows.

Aluminum and any protective oxide films and finishes are also subject to deterioration caused by air-borne abrasives. Certain air pollutants, dirt, sand, and high humidity work to break down the protective finishes. When combined with a low priority maintenance program, they will shorten the life span of an aluminum window.

Understanding the variety of aluminum alloys, tempers, finishes, and treatments used historically is important to uncovering the specific causes of deterioration and to developing sound conservation approaches. Visual examination can help determine or confirm production finishes. Simple tests using a steel needle or a rubber eraser in a small area can preliminarily identify finishes. Laboratory analysis can also be used to confirm alloys, tempers, and coatings but often require the removal of window sections and destructive testing.

Cleaning

Aluminum windows can benefit from periodic cleanings. Even a simple water wash can cut down on the accumulation of surface dirt and pollutants.

A mild soap and water may be safely applied to any aluminum finish.

The effect of different chemical cleaners on aluminum depend on many factors, including chemical concentration, dwell time, and temperature, as well as the aluminum alloy type, production method, surface finish, and coating. The Care of Aluminum, a technical guide published by The Aluminum Association, provides useful information on the maintenance of aluminum, including the cleaning of surfaces and

Figure 10. The shine and luster of an aluminum window with an original mill finish was a perfect compliment to the stainless steel exteriors found on 1940s/1950s diners. The Hollywood Diner is an authentic Mountain View Diner built in 1954. It first operated in Westbury, New York and was later moved to Baltimore, Maryland. In the 1980s it was the location site for several Barry Levinson's films including "Diner." Most of the original windows remain in this building.
application of watertight protective coatings.

The Association's technical guide lists five categories of aluminum cleaners: 1) mild soaps and detergents, and non-etching cleaners, 2) solvent and emulsion cleaners, 3) abrasive cleaners, 4) etching cleaners, and 5) special heavy-duty cleaners. In dealing with historic materials, the gentlest means possible should be used to clean aluminum windows. More aggressive cleaners should be used only where necessary.

The goal of cleaning is not to return the aluminum to an "as good as new" look, but rather to remove harmful deposits and, where appropriate, improve the existing appearance where corrosion or deposits have significantly altered the historic appearance.

In many cases of deferred maintenance, abrasive cleaning methods appropriate for aluminum will be needed to remove surface oxidation and heavy encrustation. These cleaners come in different forms, such as polishes, metal brighteners, and powders. Only certain mild abrasives should be considered for anodized, painted, or chemical conversion coatings to avoid damage to the finish. With nonfinish aluminum, abrasive cleaners may be used in combination with fine stainless steel wool or abrasive nylon pads, depending upon the need and the results of cleaning tests. Alternatively, etching cleaning may be used instead on nonfinish aluminum, again depending upon test results. When other means are unsuccessful on nonfinish aluminum, medium abrasive cleaners or mechanically driven pads of fine steel wool or abrasive nylon can be considered in limited cases. Special care must be taken to protect the glass. These more aggressive cleaners and methods should not be used simply for expediency when more gentle abrasive cleaners are also effective.

Spot tests should always be performed beforehand to determine the suitability of any application to an existing finish. Regardless of the type and strength of any required cleaner or its form of application, it is important that all cleaned surfaces be thoroughly rinsed and wiped dry.

A cyclical program of cleaning using a gentle method will help maintain a newly cleaned finish. Clear lacquers or waxes can be applied to nonfinish, anodized, and conversion-coated aluminum to help protect the newly cleaned finish as well. A clear lacquer application (sprayed or wiped on) will preserve the appearance of cleaned aluminum for an appreciable time. Wax offers a shorter protective life and will require frequent reaplication. In cases where the anodized finishes have failed and cannot be restored through cleaning techniques, painting may be a suitable option.

**Common Repairs**

Early residential and commercial grade aluminum windows share various common maintenance approaches and repair techniques. However, repair approaches must be tailored to the specific project. For example, when working with early heavy-gauge aluminum windows that emulated steel

---

Figure 11. Aluminum windows were described as a perfect choice for Lustron Homes because of their modern appearance and ease of maintenance. Along with the porcelain-enamel steel exterior wall panels, the manufacturer claimed that the only cleaning and maintenance materials required for a Lustron Home were "soap, water, and a damp cloth." Today, cleaning is recommended for any historic aluminum window as part of a cyclical maintenance program.

Figure 12. Cleaning tests may include a variety of products and methods such as mild soaps and detergents, etching cleaners, and abrasives. The gentlest means possible should be used, understanding that the goal is not to create a like-new appearance but rather to remove excessive grime and surface pollutants. Use of heavy etching cleaners or heavy-duty abrasives should be avoided on certain historic finishes. In this photograph a mild etching cleaner in jell form is being tested on a storm window with a mill finish.
window design and construction, many of the common repair procedures for steel windows can apply. However, it is important to take into account that aluminum is a much softer material and greater care must be taken to avoid surface damage.

As with any old window, certain precautions should be taken before undertaking repair work. While aluminum windows generally were designed not to be painted over time, lead paint may have been used in subsequent years to refresh the appearance, particularly on the inside. Tests for the presence of lead paint and also for asbestos in the glazing compound should be undertaken and any remedial work completed as required.

For windows that have not been regularly maintained, any original weatherstripping, if present, will probably need to be replaced. The options for installing replacement weatherstripping depend partly on how the window was originally weatherstripped. It could have been set in channels or grooves or more simply surface applied. Whether to use traditional weatherstripping or contemporary synthetic products is a decision that can only be made by understanding how the weatherstripping was integrated into the existing window and what materials are available today. Because of peculiarities of some early aluminum windows, it may be necessary to explore potential sources of weatherstripping not normally considered for windows, such as from the broader building industry or transportation field.

Where weatherstripping was not an integral part of the original window, caution should be taken not to install weatherstripping in a manner that will stress either the hardware or the window over time. Like most traditional steel windows, good quality, historic aluminum windows relied on tight alignments and proper fitting of operable parts to minimize air infiltration. When repaired and properly aligned, it may not be possible or necessary to retrofit weatherstripping. In most cases, weatherstripping should not be used to close gaps attributed to distortions around the operable window, as this will only exacerbate the problem. Rather the distortions or misalignments in the sash or frame should be corrected. New weatherstripping should be installed in a manner that is easily reversible, considering that the material will in the future need to be replaced.

It is common to find that the glazing putty is cracked, loose, disintegrating, or largely missing. This is primarily attributed to the age of the material and subsequent lack of proper maintenance. The old putty will need to be cleaned out, taking care to protect any glass that is to be reused. This is particularly important with old wire glass and certain patterned glass that is not available today. Where windows are inside glazed using aluminum beads, care should be taken in removing the beads, when in good condition, so that they can be reused. Since glazing beads may not be interchangeable even within a single window, it is important to mark each piece for reattachment in its original location. When reglazing, a glazing compound suitable for metal should be used. Glazing tape and other contemporary glazing products can be used as appropriate, provided the appearance of the glazed lights is not changed.

Some early aluminum windows were designed to accommodate either single or dual glazing (see Figure 10). With some heavy gauge aluminum windows, it may be possible to retrofit insulating glass even where dual glazing was not an original option. For enhanced energy performance, an alternate approach that is more commonly used involves replacing the existing glass with new laminated glass that includes a Low-E coating or film for enhanced energy performance.

It is important to inspect the mechanical fasteners that secure the frame to the opening and any that were used to assemble the window. Loose fasteners
will need to be tightened and deficient ones replaced with screws appropriate for use with aluminum. Welded joints that have failed should be re-welded and any cracks in the frame repaired.

**Missing or Damaged Sections**

Techniques for repairing missing or damaged sections of aluminum windows vary according to the type and quality of the historic units. One approach is to cannibalize units that will be replaced. Damaged pieces of the frame, sash, or sill can be detached by removing fasteners or cut out. Salvaged pieces can then be reattached with traditional fasteners, welded in place, or secured with contemporary bonding material. Filler material, especially made for aluminum, can be used to fill holes and, depending upon the makeup of the window, to fill depressions caused by abuse or delamination.

For larger projects involving common missing sections, such as muntins that have been cut out for window air conditioning units, a custom extrusion can be made to match the shape and profile of the missing pieces. These pieces can then be cut and welded in place. Entire units can be replicated where sufficient quantities merit the expense of such custom work. For small projects, it may be possible to have a machine shop mill the missing pieces from standard aluminum stock.

**Hardware**

A wide variety of hardware is found on older aluminum windows, including locking handles, lifts, balances, sash chains, hinges, fasteners, and casement operators. Most existing hardware will need to be cleaned and lubricated. In many cases, this requires removing the hardware to do the work and reattaching each piece in its original location, after the work has been done. When present, worn sash chains can be replaced with new ones that match the original ones.

For severely worn, broken, or missing hardware, several options exist. Specialty hardware companies may stock matching replacement or reproduction pieces. Original hardware can be duplicated or suitable replacements may be available from salvage companies. Similar hardware can be used where functional rather than visual match suffices. Alternatively, original window hardware can be taken from secondary locations within a building for use in more prominent areas, and stock new hardware used as a substitute in the secondary locations.

When retrofitting existing aluminum frames with insulating glass, special care should be taken to insure that older hardware can handle the added weight.

---

This Preservation Tech Note was prepared by the National Park Service. Charles E. Fisher, Technical Preservation Services, is the Technical Editor of the Preservation Tech Notes series. Information about the U.S. Justice Building was generously provided by Clyde McHenry of Clyde McHenry, Inc., and Cathy McIntyre and Mike Ragan of the U.S. Department of Justice. Information on the Raymond M. Hilliard Center was generously supplied by Peter Holsten and Andy Hestness of the Holsten Real Estate Development Corporation. Thanks are also extended to Charles Fisher and Rebecca Shiffer of the National Park Service for their review and assistance. Thanks also go to The Aluminum Association; Edward Bartlett, Custom Window Company; Sam Wharton, Fenestra, Inc.; and Alex Paolucci, Atlantic Refinishing & Restoration Inc., for their assistance. Unless otherwise noted, photographs are by the author.

Preservation Tech Notes are designed to provide practical information on traditional and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act, which directs the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to Preservation Tech Notes, Technical Preservation Services, National Park Service, 1849 C Street NW, Washington, DC 20240.

ISSN: 0741-9023

PTN-51

May 2008
MERGENTHALER LINOTYPE BUILDING

Chicago, Illinois

The Mergenthaler Linotype Building is a six-story printing loft building located in the South Loop Printing House National Register District in Chicago. The masonry building was constructed in 1883 and altered in 1917 with the addition of steel multipane hopper windows on the side and rear elevations. Recently renovated, the building now has residential condominiums in the upper stories and commercial space on the first floor.

The historic steel windows on the otherwise plain secondary elevations are a significant architectural feature, clearly visible from the street. The 15 large 20-light windows on the side of the building measure 6' wide by 7' high with a center-pivoting hopper, while the 9 smaller 12-light windows are the same height but only 3'9" wide. On the rear elevation, there are an additional 38 steel windows of 15 lights, measuring 3' by 7'. The individual lights are 14" by 20", a size common to pre-World War II steel sash.

During the renovation work on the building, the windows were repaired at the site and insulating glass was used in place of the existing single panes to

Many late 19th and early 20th century historic sash can be made more energy efficient through addition of insulating glass — an approach that should be considered before installing replacement sash.
improve the energy performance of the windows and the marketability of the condominium units.

Window Problems

The architect for the project, Kenneth Schroeder, AIA, with the Chicago firm of Kenneth Schroeder and Associates, was confronted with a series of problems in dealing with the steel windows. As is commonplace, lack of routine maintenance had led to rusting and mild corrosion of portions of the windows. Some of the sections, especially the hopper units, were bent, bowed or racked and a number of the 1/4" wire glass panes were broken.

In converting the building to residential use, ways of improving the thermal comfort of the occupants were explored and cost-effective means were studied for reducing energy consumption. Furthermore, a design had to be selected for additional windows that needed to be created in order to satisfy air and light requirements for the new use. Four possible approaches to the windows were examined:
- repair and repaint the existing windows;
- repair existing windows and install insulating glass;
- replace existing windows with custom-made, double-glazed steel sash; or
- remove existing units and install new aluminum double-hung thermal sash.

The following were specific considerations in assessing the four window alternatives:
1. Any window alteration would have to be compatible with the historic character and configuration of the existing steel windows.
2. Work on the windows beyond repair and repainting—including the possibility of all new replacement units—would have to be cost-effective in terms of increasing the marketability and value of the condominiums.
3. The existing wire glass would have to be replaced with clear glazing since the wire glass was considered inappropriate for the new residential use.
4. Any work on the windows would have to be accomplished within a tight time schedule.
5. Addition of screening was desirable but not critical because the downtown area was not particularly insect-prone.

Of the four possible window treatments, the two replacement options—custom-made steel sash of a matching design, and bronze anodized aluminum double-hung sash—were too expensive for the project; the latter was less expensive but still cost on the average between $400-450 per window. Furthermore, the use of double-hung sash in the large openings would have changed the historic character of the building.

For the required new window openings, a manufacturer of steel windows was located who offered a stock unit similar to the original design but with noticeable differences in the horizontal proportions and overall dimensions. These stock units were significantly less expensive than the custom steel windows and were selected for use in new openings since they were compatible with the heavy commercial style and character of the historic windows.

Figure 1. Insulating glass was installed without changing the appearance or operation of the steel window. Drawings: Martha L. Werenfels
Window Rehabilitation Solution

The decision to repair the existing windows was based largely on the costs involved. Reglazing the windows using 3/8" insulating glass, ran approximately $12 per double pane, while reconditioning the frames and hardware and repainting added another $50-75 to the average cost of each window. The average cost of $250 per window for this work was significantly lower than any of the proposed replacement units, and most of the repair cost was a result of the reglazing.

Only about half of the glazing cost was directly attributable to the use of insulating glass since from the outset, the residential use of the building tended to dictate from a marketing perspective that the existing wire glass be replaced. Thus it was decided that in lieu of only repairing and reglazing with clear 1/4" glass, which would have been the cheapest of the four identified window options, sufficient benefits could be derived by using double glazing to improve the window's energy performance (see figure 1).

In deciding what type of glazing to install, the depth of the T-shape muntin bar was a constraining factor. Since at least the 1930s, companies have been manufacturing double-glazed steel windows. In such cases, however, the depth of the muntin bars was usually greater than the 1/4" found on the windows in the Mergenthaler Linotype Building. By using 3/8" glass instead of the 1/4" wire glass, it was possible to use insulating glass in the existing windows, though an optimum distance between the double panes in terms of energy performance could not be obtained.

Thus it was decided that the cost of double glazing alone was justified considering the advantages derived from increased energy performance and reduced likelihood of condensation forming on the windows despite the new residential use. The double glazing also created no significant weight problem since 1/4" wire glass was being removed.

Preparation and Cleaning Work

After the metal glazing angles and glass were removed, the old frames were scraped off and existing paint layers and rust were removed using sand under air pressure. After cleaning, sections from several old windows that had been removed were welded into the remaining windows to replace missing...
or deteriorated metal pieces. At the same time, racked metal sections, especially the center-pivoting hopper units, were realigned by applying heat and pressure. All the metal was then painted with an anti-corrosive paint.

**Glazing and Hardware**

The original wire glass had been held in place by glazing angles bolted to the muntin bars. In removing the glass it was decided, due to deterioration of the glazing angles and the labor-intensiveness of reinstallation, that new spring glazing clips and steel sash glazing compound would be used instead (see figure 2).

The insulating glass had been delivered to the site, vacuum sealed and with a continuous glazing edge. After the bed putty was applied to the sash, the insulating glass was installed with glazing clips and face putty.

New replacement handles and chains were readily found for hopper units where such pieces were broken, deteriorated or missing. After the windows were painted and caulked, there still was air infiltration around the hopper units, so adhesive-backed foam was added as weather stripping around the hopper unit.

**Project Evaluation**

There were no real unforeseen problems with the window work and the job was finished on time and within budget. Screens were not added to the windows although it would be possible to do so if individual residents felt there was a need. Condensation on the windows has not been a problem due to the use of insulating glass; reduced air infiltration after repair; caulking and weather stripping; the presence of a good heat source near the windows; and the southern exposure of the large windows.

On the whole, the reconditioned windows are performing well and are providing the desired improvements in personal comfort (see figure 3). There was no real problem in marketing the condominiums and residents have capitalized on the interior design opportunities provided by the large windows and the loft space.

The Mergenthaler Linotype building rehabilitation has shown that the repair and upgrading of historic steel windows can improve energy performance in a cost-effective manner and that the light on the interior space from the large thin frame steel sash can be an amenity in residential conversions of loft buildings. Similar rehabilitation projects have shown that there are a variety of ways—both traditional and innovative—to preserve the character and design of historic steel windows and to have them function satisfactorily.

**PROJECT DATA**

**Building:**
Mergenthaler Linotype Building
531 South Plymouth
Chicago, Illinois

**Developer:**
Harper Realty
134 South LaSalle Street
Chicago, Illinois

**Project Date:** 1979

**Architect:**
Kenneth Schroeder, AIA
Kenneth Schroeder and Associates
714 South Dearborn
Chicago, Illinois

**Project Costs:**
The average cost for repairing each window, installing insulating glass, reconditioning the hardware and finishing was $250.
LYNDHURST GATEHOUSE
Tarrytown, New York

The two-story stone gatehouse on the grounds of the Lyndhurst Estate in Tarrytown, New York, is part of a National Historic Landmark that was once the home of railroad magnate Jay Gould. The property is owned today by the National Trust for Historic Preservation and is open to the public. Built in 1864, the South Gatehouse is used as a private residence for a caretaker.

The windows, with ashlars surrounds on the first floor and decorative wood detailing on the second, are prominent features of the building. The original double-hung wooden windows, with two-over-two pane configuration, have survived in relatively good condition. The 13 windows in the gatehouse are of five different sizes; all but one have an arched head in the upper sash and a thick vertical Mullion with a center bead.

The windows on this structure were fitted with custom-made exterior storm windows that meet specified performance criteria and yet minimize both damage and visual obstruction to the historic windows.

Design Problem
In many buildings where the historic windows are significant and will be preserved in the rehabilitation project, the installation of storm windows for energy conservation can require innovative features or some adaptation to standard window designs. This may be necessary in order to minimize damage to historic fabric and to preserve the visual qualities of the historic windows.

Such an approach was taken in the rehabilitation of the South Gatehouse windows at Lyndhurst. As guidance, the following criteria were established beforehand for designing the new storm windows:

1. The new design had to be sympathetic with the historic character of the building.
2. The windows needed to remain operable to allow for ventilation and also for use as possible fire exits.
3. Energy conservation objectives had to be met.
4. Only minimal damage to the historic windows could occur in mounting the storm windows and inconspicuous hardware had to be used.
5. Provisions had to be made for insect screens.

Design Solution
A storm window was subsequently developed that meets all of the above requirements. The storm window, in the style of a single casement, was installed on the outside of each of the historic win-

Physical damage and visual changes to historic windows should be minimized when installing exterior storm windows.
dows and attached to the existing frame (see figure 1). The arched-headed wooden storm window with one-over-one glass panes matched the size of the original double-hung sash. Molding details similar to the original were incorporated in the new storm sash. Each of the two panes in the storm sash was set in thin aluminum frames and secured in the wood storm window with standard clips. This installation technique enables the storm panels to be easily removed by a person on the inside of the house and replaced during the summer with screens (see figure 2).

Mounting hardware consisted of pin-in-socket hinges which required the drilling of only two holes in the existing frame (see figure 3). The hinges allow the window to open casement-style for egress and ventilation purposes.

Measurement and Fabrication

Each of the window openings was measured and dimensional irregularities identified. The distance from the sill to the bottom of the historic meeting rail was also measured so that a corresponding muntin on the storm sash could be fabricated.

Depending on availability, one inch thick white pine and cypress were selected. Lumber was milled to proper dimensions in the shop facilities on site. The rails and stiles were cut to length with allowances made for the curvature of the window arch.

In making arches for the five windows, a template of Masonite was first made for each. By fitting the template to the historic arch, it was then possible to trace the top of each on a piece of 5½” wide pine or cypress to make the top rails for each window.

Dowels were used to join the rails and stiles. Two holes for ¾” by 2” dowels were drilled for each joint with the exception of the top rail. For the arch, only one hole per joint was made due to the lack of space.

Before the windows were fitted together, the inner moldings on the rails and stiles were cut on the shaper to match the 9/16” quarter round molding on the historic sash.

Assembly

In fitting the windows together, the parts were glued at the joints with resorcinol glue, dowels inserted, and the clamps attached while the glue hardened overnight (see figure 4). After the joinery was completed, the tops of the stiles were cut to fit the curvature of the arch. For the first floor windows, a 5/8” by 9/16”

Figure 3. The only feature of the storm window that required expensive custom work was the pin-in-socket hinges (bottom one shown in photograph). Commercially available hardware could have been used; however this project sought to minimize physical damage to historic woodwork and thus tested a prototype design. Stainless steel was used for reduced maintenance costs. Photo: Richard Bierce, AIA
rabbet was cut along the outer edge to allow the window to fit over the existing moldings on the historic window frame.

The windows were then fitted to each opening and bottoms planed to a slight angle corresponding to the sill. Two weep holes were cut in the bottom to allow condensation to escape, and the windows were permanently labeled as to their location in the building.

Custom-made stainless steel hinges of a pin-in-socket design were attached to the left side, top and bottom, of each window. The windows were then sanded, treated with a non-toxic preservative, and primed with an oil-alkyd paint.

Inserts

The two aluminum-frame storm inserts for each window were constructed of moldings cut on a mitre. The top pane of glass was cut to follow the arch of the top rail, and the units were then assembled and labeled. Screens were cut and assembled in a similar manner. The aluminum frames were roughened with sandpaper, and painted with two finish coats. After the paint had thoroughly dried, the storm inserts were installed with small aluminum hold-downs on the inside of each window.

Final Installation

In hanging the windows, 3/4" holes were drilled in the sill and the top of the historic window frame to accommodate the stainless steel anchor. The holes were thoroughly soaked with the same wood preservative used on the sash, then filled with a polysulfide caulk before the anchor was inserted. After the windows were installed, 1 inch hook-eyes were attached to secure the windows shut while a second hook-eye, 1 foot long, was installed on each window to hold it in a fixed position when opened (see figure 5).

Project Evaluation

The storm window used on the gatehouse incorporates several desirable design features. It is a successful preservation solution by maintaining the arched head of the windows; proportioning the framing members along the basic lines of the primary sash; matching the materials of the historic window and avoiding damage to historic fabric. The casing design does not impede use of the windows for emergency egress, and the panel inserts set on the inside of the storm frame provide a convenient seasonal change from storm to screen units without relying on obtrusive multiple-jamb tracks. While the custom hardware is perhaps a luxury feature, for economy purposes standard hardware could have been substituted. The storm windows, moreover, are detailed so that almost any local mill could easily make them. This sensitive storm window design has widespread applicability to many other historic buildings where owners are seeking to maintain and upgrade the existing historic windows in an aesthetically pleasing and practical manner.

Figure 5. The new wooden storm sash was installed in the historic frame; the edge of the storm frame was rabbeted to accommodate the historic molding on the old wood frame.

Photo: Richard Bierce, AIA

PROJECT DATA

Building:
South Gatehouse
Lyndhurst Estate
National Trust for Historic Preservation
635 South Broadway
Tarrytown, New York

Project Date: January-March, 1980

Project Staff:
Wayne Trissler, Apprentice, and Joseph Lewes, Master Restorationist
National Trust Restoration Workshop
635 South Broadway
Tarrytown, New York

Materials:
Stainless Steel Hardware-
Wesco F. G. Corporation
Bridge Street
Box 3
Irvington, New York

Project Costs:
The fabrication of the windows was undertaken by an apprentice at the National Trust Restoration Workshop at Lyndhurst. No cost figures are available.
This PRESERVATION TECH NOTE was prepared by the National Park Service in cooperation with the Center for Architectural Conservation, Georgia Institute of Technology. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Coordinator for the TECH NOTES. Special thanks go to Alan Keiser, Director of the National Trust Restoration Workshop for his time and assistance in providing information concerning the window work on the gatehouse. Thanks also go to the following people who contributed to the production of this TECH NOTE: John H. Myers and Laura A. Muckenfuss, Center for Architectural Conservation, and Preservation Assistance Division staff, particularly Kay D. Weeks, Martha L. Werenfeld, Mae Simon, Michael J. Auer, and Martha A. Gutrick. Cover, Gatehouse Photo: Courtesy, National Trust for Historic Preservation.

This and many of the TECH NOTES on windows are included in "The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings" (available late 1984), a joint publication of the Preservation Assistance Division, National Park Service and the Center for Architectural Conservation, Georgia Institute of Technology. For information, write to The Center for Architectural Conservation, P.O. Box 93402, Atlanta, Georgia 30377.

PRESERVATION TECH NOTES are designed to provide practical information on innovative techniques and practices for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures, and standards. This TECH NOTE was prepared pursuant to the National Historic Preservation Act Amendments of 1980 which directs the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to TECH NOTES, Preservation Assistance Division, National Park Service, Washington, D.C. 20240. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the authors and the National Park Service are appreciated.

ISSN: 0741-9023
PTN-3
January 1984
OLD WATKINS NATIONAL BANK

Lawrence, Kansas

The Old Watkins National Bank (now known as the Watkins Community Museum) is an impressive example of Richardsonian Romanesque architecture in Kansas. Built in 1887, the building is individually listed on the National Register of Historic Places and is owned by the Douglas County Historical Society.

The windows are a prominent feature of the building. The 102 windows, a majority of which are 5' wide by 10' high, are in twelve sizes and five styles. Many have arched tops. The monumental double-hung windows help to convey the grand qualities of the original design both on the exterior and in the spacious interior (see figure 1). Made of curly and burly pine, the windows are exquisitely trimmed on the interior, and the distinctive natural wood grain is especially pronounced in the jamb panels and interior shutters. Unlike the more usual shutters which fold against the jamb, these shutters slide vertically within multiple jamb tracks.

Design Problem

As with most building owners, the historical society was concerned about energy usage and thermal comfort as well as the need to have closely regulated environmental control to protect museum collections. As part of an overall rehabilitation program, an energy audit was initially performed by the local utility company. Although the historic wood windows were well-constructed and not seriously deteriorated, they were identified as a major contributor to energy usage because of their number and large sizes. Single glazing, lack of weather stripping and cracks around the window frames all added to winter heat loss, summer heat gain and appreciable air infiltration. As a result of the energy audit, the project architect, James Williams, AIA, investigated several storm window systems.

Use of exterior storm windows was initially explored both for energy conservation purposes and as a way to extend the useful life of the original windows (see figure 2). Unfortunately, the prices quoted for exterior storm windows by local contractors were around $65,000, nearly double the budgeted amount. In addition to the high cost of exterior storm windows, one further problem with an exterior storm application arose when it was discovered that the decorative terra cotta capitals adjacent to the upper level window openings returned against the original frames. As a result, the proposed exterior storm windows could not be easily installed in these locations without cutting back or covering portions of the terra cotta (see figure 3).

The numerous problems with exterior storm windows encountered in this project led to consideration of an interior storm system. Here too, there were specific requirements:
1. The impressive interior woodwork around the windows could not be damaged.

2. The new window unit could not alter the appearance of the windows as viewed from the outside and the basic character of the window needed to be preserved on the inside as well.

3. The storm window needed to have venting capability in case condensation occurred between the storm unit and the original sash to protect against damage to the original sill.

4. The windows needed to be less expensive than the exterior storm windows.

5. The interior shutter system still used in various rooms for sun control needed to remain operable.

6. The energy conservation objectives would have to be met.

**Design Solution**

In searching for an interior storm window that met both the functional requirements and the concerns about visual qualities, the architect chose a commercially available metal storm window system. The storm window was designed to fit within the existing wooden jamb, thus resulting in minimal damage to historic material (see figure 4).

The interior windows were nearly $20,000 cheaper to install than the bids received for exterior storm windows. Of particular significance, the storm sash were not readily visible from the outside, and on the inside the thin bronze-finished frames blended in well with the decorative finish and fine detailing of the original windows.

Selecting an interior storm window *per se* had certain inherent advantages in this case over exterior applications: (1) no obtrusive structural muntins were necessary because wind pressure was not a major factor; (2) fabrication of the storm windows on the first floor was significantly less expensive since the original windows were squared-off at the head on the interior unlike the arch shape found on the exterior; and (3) installation costs would be appreciably lower since problems created by cutting back the decorative terra cotta

---

**Figure 1.** The monumental windows are elegantly detailed on the interior and contribute to the grandeur of the spacious banking rooms. The original interior shutters are still being used for comfort and light control. Photo: Charles E. Fisher

---

**Figure 2.** As part of the planning, the architect prepared sketches of 4 possible window treatments to improve the energy performance of the windows.

---

**Sketch 1** is of a replacement wood window with insulating glass. This proposal was dropped because of cost and the fact that the historic windows were significant and still in good condition.

---

**Sketch 2** reveals the problem of applying an exterior storm window. The terra cotta detailing that returned against the window would have to be cut back to permit proper installation.
capitals on the exterior of the second floor openings were avoided.

**Storm Window Detail**

The thin aluminum storm window frame (½" wide, 1½" deep) was attached to a small new subframe by two pins that allowed the windows to pivot open for cleaning and venting in case entrapped condensation was ever a problem (see figure 5).

The subframe consisted of a ½" thick metal angle screwed to the wood jamb, serving as support and as a stop for the storm sash. On the large windows, the metal angle was paired to form a horizontal muntin, in line with the historic meeting rail, to accommodate an upper and lower storm panel, both of which pivoted (see figure 6). The frames were mounted in a location that provided a sufficiently wide dead air space for energy conservation purposes, yet still allowed the interior shutters to remain operable (see figure 7).

Mounted on pivot pins, the storm window relied on the pile weather stripping which ran continuously along the edge of the frame to serve as the seal between the metal subframe and the metal storm (see figure 4). Neoprene weather stripping was also added to the surface of the subframe to serve as a compression seal with the storm frame. Clear silicone caulk between the wood jamb and the subframe completed the seal.

**Assembly and Installation**

The frames were custom-fitted to each opening and prefabricated by a local glass dealer. For ease of installation, the glazing was not done at this time. At the site, the sash frames were positioned in the existing jambs with the aid of a rolling scaffold. A space of nearly 1½" was provided between the existing glass, which is in a very thick wood frame, and the back of the storm glass; this space serves as a dead air pocket for energy conservation.

To mount the frames, holes were drilled and hardware attached for the lock and pivot mechanisms; the storm frames were then attached and the loose end of the hold-open arms were screwed.

*Figure 3. Exterior storm windows were initially considered but presented several problems. The terra cotta capitals on the pilasters returned against the windows, making normal installation difficult without damaging the terra cotta. Many of the windows also had round heads which would require additional custom work—these same windows on the interior had square tops. Photo: Charles E. Fisher*
to the metal subframe. Once the glass was installed, the work was essentially completed.

**Project Evaluation**

The storm window system chosen for the building fulfilled the criteria established at the beginning of the project. Interior storm windows were installed on 92 of the windows in 1981 at a cost of $45,068 ($12.07 per square foot of opening), and an initial cost savings of nearly $20,000 was realized over exterior storm applications. A portion of the cost saving was attributed to the fact that, as interior storm windows, they were installed by the contractor during his slow winter months. The payback period for the storm windows will be accurately determined only by in-place performance. However, it would appear that the storm windows are reducing the energy consumption by more than 40% — a figure that exceeded the theoretical calculations. Long-term maintenance of the storm windows is expected to be low because of the quality of construction and because the windows will not be opened on a daily basis.

Other benefits have resulted from
Figure 5. The interior storm window was designed to fit within the existing wooden jamb. The large size of the window necessitated the use of operable storm panels, intersecting at the historic meeting rail. Here the lower storm panel is in an opened position for cleaning. Photo: Charles E. Fisher

Figure 6. The windows were too large for only a single storm panel, necessitating the use of a structural subframe at the mid-section of the window. Both the upper and lower storm panels are operable and come together opposite the historic meeting rail. This element of the storm window is sufficiently thin that it is not readily discernable from the outside. Photo: Charles E. Fisher

Figure 8. The decorative jamb panel on the left and the interior shutter tracks were unaffected by the installation of the interior storm window shown on the right. Photo: Charles E. Fisher

Figure 7. Continued use of the unique shutter system required that the frame of the interior storm window be narrow. The storm windows are set between the shutters and the historic sash. Photo: Charles E. Fisher
this project that cannot be directly measured in dollars. Former hot and cold spots in the building have been greatly reduced. Patron comfort has been noticeably improved both thermally and from reduced street noise level.

In summary, the interior storm window solution not only provided the owner with initial cost savings in installation, but it also reduced fuel consumption, met all functional requirements, and carefully addressed historic preservation concerns (see figure 8). The thin frame storm window, set within the existing jamb and mounted so as to pivot, was a sensitive solution which is also being used on other projects involving rehabilitations of historically important commercial buildings.

**PROJECT DATA**

**Building:**

Elizabeth M. Watkins Community Museum (formerly the Old Watkins National Bank)
1047 Massachusetts Street
Lawrence, Kansas

**Project Date:** Winter 1981

**Project Staff:**

James Williams, AIA
Project Architect
123 West Eighth
Lawrence, Kansas

Kennedy Glass, Inc., Contractor
P.O. Box 681
Lawrence, Kansas

Steve Jansen
Director, Watkins Community Museum
Lawrence, Kansas

**Special Supplies:**

Interior Storm Windows—
Kawneer Company, Inc.
1105 N. Front Street
Miles, Michigan

**Project Costs:**

Total costs, including installation for the 92 storm windows was $45,068, equaling $12.07 per square foot. Small storm windows were up to four times as expensive per square foot as the largest ones. Units were not installed on 6 attic and 4 basement windows.

---

This PRESERVATION TECH NOTE was prepared by the National Park Service in cooperation with the Center for Architectural Conservation, Georgia Institute of Technology. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Coordinator for the TECH NOTES. Information on the window work at the museum was contributed by Steve Jansen, Director of the Elizabeth Watkins Community Museum, Jim Williams, AIA, and particularly Terry W. Marmet, Historic Preservation Division, Kansas State Historic Society, who helped with portions of the text. Special thanks go to the following people who contributed to the production of the TECH NOTE: John H. Myers, Center for Architectural Conservation, and Preservation Assistance Division staff, particularly Michael J. Auer, Martha A. Gutteck, Mae Simon, and Martha L. Werenfels.

This and many of the TECH NOTES on windows are included in "The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings" ( available late 1984), a joint publication of the Preservation Assistance Division, National Park Service and the Center for Architectural Conservation, Georgia Institute of Technology. For information, write to The Center for Architectural Conservation, P.O. Box 93402, Atlanta, Georgia 30377.

PRESERVATION TECH NOTES are designed to provide practical information on innovative techniques and practices for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures, and standards. This TECH NOTE was prepared pursuant to the National Historic Preservation Act Amendments of 1980 which directs the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to TECH NOTES, Preservation Assistance Division, National Park Service, Washington, D.C. 20240. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the author and the National Park Service are appreciated.

ISSN: 0741-9023  PTN-5  January 1984
COLCORD BUILDING
Oklahoma City, Oklahoma

The Colcord Building, constructed in 1910, is one of the few remaining historic office buildings in downtown Oklahoma City. Designed by William A. Wells, the 12-story concrete structure is elaborately decorated with ornamental terra-cotta panels at the first, second, and twelfth floors. The bold scale and setbacks of the wooden windows surrounded by terracotta are significant design features of this National Register property (see figure 1).

During a recent renovation of the building, alternatives were investigated for improving the energy performance of the windows. After careful evaluation, the decision was made to fit a new storm panel to the existing sash in a manner that was cost-effective and also preserved the window’s distinctive qualities.

Rehabilitation Design Problem

The Colcord Building contained 507 single-glazed, double-hung window units with each sash containing a single light. The units ranged in size from 22" by 66" to 48" by 66", which translated into approximately 7,700 square feet of glass surface area. Since energy costs can be increased by up to 25% as a result of loose-fitting single-glazed windows, it was financially important for the owner to upgrade the existing windows or to replace them.

The architect investigated the following approaches:
1. repairing the existing windows;
2. adding weatherstripping to the existing units;
3. adding a second layer of glazing to the existing windows, either as a separate storm window or as applied storm panels; and

Many late 19th and early 20th century historic wooden windows can be made more energy efficient through addition of an interior storm unit piggybacked onto the historic sash—an approach that should be considered before installing replacement windows.
4. replacing the existing windows with new double-glazed thermal windows.

The need to seek a cost-effective and yet compatible solution quickly eliminated two common options. The first was the use of an exterior storm window since it would have altered the deep set back which was a character-defining feature of the building. The second alternative was the use of a modern replacement window. The cost of replicating 507 double-hung windows out of wood and installing thermal glazing was beyond the budget of the owner. A much less expensive solution, which was investigated, involved the replacement of all windows with a metal frame, fixed sash and solar grey heat absorbing insulating glass. While the cost estimate of $300 per unit was within budget, the architect felt that such a solution was unacceptable since it would have drastically changed the building’s historic appearance.

The architect then investigated repairing and upgrading the existing sash. This work would involve tightening the loose members of the window sash, adding weatherstripping and installing an interior storm panel.

Figure 1. Deeply recessed windows with ornamental terra-cotta surrounds were character-defining features of the building which the owner wanted to retain. Photo: Jack Graves, AIA

Rehabilitation Design Solution

While researching new window units, the architect found a commercially available wooden replacement window that incorporated a removable storm panel piggybacked onto the single glazed sash. This second layer of glazing was recessed on the inside of the primary wooden sash, allowing the double-hung window to operate without interference from the applied panel. The architect applied this concept to the Colcord Building’s windows and proposed to retrofit a recessed storm panel to each existing sash, provided it would not structurally weaken the sash in the process (see figure 2).

This approach would necessitate routing or cutting out a portion of the historic wooden sash and would add to the weight of the sash due to the attached storm panel. The sash rails and stiles measured 1-7/8” deep by 2” wide and were in sound condition. They were therefore capable of tolerating the required cut—½” deep by ½” wide. The issue of the additional weight of the storm panels was directly related to the choice of materials selected for the piggyback units. Since acrylics are purported to be 40% lighter than glass and 15% more thermally efficient for the same thickness, the architect investigated their use. Because of expense and the tendency of acrylic to bow or discolor due to sun exposure and to scratch when being cleaned, the architect selected instead glass panels set in aluminum frames. By lubricating the existing sash chains, the sash could accommodate the additional weight of 3 to 8 pounds without affecting operability.

The use of interior storm panels affixed to a sash can create a potential problem of trapped condensation. To avoid this possibility, the architect specified two features. The first was a neoprene gasket as an air seal between the wooden sash and the aluminum frame of the storm panel; the second was the creation of ventilation holes in the wooden sash stiles. The vent holes, drilled laterally through the stiles, were to provide a minimum of air circulation should moist air condense between the layers of glazing.

Figure 2. Cutaway view of the proposed retrofit solution showing how the historic sash would receive a recessed storm panel through routing or cutting an inside rabbet. Drawing: Sharon C. Park, AIA

Repair and Retrofit of the Sash

The construction manager developed a system of scheduling work during the tenants’ non-working hours. The two-man crew undertaking the repair of the windows could complete six window units during an evening shift. To accomplish the work as efficiently as possible, a temporary workshop with jigs and benches was set up on the floor where the men were working. This portable workshop was relocated as the men progressed through the building.
Each sash was first pulled from the window frame by removing the parting bead and stop bead from one side of the window jamb. While the sash was out of the frame, the frame itself was repaired, old paint scraped off, and new spring-bronze weatherstripping installed. In addition, the sash chains were lubricated prior to installation of a plywood panel intended to give temporary closure to the window while work was underway.

After each sash was taken to the workbench, the glass was carefully removed and set aside. The sash was then placed horizontally on the bench and the inside face of the sash was routed out to create a $\frac{1}{2}$" by $\frac{3}{4}$" recessed channel for the storm panel. Loose paint and remaining dry glazing putty was scraped from the sash. At this point ventilation holes should have been drilled, yet because of a misunderstanding, the carpenters omitted this feature.

Once the sash was repaired, the original glass was reinstalled and spring-metal weatherstripping was applied to the underside of the lower sash rail and the meeting rail. The routed opening was then measured and the storm panels were fabricated in the basement by the storm window subcontractor. The repaired sash were then rehung in their original window openings and later the storm panels were applied.

### Assembly of the Storm Panels

The storm panels were made of single thickness float glass set into an extruded section of enameled-finish aluminum fitted with an integral neoprene gasket. A simple hand crimping tool was used to affix the metal section around the float glass.

The method for mounting the storm panels posed the final problem for the architect. The commercially available storm panels used concealed retractable clips to hold the panels in place. These clips allowed for the easy removal of the storm panels for cleaning. However, because the clips would have added substantially to the cost of the storm panels and would have required deeper routing of the historic sash, it was determined that an alternate attachment method was needed.

As the panels would only be removed for maintenance purposes, the architect determined that the panels simply could be screwed in place, using a neoprene gasket set on the back side of the panel as a seal (see figure 3). Should the panels ever need to be removed, an electric screw gun would do the job quickly (see figure 4).

Figure 3. The completed retrofit shows the storm panel screwed onto the historic window. Photo: Tamara Coombs

### Cost of the Retrofit

The total cost of repairing the historic wooden windows, weatherstripping and retrofitting the storm panels was under $100 per window opening. This was a 66% saving over the original proposal to use a replacement metal-framed thermal glass unit. Several factors combined to make the retrofit a cost effective solution. The use of traditional tools and standard woodworking techniques ensured that the work could be easily carried out at the site by the subcontractor. Scheduling of the work permitted full use of offices by tenants during the day. Furthermore, material costs were low and the workmen established an efficient method for repairing and upgrading the existing windows.

The low cost of the retrofit and the added insulating qualities of the upgraded wooden windows provided the owner with a cost-effective solution (see figure 5). The architect computed that with the combined benefits of low initial expense in retrofitting the historic windows and the decreased fuel bills associated with the improved thermal performance of the windows, the owner should have a complete return on his investment in 7 years.
<table>
<thead>
<tr>
<th>Window Type</th>
<th>U-Value</th>
<th>Cost (1980)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary wooden sash with single glazing</td>
<td>1.00</td>
<td>$0. — existing</td>
</tr>
<tr>
<td>Metal framed replacement window with double glazing, non-thermal-break</td>
<td>.69</td>
<td>$300</td>
</tr>
</tbody>
</table>
| Primary wooden sash repaired with new interior storm panel | .49     | $20 — for repair and weather stripping  
|                                                  |         | $80 — for routing sash storm panel fabrication and installation |

Figure 5. Thermal efficiency and costs for alternative windows, the Colcord Building. Note that the U-Value is the coefficient of heat transmission of materials. The lower the number, the greater the insulating quality of the material. The best value, therefore, is the repaired wooden window with the new interior storm panel which cost $100 per unit.

Project Evaluation

The repair and thermal upgrading of the wooden windows at the Colcord Building successfully combined historic preservation goals and cost considerations. Because the windows were in good condition, heavily constructed, and of a simple one-over-one configuration, a recessed interior storm panel was a practical solution. The dry Oklahoma climate and the neoprene gasket used helped to avoid the problems generally associated with condensation between non-sealed glazing layers. The vent holes, originally specified and always recommended, were not necessary in this case; after four seasons there has been no evidence of condensation. The approach used at the Colcord Building is an excellent example of how historic wooden windows can be economically repaired and upgraded to meet today’s energy needs without replacing historic windows.

PROJECT DATA:

Building:
The Colcord Building  
Oklahoma City, Oklahoma

Developer:
The Colcord Associates  
The Colcord Building  
Oklahoma City, Oklahoma

Project Date: 1980

Architect:
Jack M. Graves, AIA  
Architectural Design Group  
117 Park Avenue  
Oklahoma City, Oklahoma

Project Manager:
William L. McNatt & Co.  
217 East Sheridan St.  
Oklahoma City, Oklahoma

Project Cost:  
$50,500 for window repair, weatherstripping, addition of piggybacked interior storm panels and repainting of 507 windows ($99.60/unit)

This PRESERVATION TECH NOTE was prepared by the National Park Service, based on a published Preservation Case Study entitled “Improving Thermal Efficiency: Historic Wooden Windows (The Colcord Building),” National Park Service, 1982. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Coordinator for the PRESERVATION TECH NOTES. Thanks go to the following people who contributed to the production of this Tech Note: John H. Myers and Laura A. Muckenfuss, Center for Architectural Conservation; Georgia Institute of Technology, and Preservation Assistance Division staff, particularly Michael J. Auer, Martha A. Gutrick, Brenda Johnson and Mae Simon. Cover, Colcord Building  
Photo: Ward Jandl.

This and many of the PRESERVATION TECH NOTES on windows are included in “The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings” (available late 1984), a joint publication of the Preservation Assistance Division, National Park Service, and the Center for Architectural Conservation, Georgia Institute of Technology. For information write to The Center for Architectural Conservation, P.O. Box 93402, Atlanta, Georgia 30377.

PRESERVATION TECH NOTES are designed to provide practical information on innovative techniques and practices for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards. This publication was prepared pursuant to Federal tax laws which direct the Secretary of the Interior to certify rehabilitations of historic buildings that are consistent with their historic character; the advice and guidance provided in this Tech Note will assist property owners in complying with Federal tax requirements.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Preservation Assistance Division, National Park Service, Washington, D.C. 20240. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the author and the National Park Service are appreciated.

ISSN: 0741-9023  
PTN-8  
September 1984
COLONIAL WILLIAMSBURG
Williamsburg, Virginia

The Williamsburg National Historic Landmark District consists of approximately 500 buildings that have been restored or reconstructed to their 18th century appearance. A vast majority of the buildings are owned by The Colonial Williamsburg Foundation; many opened to the general public as part of an educational program.

Twenty-three of the non-exhibition buildings, most of which are used for rental housing, were selected for retrofitting storm windows as part of Colonial Williamsburg’s ongoing energy conservation program. A simple commercially available interior storm window system was chosen and certain modifications were made for aesthetic and functional reasons.

Rehabilitation Design Problem

In improving the energy performance of windows in historic buildings, installing a system of double glazing is usually one of the first considerations in areas with long heating seasons. Installation options may include adding a traditional exterior or an interior storm window; routing out the frame of the historic sash to insert a double-glazed thermal unit; or under certain conditions, replacing the deteriorated historic sash with a new double-glazed one that preserves the historic character of the window.

In assessing these options, it is understandable that the initial cost of installation will be a major consideration, but it should not be the controlling factor. In working with historic buildings, emphasis should be placed on not only maintaining the historic appearance but also preserving as much of the historic building material as possible. In addition, there are often special considerations based on the use of the historic building, as in the case of those owned and operated by The Colonial Williamsburg Foundation.

When Colonial Williamsburg began an accelerated program of energy conservation for their many historic and reconstructed buildings, they surveyed those buildings not open to the public to ascertain the possibility of improving thermal performance and reducing the air infiltration of the windows. Since nearly 40% of the windows in the historic buildings are all or in part original, the decision was made to examine the possible use of storm windows. To minimize the visual and physical alterations to the windows, especially as viewed from the outside, an interior storm window system was considered the best approach. Since half-screens had previously been installed on the inside of most of the buildings, and these were still in good condition, new screen units were not required.

The following design criteria were thus established for the interior storm window systems:

1. The storm window had to be...
largely invisible to the general public as viewed from the outside.

2. No mechanical fasteners could be used that would damage the historic woodwork.

3. The storm window needed to be removable or self-storing to allow natural ventilation during the summer months.

4. Installation had to be achieved with minimum inconvenience to the tenants.

5. Air infiltration needed to be appreciably reduced both for energy reasons and for improved personal comfort of the tenants.

6. The storm units needed to accommodate the irregularities of the historic windows and also the varied assortment of draperies, blinds and window trim.

7. As viewed from the interior, the storm windows had to be as unobtrusive as possible.

8. A reasonable payback period for the windows through improved energy performance was required.

Rehabilitation Design Solution

The interior storm window system selected by Colonial Williamsburg consisted of a clear acrylic sheet in a polymer frame that contained a flexible magnet on the back side. When the storm window was set against an adhesive-backed steel strip pre-attached to the historic interior window trim, a magnetic seal was formed (see figure 1). The advantages to this design solution were the ease of installation without any damage to the original woodwork or sash, and the small visual impact it had on the exterior appearance of the window.

Two potential drawbacks of this and other types of interior storm windows were recognized from the beginning. First, the addition of the interior storm window could result at times in a slight shadow effect created by the wooden muntins of the original sash reflecting off the storm glazing. The other potential problem was that condensation could be trapped between the original sash and the storm unit. In the past, condensation had occurred during winter months, particularly on the north facades where high air infiltration due to prevailing winds was common, and also in rooms with high humidity, such as bathrooms and kitchens. With the new storm windows in place, it was assumed that there would be fewer condensation problems. If moisture runoff from condensation did occasionally collect on the sills of individual windows, it could be wiped off. Based on the results from the test buildings, however, condensation has not been a problem to date. Building conditions, use, and climatic differences might lead to different results, however, on other projects.

Single-Unit Storm Window

Two different storm window designs, single unit and split unit, were utilized in order to accommodate the varying window sizes and operability requirements. The least expensive design was the single-unit storm window covering the entire window opening and used in buildings with year-round climatic controls in which operable windows were unnecessary.

There are size limitations for the use of the single unit. For example, had the windows been as large as 4 by 8 feet or particularly long and narrow, a split unit would have been required to avoid potential problems from thermal expansion. Other allowances, for expansion and contraction would also have been necessary had any of the storm units been set within the jamb rather than surface-mounted. In the case of the buildings at Colonial Williamsburg, the window sizes were such that any thermal expansion, according to the contractor, would only result in the storm window slightly "creeping" along the steel strips with the magnetic seal not breaking.

Most of the historic windows at Colonial Williamsburg had been trimmed with a stool so that a magnetic seal was obtained only on three sides of the polymer frame (see figure 2). A small metal angle frame or wood stop could have been added to the stool to permit a magnetic seal on the fourth side but such alterations were avoided.

Figure 2. The thin-framed storm unit is shown attached by a magnetic seal to the existing trim. The protective film on the acrylic will later be removed.
Photo: Tom H. Taylor.

A slightly different polymer frame configuration was used for the bottom of the storm window in cases where a window stool existed. The sill framing was attached to the acrylic sheet like the typical polymer frame, with the exception that the bottom was extruded with a \(\frac{1}{4}\)" U-channel that had a latex gasket glued in place to form a tight seal (see figure 1).

Figure 1. The interior storm window system chosen consisted of a clear acrylic glazing sheet set into a polymer frame that adhered to the existing window trim through use of a magnetic seal. Drawing: Christina Henry.
Split-Unit Storm Window

The storm window design most commonly used at Colonial Williamsburg consisted of a separate upper and lower part with an interconnecting meeting bar. This style was used in windows where the original double-hung sash needed to remain operable. A split-unit interior storm window has an advantage over a single unit in that it did not need to be removed and stored in the summer months. By attaching the lower unit to the upper unit via a magnetic seal, the storm window could be left in place, thereby avoiding problems of storage and reducing the chances of the acrylic sheets being scratched or warped (see figure 3).

Figure 3. Vertical section showing a split unit in place and the option of piggybacking the lower unit onto the upper for storage during the summer. See figure 6 for detail on the manner of attaching the piggybacked unit. Drawing: Christina Henry.

The design of the split units met two important considerations: (1) the meeting bar of the interconnecting units could be located so as to have minimal visual impact from the exterior, and (2) a sound connection between the split units was created. To accomplish the latter, the standard ¼" U-channel with a latex gasket used on the stool framing was, in turn, used on the upper horizontal edge of the lower window unit (see figure 3). On the lower horizontal edge of the upper window unit, a slightly larger U-channel was incorporated into the bottom of the polymer frame to fit snugly over the upper facing U-channel and gasket used on the top of the lower unit (see figure 4). This feature thus served to diminish air infiltration and also provided additional reinforcing along the midsection of the complete storm unit.

Figure 4. The intersection on the upper and lower units was made structurally sound and weather tight by using two interlocking U-channels along with a latex gasket. Photo: Tom H. Taylor.

The placement of this meeting bar primarily depended on its visual impact on the outside. Where the historic upper and lower sash were the same size, the meeting bar of the interior storm was lined up as closely as possible behind the meeting rail of the historic sash (see figure 5). In a number of windows, however, the pane configuration made it harder to disguise the appearance of the interior storm meeting bar from the outside. These windows had 9 panes over, the bottom sash being considerably larger. In such cases, it was specified that the bottom of the top storm unit would stop at the first horizontal muntin below the meeting rail on the historic sash.

Figure 5. The meeting bar of the split storm unit was located adjacent to the historic meeting rail in windows where the upper and lower sash were the same size. Photograph shows the installers checking to make sure the lower unit will properly align. Photo: Tom H. Taylor.
Self-Storing Feature of the Split-Unit Window

To allow for the storage of the lower unit, an adhesive-backed steel strip was attached to the face of the vertical polymer frame on the upper unit. Thus the two vertical framing members in the upper unit had a magnet on one side and a steel strip on the other. The addition of the metal strip allowed the lower unit to be magnetically attached to the steel on the upper unit when in a storage position (see figure 6).

To keep the upper unit from creeping downward due to the additional weight of the piggybacked lower storm, a 3/8" shelf with a 3/16" upward turn was formed in the two wood-adhering vertical steel strips at a point aligning with the bottom of the upper unit (see figure 7).

A similar feature was added at the bottom of both single and split units when no stool existed in the historic window. To deter possible creeping and, as a safety measure, the bottom of the vertical steel strip was turned 90 degrees outward to act as a small shelf for the storm window. A small plastic tip was attached to the sharp edge of this shelf to protect draperies.

Figure 6. Horizontal section of the upper storm unit shows how with an additional adhesive backed steel strip added to the sides of the upper storm frame it was possible to piggyback the lower storm unit for storage purposes during the summer.
Drawing: Christina Henry.

Figure 7. (a) In cases where there were no stools and also where a split unit was used to facilitate self-storage, small "shelves" were made in the vertical steel strips to deter creeping. Photograph shows a 90 degree angle at the bottom of the vertical steel strip in a situation where there was no stool.
Photo: Tom H. Taylor. (b) The adjacent drawing shows the two "shelves" used with split units as well as a top safety catch formed at the end of the steel strip.
Drawing: Christina Henry.
Fabrication and Installation

For the convenience of the contractor and the residents of each building, it was decided not to fabricate the windows at the job site. Working on one building at a time, the contractor measured each window, cut the acrylic sheets, and attached the polymer frames at the shop. Where the historic windows were skewed — some having lost their rectangularity due to settling — the storm units were cut oversize at the shop to allow for custom fitting at the site. The protective masking on the acrylic was left in place until final installation in order to reduce the chances of scratching. It was necessary, however, to roll the masking back from the edges when attaching the polymer frames.

Prior to shipment to the site, the adhesive-backed steel strips, which were to be mounted to the wooden window trim, were cut and temporarily affixed to the bar magnet set in the polymer frame; the pull-off tape was left on. Affixing the adhesive steel strip to the bar magnet greatly facilitated proper alignment onto the existing wooden window during the final installation.

After removing the blinds and draperies, the prefabricated storm window was held up to the historic window and checked for any necessary adjustments. For windows that were skewed, the polymer frames and the acrylic glazing were easily cut onsite for a correct fit. When ready for installation, the masking tape was removed from the adhesive side of the steel strip and, with the steel strip still attached to the polymer frame (via the magnet), the window was aligned and pressed firmly against the wooden trim. In this way, the steel strip adhered to the wooden trim while maintaining a correct alignment with the magnet in the polymer frame. In some cases, due to irregularities in the surface of the wooden trim, it was necessary to build up behind the steel strips using double faced tape to accommodate gaps as much as ⅛". The storm window was then checked for ease of removal and the protective masking removed from the acrylic. Two workers were able to install about 25 windows in an average working day.

Post-Installation Evaluation

The unobtrusive nature of these storm windows is an advantageous feature, along with the fact that no physical damage or alteration to the original window is required (see figure 8).

Building tenants have noticed a major increase in personal comfort during the winter months, especially while sitting near the windows, and have experienced a substantial reduction in outside noise. Specific energy savings have not been calculated, but tenants report significant energy savings during the first winter.

It is anticipated that the acrylic glazing will be scratched over the long term, especially since some of the tenants have elected to store the lower storm units elsewhere during the summer rather than piggyback them. Colonial Williamsburg gives its tenants specific cleaning instructions including information on available products to remove minor marks.

There are available for the split units separate screens which can be installed in the bottom half and removed during winter months. These were not used at Colonial Williamsburg because of interior half screens already existing within the jamb.

These single-and split-unit storm windows have been successfully used in both commercial and residential rehabilitation projects in other states. By minimizing physical damage and changes in the visual qualities of the historic window, this interior storm window has provided two features desirable for other historic buildings.

Figure 8. The unobtrusive interior storm window required no physical damage or exterior visual alteration to the original window. Photo: Tom H. Taylor.
Project Staff:
Tom Taylor, Jr., Chief, Architectural Conservator
Bill Black, Project Architect
Paul Hurley, Superintendent, Building Maintenance Department,
The Colonial Williamsburg Foundation
P.O. Box C
Williamsburg, Virginia
Sam Massey, Jr., Window Consultant and Contractor
Vencon, Inc., P.O. Box 210
Shacklefords, Virginia

Materials:
Magnetrtrim Window—
Energy Options of Virginia, Inc.
8439 Glazebrook Avenue
Richmond, Virginia

Magnette Window—
Viking Energy System Co.
275 Circuit Street
Hanover, Massachusetts

Project Costs:
Manufacture and installation of 461 interior storm windows (7,410 square feet) on 23 buildings-$34,124 ($5.28 square foot).

This PRESERVATION TECH NOTE was prepared by the National Park Service in cooperation with the Center for Architectural Conservation, Georgia Institute of Technology; funding assistance was provided by the Office of Solar Heat Technologies, Conservation and Renewable Energy, U.S. Department of Energy. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Coordinator for the PRESERVATION TECH NOTES. Information on the interior storm window installation work at Colonial Williamsburg was generously supplied by Sam Massey, Jr., who served as the window contractor; by Nicholas A. Pappas, FAIA, Foundation Architect, and Tom H. Taylor, Jr., Chief, Architectural Conservator, The Colonial Williamsburg Foundation. Special thanks go to Kay D. Weeks, Preservation Assistance Division, National Park Service, for her help in writing this Tech Note. Thanks also go to the following people who contributed to the production: John H. Myers, Center for Architectural Conservation, and Preservation Assistance Division staff, particularly Michael J. Auer, Christina Henry, Brenda Johnson, Martha L. Wrenfels, Martha A. Gutrick, and Mae Simon. Cover Photo: Tom H. Taylor.

This and many of the PRESERVATION TECH NOTES on windows are included in “The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings” (available late 1984), a joint publication of the Preservation Assistance Division, National Park Service and the Center for Architectural Conservation, Georgia Institute of Technology. For information write to The Center for Architectural Conservation, P.O. Box 93402, Atlanta, Georgia 30377.

PRESERVATION TECH NOTES are designed to provide practical information on innovative techniques and practices for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures, and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act Amendments of 1980 which directs the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Preservation Assistance Division, National Park Service, Washington, D.C. 20240. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the authors and the National Park Service are appreciated.

ISSN: 0741-9023 PTN-9 September 1984
THE DRAKE HOTEL
(DRAKE TOWER)
Philadelphia, Pennsylvania

The 30-story Drake Hotel in downtown Philadelphia was the city's largest building when constructed in the late 1920s. The brick-clad art deco building, accented with sculptured terra cotta decoration, incorporates Spanish Baroque detailing along with a strong silhouette to create a distinctive appearance against the city skyline. Built with 753 rooms for use as apartments and hotel lodging, this long narrow building has recently been renovated exclusively for use as apartments.

The Drake Tower, as it is known today, has over 1600 steel casement windows, richly adorned with terra cotta detail on the lower and uppermost floors (see figure 1). In between, the wall is simply detailed, characterized by the expanse of masonry and the organization and appearance of the steel casement windows with their multipane configuration and vertical meeting line. During the recent renovation, the steel casement windows were maintained and their energy performance enhanced inexpensively through addition of interior storm windows.

Physical damage and visual changes to historic windows should be minimized when installing storm windows.
Problem

There are a number of window sizes and styles in the building ranging from those with arched transoms on the upper floors to small single casements stacked vertically in bathroom locations. The predominant window type consists of a paired casement unit, measuring approximately 3 feet wide by 4\% feet high. These units are hinged on the jamb side, closing against a center mullion bar. On the interior the windows have a slightly splayed plaster jamb, devoid of any trim except for a rather simple wooden apron.

Having established that the casement units were in relatively good condition, the project architect examined ways to improve their energy efficiency. Caulking around the frames and adding weatherstripping to the operable casement would considerably reduce air infiltration, but would not address the heat loss through the glass and the non-thermally broken metal frame. Double glazing was considered desirable and yet there were very limited choices. The shallow 7/8” glazing depth and narrow width of the glazing bars in the existing frame precluded retrofitting insulating glass within the individual lights. Since operable windows for seasonal use were a requirement for marketing, the addition of a fixed acrylic or glass panel was not considered. Similarly, an exterior storm unit would prohibit operation of the windows, unless “piggybacked” individually onto each of the casement pairs. An exterior applied storm panel piggybacked onto each operable sash would create aesthetic problems with the appearance of the windows.

Solution

A system to improve the energy performance of the windows was developed by the architect, based on an approach that the firm had specified for other similar projects. It involved the installation of a new horizontally sliding storm window unit, mounted on the interior of the window jamb. The 2 storm panels would run the full height of the opening and would slightly overlap to allow for an effective weather seal (see figure 2). The intersection of the 2 storm panels thus would align at the vertical mullion of the existing paired casement windows. Since the interior face of the steel mullion was 2 1/4 inches wide, the visual impact on the windows of the intersection of the frames of the two storm panels would be minimal. For insect control, especially on the lower floors, a screen panel half the width of the opening was specified, set within a third track of the aluminum subframe (see figure 3).

Repair Work

The steel casement windows required basic maintenance work. This work included cleaning, repainting where necessary, limited replacement of cracked glass, and the application of an anti-corrosive paint. The hardware was cleaned and oiled (see figure 4), and the frames caulked on the exterior both to keep water from entering and rusting the steel subframe as well as to reduce air infiltration. The relatively tight closure of the cleaned and repainted casements, coupled with the planned installation of the interior storm unit, rendered the additional expense of retrofitting weatherstripping to the casements unnecessary.

Aluminum Storm Window

Several important factors were taken into account to ensure the successful installation and operation of the storm windows. First, care was taken to make sure that the aluminum window section was thick enough to prevent racking of the sliding sash. For the 3’ by 4\%’ opening, a 5/8” thick sash frame was used, set into an aluminum 1 1/4” subframe screwed to the existing jamb (see figure 5). Openings larger than these may require thicker frames. Second, correct installation procedures were essential to ensure that the slider unit functioned properly. This required that each subframe be squared off when installed in the existing jamb, since changes in alignment may have
occurred to the window opening over the years (see figure 6).

Working one floor at a time, the aluminum storm frames were custom-fitted to each opening and prefabricated by the window company. Installation work was easily scheduled since all work could be accomplished from the inside. After the frames were installed, a silicone sealant tinted brown was applied around the intersection of the aluminum subframe and the existing jamb on the exterior face to reduce further air infiltration. In addition, the sash stiles had pile weatherstripping on the inner and outer faces for additional tightness.

Rehabilitation Costs

The cost of repairing and repainting the historic steel windows was $55,000, or $34 per window. Installation of the combination storm/screen interior unit averaged $62 per window for the ap-
approximately 1600 windows, bringing the total cost to $96 per window.

**Evaluation**

The installation of the storm units had little visual impact on the exterior appearance of the Drake (see figure 7). This is largely due to the selection of an interior application, use of a dark color for the storm frames, the alignment of the intersection of the two storm panels at a point behind the steel mullion on the historic window, and the setback of the storm unit nearly flush with the interior wall. On the inside, the storms are neatly set within the opening and aesthetically are not disruptive (see figure 8).

Potential condensation problems exist with many storm window applications. The window contractor initially had expressed concern over possible condensation forming on the windows directly above wall air-conditioning units. This certainly was a problem with the historic windows. With installation of the storm units, there has been no problem with condensation forming on the windows over the past two years.

Much of the success of sliding aluminum sash rests on the use of good frames and hardware, and on proper installation. While friction sliders were used for the sash, more expensive ball-bearing rollers would have provided for smoother operation. The subframes for the storm and screen panels are properly squared in each opening and preclude the storm units from catching or jamming during operation. The storm windows along with the historic casement unit have provided a sound weather seal. An added benefit of the work was that the street noise has been considerably reduced within the apartments, particularly on the lower floors.

This simple method for upgrading the performance of the windows proved both practical and cost effective, while preserving both the appearance and the materials of the historic windows.

---

Figure 5. The interior storm window system consisted of an aluminum subframe and sliding aluminum-frame panels with glazed and screened units. Drawing: Christina Henry.
Figure 6. The subframe had to be squared off when installed in each window opening to prevent racking of the sliding panels. Photo: Christina Henry.

Figure 7. The dark frame color and careful installation of the interior storm window resulted in little visual impact on the exterior appearance of the building. Photo: Charles Fisher.

Figure 8. The storm units are neatly set within the opening and aesthetically are not disruptive. Photo: Charles Fisher.
PROJECT DATA:

Building:
The Drake Tower
(formerly Drake Hotel)
1512-1514 Spruce Street
Philadelphia, Pennsylvania

Owners:
Samuel Mindel and Eric Rosenfeld
New York, New York

Project Date:
March 1984 – May 1986

Cost:
Repair and repainting of approximately 1600 windows cost $55,000. The cost of the interior storms averaged $62 per window, totaling approximately $100,000. The total cost of the window work was $155,000, or $96 per window.

Project Architect:
Richard Klein
Goldfarb/Klein and Associates
260 South 23rd Street
Philadelphia, Pennsylvania

This PRESERVATION TECH NOTE was prepared by the National Park Service. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Coordinator of the PRESERVATION TECH NOTES. Information on the rehabilitation work at the Drake Tower was generously supplied by Barbara Murry, building manager of the Drake Tower. Special thanks go to Michael J. Auer, Brenda Siler, and Theresa Robinson of the Preservation Assistance Division who contributed to the production of this Tech Note. Cover Photo: Mort Bond, National Register Collection.

PRESERVATION TECH NOTES are designed to provide practical information on practices and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards. This Tech Note was prepared pursuant to the National Historic Preservation Amendments of 1980 which direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Preservation Assistance Division-424, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127.

ISSN: 0741-9023
PTN-20
November 1986
D: Second Floor, South Elevation

- Replace molding
- Small repair with mortar
- Replace with nine light sash to match upper

E: Second Floor, North Elevation

- Replace molding
- Install new glass
- Replace rail or consolidate with epoxy
- Sash weights missing - install new to match; replace all sash cord using sash chain
- Interior - consolidate apron using epoxy

F: Second Floor, East Elevation

- Replace molding
- Small repair with mortar
- Replace outer tracks and parting stops
- Install new glass

- Interior - replace soffit of head

E: Second Floor, South Elevation

- Transom missing
- Install new to match

- Interior - fill open joints, repair transom mechanism
- Right transom missing - install new wood transom to match
PROTECTING WOODWORK AGAINST DECAY WITHOUT CHEMICAL PRESERVATIVES

The survival of millions of historic wooden windows is a testament to their long useful life. Faced with windows that are beyond repair, however, many owners are reluctant to install wooden replacement windows, in part due to the belief that without constant maintenance the windows will quickly decay. Studies undertaken by the Forest Products Laboratory (FPL), U.S. Department of Agriculture, have convincingly shown that when wooden elements in windows are treated with a water-repellent very little decay will occur in the new windows even if many years of maintenance neglect follow. This important finding was an outgrowth of a research project to determine alternatives to potentially toxic chemical wood preservatives.

Problem

When old wooden windows in historic buildings have to be repaired or replaced, it is always advisable to incorporate treatments that will extend the useful life of the new wood. Application of a water-repellent chemical preservative, such as pentachlorophenol, to new wood prior to painting traditionally has been recommended. The toxicity of some formulations, however, poses potential health problems. A treatment to prolong the useful life of the new wood — and therefore the windows — is needed which avoids certain potential health hazards.

Solution

A 20-year test on wooden windows by the FPL in Madison, Wisconsin, has concluded that there is a safer alternative to traditional water-repellent chemical preservatives for treating wood in order to prevent decay. It was found that the easiest way to prevent decay in woodwork items such as frames and sash is the application of small amounts of wax to the surface. The wax, in the absence of chemical preservatives, protects the wood from excessive moisture and provides good long-term protection to window units and other wood exposed above ground.

Twenty years ago, test window units at FPL were dipped for 3 minutes in either a solution of water-repellent with a chemical preservative or a water-repellent without chemical preservatives. Some units were left untreated as comparison controls. After only 6 years' exposure on an outdoor test in Madison, the untreated samples were so badly decayed that they fell apart as they were being removed. Figure 1 shows where three of the control (untreated) window units were installed. Figure 2 shows a portion of the untreated window frame and the extensive decay.

A close-up view of the window unit treated with a water-repellent chemical preservative shows how well this unit was protected against decay for 20 years (see figure 3). All test units were painted originally but never repainted. Most paint

Deteriorated architectural features should be repaired rather than replaced wherever possible. In the event replacement is necessary, the new material should match the material being replaced in composition, design, color, texture, and other visual qualities.
was gone from exposed surfaces after 10 to 12 years’ exposure. The water repellent with a chemical preservative treatment was very effective in protecting the window unit long after all the paint had weathered away.

But the most surprising result in the 20-year test was that shown in Figure 4. Window units treated with a simple water repellent (1.5 percent paraffin wax in mineral spirits plus 10 percent exterior varnish resin with no chemical preservatives) performed as well as did the water-repellent preservative (which contained both wax and a chemical preservative). This showed that a nonchemical water repellent like paraffin wax with a small amount of resin, such as exterior varnish, was capable of providing protection to wood exposed above ground to the elements for 20 years in a northern climate.

A water-repellent treatment alone can provide excellent decay resistance to outdoor painted woodwork without the addition of a chemical preservative. This can represent a saving of money and resources and judicious avoidance of chemical preservatives in items such as windows, sheds, porch and fence rails, and other above-ground wood products.

The water-repellent treatment is easily done before or after construction and before painting. A simple formula, easily prepared, is:

- Exterior varnish 3 cups
- Paraffin wax 1 ounce
- Mineral spirits Add to
- or paint thinner make 1
- or turpentine gallon

Treatment is best done by dipping the wood for 1 to 3 minutes in the solution. If dipping is inconvenient, liberal brush application can be made—paying particular attention to heavy treatment of all board ends and joints. The treated surface can be painted after 2 or 3 days of warm weather. In fact, paint should last longer over the treated surface than over untreated wood.
Conclusion

The field test conducted by the Forest Products Laboratory showed that there are safer treatments for protecting woodwork in northern climates than many commonly used. The combination of pretreating and painting provides good long-term protection against decay. Of equal interest, the test showed that there are effective ways to prevent decay in wooden window elements even where the windows are exposed to long periods of maintenance neglect.

In the southeastern states and in the Pacific Northwest where there is a high decay potential due to the combination of higher moisture and moderate to warm temperatures, it is still recommended that wooden windows be treated with both a water-repellent and a chemical preservative. A number of newer, less toxic chemical preservatives are now commonly available and will provide similar long-term protection.

Figure 4. Close-up view of window unit treated with a paraffin-wax water-repellent without a chemical preservative. After 20 years' exposure, firm wood resists penetration by the knife blade. Photo: Courtesy of the Forest Products Laboratory
This PRESERVATION TECH NOTE was prepared by the National Park Service in cooperation with the Center for Architectural Conservation, Georgia Institute of Technology, Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Coordinator for the TECH NOTES. Substantial portions of the text have been reprinted from "Protecting Woodwork Without Preservatives," by William C. Feist, Chemist. We wish to thank the Forest Products Laboratory, Forest Service, U.S. Department of Agriculture for their permission to reprint this material. Special thanks also go to the following people who contributed to the production of this TECH NOTE: John H. Myers, Center for Architectural Conservation, and Preservation Assistance Division staff, particularly Kay D. Weeks, Martha A. Gutrick and Mae Simon.

This and many of the TECH NOTES on windows are included in "The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings" (available late 1984), a joint publication of the Preservation Assistance Division, National Park Service and the Center for Architectural Conservation, Georgia Institute of Technology. For information, write to The Center for Architectural Conservation, P.O. Box 93402, Atlanta, Georgia 30377.

PRESERVATION TECH NOTES are designed to provide practical information on innovative techniques and practices for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures, and standards. This TECH NOTE was prepared pursuant to the National Historic Preservation Act Amendments of 1980 which directs the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to TECH NOTES, Preservation Assistance Division, National Park Service, Washington, D.C. 20240. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the author and the National Park Service are appreciated.

ISSN: 0741-9023 PTN-4 January 1984
LAWRENCE-WENTWORTH HOUSE
Lowell, Massachusetts

The Lawrence-Wentworth House, originally the home of one of Lowell's antebellum mill owners, has had numerous alterations and changes in use since its construction in 1831. Its original Greek Revival street facade was altered sometime after the Civil War to such an extent that it appears more Victorian than Greek Revival.

Beginning at the turn of the century, the single family residence was converted to a boarding house, a succession of commercial uses, and finally to offices for a social service organization. Sometime during this series of changes, the Victorian double-hung wooden sash on the first floor were replaced with mill finish aluminum jalousies as shown in the above photograph of the rear facade. The Victorian wooden sash, consisting of a two-over-two (2/2) light configuration, survived on the second floor.

After experiencing several years of sizable increases in energy costs, coupled with the inherently poor thermal performance of the jalousie sash on the first floor, the owner, Unitas, Inc., a service organization to Lowell's Hispanic community, came to the Lowell Historic Preservation Commission requesting assistance in replacing these visually obtrusive and thermally inadequate windows.

Design Problem
The Victorian 2/2 sash on the second floor were still in serviceable condition and were already fitted with storm windows. Consideration was therefore given to the installation of 2/2 replacement sash and frames on the first floor that would match the visual qualities of the remaining historic windows and at the same time incorporate the energy efficiency features of double glazing and weather stripping. Another important goal was to reduce cost without altering the appearance of the windows or affecting their performance.

Design Solution
Studies have shown that when treated with a water repellent coating, and properly fabricated and installed, new wood windows will provide long service. Since the exterior wood siding, trim, upper floor windows and painted masonry would all require periodic repainting, this maintenance consideration was not a major factor in the decision to install wooden replacement windows.

A full-scale measured drawing was made of an existing second floor window as a guide in detailing the replacement window. This investigation revealed that the single-glazed 2/2 sash were 1⅛" thick, and that the entire width of the box frame was exposed on the exterior.

In reaching the decision to install wooden windows, the important techni-

Replacement of missing architectural features or insensitive later replacements should be based on accurate duplication of features, substantiated by historic, physical, or pictorial evidence. The composition, design, color, texture and other visual qualities of the historic feature should be matched.
The selected replacement sash were designed to have two individual lights of insulating glass in each sash with an integral (as opposed to a "fake" or applied) muntin. Based on the experience gained by the Lowell Historic Preservation Commission in previous projects, the muntin of the new sash was made only 1" wide, closely matching the appearance of the historic ¼" wide vertical muntins remaining in the upper floor windows (see figure 1). This slight change in muntin width is hardly noticeable. The results might have been different if the old and new sash had existed side by side; if the number of panes had been greater and the panes themselves been smaller; or if the historic muntins had been thinner.

The new sash were made 1½" thick, an increase of ¼" over the historic sash, in order to allow a sufficiently deep rabbet in which to set the ½" insulating glass and to provide added support for the double weight of the glass.

Fabrication and Installation

Along with full scale working drawings for the new window, written specifications for both sash and frame fabrication and installation were prepared. These documents were sent to several window shops and installation contractors to obtain separate quotations for fabrication and installation.

The ten new windows were to be delivered fully primed and assembled. Of the ten windows, six were detailed for masonry openings and four for frame openings. No more than two windows were the same size, and there were seven different sizes in all. Only the six principal windows, averaging 21 square feet each, were of 2/2 configuration. Replacements for the four smaller jalousie windows, positioned in less prominent rear or side locations, away from the front of the building, were designed in 1/1 light configuration, but were otherwise identical to the larger windows.

Two types of a commercially-available rigid metal weather stripping, formed from rolled zinc sheets, were installed in preference to a less permanent vinyl, foamed plastic, or spring-metal weather stripping. At the heads, jambs and sills, the weather stripping consists of a continuous flange over which fit the grooved rails and stiles. At the meeting rail, the weather stripping consists of two interlocking hooks (see figure 2). The weather stripping protrudes only a short distance above and below the meeting rails along the jambs and is almost totally concealed when the windows are shut. It is extremely durable and is virtually unaffected by corrosion or chemical decomposition.

The sealed insulating glass units, installed in the fabricator's shop, were first caulked with a thin bead of non-hardening water-based (containing no oil) sealant. The sealant was applied at the corner of the glass unit so as not to touch the butyl compound used to seal the edge of the insulating glass (see figure 3). The water-based sealant serves as an important barrier between the separate butyl-seal on the insulating glass and the standard oil-based glazing compound as used in the actual glazing. The oil-based glazing compound was chosen in preference to the standard wood molding strips to provide a cheaper, more flexible and more weather-resistant glazing. It also matches the historic glazing treatment.

The historic windows in the Lawrence-Wentworth House were balanced in standard fashion with sash weights and pulleys. Since many were missing on the first floor, less costly spiral tube balances were specified for the new windows (see figure 1). The spiral tube balances were attached at their top to the face of the jamb near the top of the window. The longer balance tube for the lower sash, therefore, is visible above the closed lower sash inside the building, just as the sash cord is exposed on a weight balanced sash. The tube balances, however, are not seen from the exterior and their use permitted a more energy efficient window frame. The empty boxes, which would have held the sash weights, were filled with insulation; air infiltration was further reduced since there were no pulley mortises in the frame.

The spiral balances also allowed the use of a less expensive L-shaped, shop-fabricated frame, and the look of the historic box frame was accomplished with masonry-anchored nails, steel framing clips, and flat interior casing stock (see figure 1).

The new wooden frame was thus identical in appearance to the historic frame on the building. The width of the historic frame was reproduced along with the wooden brick molding used to trim the exterior of the masonry openings (see figure 4).
Figure 2. Several types of zinc weather stripping were used. Drawing: Penelope S. Watson

Project Costs

The ten windows were fabricated to specification, including such features as wood preservative treatment and sash locks, for $2520 ($13.40 per square foot).

The installation work, undertaken in 1983, included preparation of the window openings; installation of the windows and interior stops; and the attachment of exterior brick molding and all interior trim, which had been selected from flat or molded stock. Priming unprimed elements and caulking were also included in the installation work, which totaled $1800 ($9.52 per square foot).

Total cost of the ten windows less finish painting, which was done as part of the general exterior repainting, was $4320 ($22.92 per square foot). Wooden frame half screens mounted on the interior and set in aluminum tracks were also furnished and installed for a total of $490 for the ten windows.

Project Evaluation

The window work on the Lawrence-Wentworth House shows the practicality of replacing windows on a selective basis. In replacing only the first floor windows, significant cost savings were achieved and the 2/2 Victorian windows on the second floor were saved. This project clearly shows that energy conservation and other cost-reducing measures can be achieved in replacement windows that reproduce the visual qualities of the historic windows.

The use of spiral balances and insulating glass, the increase in the sash thickness, modifications to the box frames, and the slight widening of the integral wood muntin were accomplished in a sensitive way in keeping with the Secretary of the Interior's "Standards for Rehabilitation." This approach has limitations, especially when dealing with very thin historic muntins, where to accommodate the weight of insulating glass and for suitable glazing, the width of the muntin would have to be increased substantially. In many cases, however, involving two- and four-light sash, this application can be adopted without perceptibly increasing the width of the muntin or diminishing the historic character of the window.
This PRESERVATION TECH NOTE was prepared by the National Park Service in cooperation with the Lowell Historic Preservation Commission, and the Center for Architectural Conservation, Georgia Institute of Technology. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Coordinator for the TECH NOTES. Special thanks go to the following people who contributed to the production of this TECH NOTE: John H. Myers, Center for Architectural Conservation, Penelope S. Watson of the Lowell Historic Preservation Commission, and Preservation Assistance Division staff, particularly Michael J. Auer, Martha A. Gutrick, and Mae Simon. Photo on page 1 by Jim Higgins.

This and many of the TECH NOTES on windows are included in "The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings" (available late 1984), a joint publication of the Preservation Assistance Division, National Park Service and the Center for Architectural Conservation, Georgia Institute of Technology. For information, write to The Center for Architectural Conservation, P.O. Box 93402, Atlanta, Georgia 30377.

PRESERVATION TECH NOTES are designed to provide practical information on innovative techniques and practices for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures, and standards. This TECH NOTE was prepared pursuant to the National Historic Preservation Act Amendments of 1980 which directs the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to TECH NOTES, Preservation Assistance Division, National Park Service, Washington, D.C. 20240. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the author and the National Park Service are appreciated.

ISSN: 0741-9023 PTN-6 January 1984
Building 149 is a 10-story 700,000 square foot reinforced concrete structure built during 1917-1919 for use as a naval warehouse and offices. It is located in the National Historic Landmark Boston Navy Yard, which was established in 1800 and which comprises approximately 130 acres and nearly 90 buildings associated with the naval shipyard operations. Portions of the installation now owned by the Boston Redevelopment Authority consist of shipways, ware- houses, offices and residences. Vacant since the decommissioning of the shipyard in 1974, Building 149 recently has been renovated for use as offices and retail space by a private development firm under a long-term lease.

The building’s fenestration—nearly 2000 steel window units set within 500 openings—was considered a very distinctive feature of the building. Through careful planning and attention to detail, an innovative aluminum replacement window system was developed by the project team that successfully maintained most of the distinguishing features of the original windows.

Problems

The inside-glazed, historic green-painted windows had narrow ⅜” wide muntins with an exterior cove bead shape profile to the muntin. Most of the openings consisted of a bank of 4 side-by-side window units. Each of the middle two units consisted of 20 divided lites, including a 6-lite center hopper; the two end units were fixed and contained only 16 lites (see figure 1). Typical of pre-World War II steel windows, the glass panes had a narrower width than height. The vertical mullion connecting each unit was approximately 3” wide, noticeably dividing each opening into 4 window units.

The contractor’s survey of the historic windows in the spring of 1984 revealed that extensive rusting of the frames had occurred and that many were racked. The severe rusting had also contributed to the spalling of sections of the concrete sills, jambs, and spandrels (see figure 2). Repair and upgrading options to maintain the historic windows were quite limited due to the size of the glazing bars. The shallow depth of the metal glazing bars (muntins) seemingly precluded the installation of sealed insulating glass within the existing lites, even if the windows could structurally support the additional weight. The only practical way of double-glazing would have involved the use of interior storms with units that were either operable or were removable for ease of cleaning. Even then, however, the severe deteri-

Every reasonable effort should be made to match the historic windows when replacement windows are required.

Charles E. Fisher
Preservation Assistance Division
National Park Service
oration of the steel windows still would have needed to be addressed. Considering the size of the bay openings, the decision was made to replace the windows.

Four replacement options were considered:
1. Replacement with matching steel units in combination with an operable interior storm window system.
2. Installation of large sheets of insulating glass, maintaining the principal 4-part division of each bay while eliminating the small multi-lite pattern which existed.
3. Installation of large insulating glass units, maintaining the principal 4-part division, and applying an exterior aluminum grid in an attempt to recapture the appearance of the historic multi-lite steel windows.
4. Development of an aluminum window system with true divided lites with insulating glass, maintaining as close as possible the profiles of the historic glazing bars and overall historic appearance.

The use of steel replacement windows was considered only briefly because a double-glazed system in such large openings would be high in cost, and would not be able to retain the narrow sight lines and profile of this particular type of steel window. The existing profile was available in a replacement steel window but could accommodate only single glazing, which was not considered adequate by the developer for energy purposes. Thus an interior storm window would have been necessary; however, the large size of the window openings would have required an expensive commercial storm window.

Figure 1. Most of the openings consisted of a bank of 4 side-by-side steel window units. Each of the middle two units consisted of 20 divided lites, including a 6-lite center hopper; the two end units were fixed and contained only 16 lites. Photo: William MacRostie

A mock-up of the second alternative was installed, consisting of a fixed aluminum window with large sheets of insulating glass. Each opening had three vertical mullions, dividing the opening into 4 parts; this matched the principal division of the historic windows. Since the glass was not divided further into smaller lites, there was a dramatic change in the appearance of the building, and this alternative was quickly dismissed.

The third alternative, however, was seriously considered since it provided for an addition of an exterior aluminum grid applied to the face of the fixed aluminum window described in the second alternative. The grid was intended to simulate the appearance of the historic windows. The extruded aluminum grid would duplicate the cove-head profile of the exterior portion of the historic glazing bars and would be attached directly to the glass, using a special epoxy glazing tape. This system had been used recently by at least one developer on a similar project. The estimated fabrication and installation cost of this window solution was $1.1 million for the 500 openings.

The project director, Richard Graf of The Congress Group, Inc. (developer) and the Boston Redevelopment Authority (holders of the ground lease) both had reservations concerning the long-term performance of the exterior aluminum grid. In the late 1970s there had been a number of projects where wooden muntin grids had been glued directly to the glass and where subsequent failure had occurred. Besides the question of the performance of glued-on aluminum grids, there were some visual changes that would result from the exterior applied grid compared to the original glazing bars. The Boston Redevelopment Authority was also concerned over the growing use of false muntins in the rehabilitation of large industrial buildings within the historic navy yard and the negative impact it was having on the overall architectural character of the district.

These collective concerns and the need for rapid approval of the rehabilitation plans led to the decision by the developer in May, 1985 to choose a fourth alternative: an entirely new aluminum window system.

True divided lites with insulating glass would be used as part of the new system with muntin profiles and framing members that closely matched the historic design.

Planning

The project architect and construction manager were responsible for preparing preliminary design guidelines for the new window system. Two local window contractors submitted bid proposals. One company proposed that the glass be exterior-glazed using inte-
gral muntins that were close to 1/2" in width. The other company showed an interior-glazed window and claimed that the integral muntin could be made as narrow as 1/8". Since inside glazing would facilitate both installation and maintenance, the decision was made to work with this company in the design of the windows to be used in Building 149. The contractor's bid for this window system was $1.4 million, which was approximately $300,000 more than the applied grid.

Further development of the window system was required and the window needed to be performance tested—all requiring fast track scheduling. A development and construction team for the window work was assembled consisting of the following parties: the developer, the project architect, the window contractor, the window fabricator in Denver working with the window contractor, a testing laboratory in Boston that would assist with the performance needs and design of the window, the general contractor, a preservation consultant and an independent testing laboratory in Dallas responsible for final testing.

The engineering and design of the new window systems required close and frequent coordination between the various team members because of the number of important issues which needed to be resolved, all within a very short time frame.

One of the first major design issues to be resolved concerned the need to match as closely as possible the shape and dimensions of the original 3/8" wide glazing bar (muntin) with its decorative cove-bead exterior profile to simulate the profile of the original steel window muntins. The project team concluded that in order to keep the muntin on the aluminum window as narrow as possible, the traditional cast thermal break (cast plastic) feature of most modern windows could not be used. Instead, a series of spacers and gaskets were used as the principal means of obtaining a thermal break in the window for energy purposes. Drawing: Peter Charles

Figure 3. Drawing of the aluminum replacement windows shows how the cove-bead muntin profile of the original steel windows was closely matched in the integral muntin system designed for the aluminum replacement window. A series of spacers and gaskets were used as the principal means of obtaining a thermal break in the window for energy purposes. Drawing: Peter Charles

designed to ensure that moisture buildup behind the glazing tape would seep outside, rather than inside the building (see figure 3). A twenty-foot mockup was eventually constructed and successfully tested according to accepted industry standards.

A third important design consideration centered on how to keep the framing members and muntins narrow enough to maintain the thin profiles of the steel windows. The need for a thermal break in addition to the use of aluminum, which is structurally weaker than steel, necessitated some increases in sections and profiles. A technique more commonly found in skylight construction was used to hold the glass in place. This consisted of screwing members together rather than using snap-on aluminum sections to secure the glass. Snap-on sections would have required more metal and wider profiles.

A fourth design and engineering issue arose with the construction detailing of the muntin joints. The decision was reached to face glue the joint on the front and spot weld behind. The fifth issue concerned the visual impact of the spacer used in the insulating glass. The original plans called for an aluminum spacer that turned out to be too shallow in width to properly glaze the sealed insulating unit. Since the acceptable width required a slight encroachment beyond the edge of the muntin, there was a concern over the potential visual impact. By selecting a bronze spacer, the metallic reflection that would have occurred from the typical aluminum mill finish was avoided and the visible portion of the dark bronze spacer was not noticeable from the street below.

The sixth design issue, which ultimately was not resolved, concerned
operability of the windows for ventilation. While there were some advantages to having operable windows, they were not paramount considering the building's new use as offices. With aluminum frames, a 6-lite hopper or projecting section as existed in the historic windows was not considered practical at that time. The primary reason was the need to keep the aluminum sections as narrow as possible to match that of the original steel. Given the structural requirements of an aluminum window, it was considered possible to fabricate only smaller operable units (1-3 lites). With the tight construction schedule, the additional development time that would be required, and the higher construction costs, the decision was made to proceed with a fixed window. This meant that there would be a noticeable change in one feature of the historic windows as a result of deleting the hopper section in the middle of two window units. The overall appearance of the new window and the building itself was judged to be sufficiently close to that of the historic appearance, however, that a marked change in character would not result.

The seventh and last major design decision concerned the number of pane divisions to be provided in each of the four sections of the window openings. The relationship of solids to voids (frame to glass) was important to retain. Since the muntins were to be increased in width from ¾” to 1½”, discussions arose concerning possibly reducing the number of lites. Besides cost savings, changing the number of lites would help solve another problem stemming from plans to lower the sills due to the high sill height within the building. The lite pattern that was developed while reducing the number of lites, maintained the vertical orientation of the glass panes, and the proportion of solids to voids, further reducing any visual impact of the slightly wider aluminum muntins.

Window Design

The basic aluminum window unit consisted of 9 different aluminum extrusions, including the decorative cove-bead muntin. The muntin assembly actually consisted of 3 extruded aluminum sections. The principal muntin section was the cove bead portion that had a long glazing channel with a receptor at the end (see figure 3). Attached to the interior-facing side of the muntin was a U-shaped glazing stop secured by self-tapping screws to the receptor on the cove-bead section. This stop secured the glass in place. For aesthetic purposes, the stop had a snap-on cover to hide the screws and create clean lines on the interior. Through the use of neoprene gaskets and plastic and neoprene spacers, a thermal break was achieved, broken only by the screws.

While the horizontal muntins were continuous across the window unit, the vertical muntins had mitre joints where they intersected the horizontal muntins. The vertical muntins were secured through a combined use of epoxy glue and spot welding (see figure 4). A system of weep holes and channels was provided to ensure that any water trapped between the glazing tape and the glass and muntins would be diverted to the outside of the windows.

The overall window unit was not set into reglets as were the original steel windows but rather were bolted to the masonry because of the greater depth of the aluminum jambs. To keep the width of the frames sufficiently narrow to match the historic appearance, a ¾” wide jamb was designed, narrower than standard window jambs (see figure 5). Due to high wind loading requirements for Boston, steel reinforcing bars were needed at certain corner windows, but otherwise, the aluminum window system was designed and successfully tested with the narrow jambs.

Window Fabrication and Delivery

Through weekly meetings among the window project team, it was possible to provide for a rather complex manufacturing process for the overall windows that yielded cost savings and also met a very tight production schedule.

Figure 5. The frame of each window unit was designed with a width of ¾” in order to closely match that of the original windows. The frames were bolted to the face of the jambs, sill, and head of the masonry opening. Drawing: Peter Charles
The 9 extrusions required for the aluminum windows were manufactured in Portland, Oregon, and painted the historic green color in Salt Lake City; both companies had worked before with the fabrication plant. Fabrication took place in a window plant in Denver that previously had done work for the Boston-based window contractor. The fabrication work was complicated by the fact that there were a number of size variations for each of the 9 different types of windows in the building, although approximately 500 of the 2000 window units were the same size. The greatest variation occurred in the height rather than the width of the windows (see figure 6). A maximum of ¾" tolerance was allowed around the sides of the overall window units in each opening; such tolerance was necessary because many of the openings were skewed.

While the windows were being manufactured, the tempered glass, required by the Fire Department, was cut in a plant in Tennessee and shipped to Easton, Massachusetts, where the glass was made into insulating units. The window contractor helped to coordinate all this work and was responsible for insuring that the glass was properly sized and that the spacers in the insulating glass did not encroach more onto the visible glass area than was specified. A number of the units had to be sent back to the glass assembly shop in Easton due to inaccurate sizing or misalignment of the bronze spacer. This work involved

the greatest problem and biggest expense, since the limited tolerance for encroachment onto the glass area required very careful work (see figure 7).

Installation and Scheduling

While the windows were being assembled, the existing openings were being prepared. The work included the installation of all new cast concrete sills due to the lowering of the sill height. The windows were shipped to the site and installed unglazed.

The scheduling of the work reflected the fast track of the project as a whole. The decision to go with true muntins was made in May 1985; by June the general design of the window had been made and by July the final extrusion drawings were approved by the architect and consultant. By mid-August, the extrusion work was underway in Oregon and in September, the final testing by an independent laboratory in Dallas, Texas, was complete and the go-ahead for production was given. Fabrication started in September and the last of the windows were shipped from Denver in late December 1985. Installation of the windows began in January 1986 and final glazing was complete by June 1986, well in time to coordinate with the scheduled completion date.

The local window contractor was responsible for coordinating the extrusion and painting work, the window assembly, glass manufacturing and installation. Vital to the success of such complicated work was the close coordination and series of weekly meetings between the architect, developer, facade consultant, construction manager, and window contractor. During installation, the facade contractor—responsible for the rest of the exterior work—was also a participant.

Costs

The total cost of the window work was $1.4 million. It was hard to estimate the total development cost of the new window system, although design and testing cost somewhat in excess of $50,000. Despite the special work required and the complexity of the development and manufacturing work, the window system was only $300,000 more expensive than the grid system initially proposed and subsequently abandoned due to performance and aesthetics considerations. The resulting windows cost approximately $25 per square foot installed. Except for several changes at the building expansion joint, there were no cost overruns due to the window design. The window contractor, however, absorbed some unforeseen labor costs in this initial project.
Evaluation

The window work at 149 Constitution Park was noteworthy in several ways. First, it represented a significant improvement over past attempts to recapture the distinctive qualities of a steel industrial window with narrow cove-head glazing bars, using an aluminum replacement system with insulating glass (see figure 8). Equally important was the manner in which the new window system was developed for the project.

The risks that were inherent in developing a totally new window system for a large rehabilitation were minimized by the team of highly qualified people; who coordinated closely and who kept to a tight schedule. The additional costs incurred in the development of the new window was not excessive considering the massive size of the project; the manufacturing and installation of the new windows with true divided lites did, however, appreciably increase the cost of the window work. The results, however, are quite impressive and this innovative window system is commercially available for use in other projects.

This project shows just one way that significant improvements can be made on the quality of aluminum replacement windows used in historic buildings. The planning team involved in this project also identified further improvements that might be possible with this particular window system. While the new windows lack the hopper detail and altered the size and number of the muntins, many of the characteristics of the large steel industrial windows have been retained.

The project team were concerned not just with appearance but also with quality, engineering and high performance. This is important since poorly built windows, whether old or new, can lead to excessive maintenance and high energy costs. The assembled team brought together the different professions and perspectives needed to produce an energy-efficient, cost-effective and aesthetically acceptable product.

While the window work was on a fast track from planning to completion, the decision to address the window issues early in the overall planning of the project provided the necessary lead time. Too often, window issues are addressed late in the planning of a project, providing little time to fully explore available treatment options. Where an innovative solution is necessary, as with 149 Constitution Park, extensive planning is crucial to the successful execution of the work.

Figure 8. The window work at 149 Constitution Park represented a significant improvement over past attempts to recapture the distinctive qualities of a steel industrial window with narrow cove-head glazing bars, using an aluminum replacement system with insulating glass. Success was achieved through careful and well coordinated planning. Photo: Charles Fisher.

PROJECT DATA:

Building:
149 Constitution Park
Charlestown Navy Yard
Boston, Massachusetts

Developer:
The Congress Group, Inc.
Boston, Massachusetts

Project Dates: 1985-86

Project Director:
Richard Graf
The Congress Group, Inc.
Boston, Massachusetts

Architect:
Amir Man
Project Architect
Huygens and DiMella
Boston, Massachusetts

Construction Manager:
Morse/Diesel
Boston, Massachusetts

Consulting Testing Laboratory:
Thompson and Lichtner
Boston, Massachusetts

Testing Laboratory:
The Dallas Laboratories
Dallas, Texas

Preservation Consultant:
William MacRostie
Heritage Consulting Group
Washington, D.C.

Windows:
Custom Windows
Denver, Colorado
L. Rubin Glass and Aluminum, Inc.
Saugus, Massachusetts

Project Costs:
The total construction cost of the window work was $1.4 million or $25 per square foot of window.
There were additional development costs for the design and testing of the window which were approximately $50,000.

This PRESERVATION TECH NOTE was prepared by the National Park Service in cooperation with the Center for Architectural Conservation, Georgia Institute of Technology. Charles E. Fisher, Preservation Assistance Division, National Park Service serves as Technical Coordinator for the PRESERVATION TECH NOTES.
Information on the rehabilitation work at 149 Constitution Park was generously supplied by Richard Graf, Project Director, The Congress Group, Inc. Thanks also go to Peter Charles, Architect, Center for Architectural Conservation, for the drawings appearing in this Tech Note and to the following Preservation Assistance Division staff who contributed to the production: Michael Auer, Brenda Siler, Kay Weeks, and Theresa L. Robinson.

This and other Tech Notes on windows are included in "The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings; a joint publication of the Preservation Assistance Division, National Park Services and the Center for Architectural Conservation, Georgia Institute of Technology. For further information write to The Center for Architectural Conservation, P.O. Box 93402, Atlanta, Georgia 30377.

PRESERVATION TECH NOTES are designed to provide practical information on practices and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards.

ISSN: 0741-9023
PTN-22
December 1986
MILLS NOS. 5, 6 and 8
Suffolk Manufacturing
Company
(Wannalancit Office and
Technology Center)
Lowell, Massachusetts

The three connected buildings of the former Suffolk Manufacturing Company in Lowell, known as Mills Nos. 5, 6 and 8, were built in 1862 (No. 5) and 1880 (Nos. 6 and 8), at a time when the city of Lowell was one of the predominant centers of the textile industry in the United States. Located within the Locks and Canals National Register Historic District, this impressive complex of mill buildings housed in more recent years a synthetic textile weaving operation under the ownership of the Wannalancit Textile Company. In 1981 the buildings were acquired for development as the Wannalancit Office and Technology Center, a project involving 286,000 square feet of rental space.

The long unbroken pattern of some 900 small-paneled windows dominates the facades of these buildings and is clearly their most significant architectural element. At the time of the conversion to an office complex, the original double-hung windows, arranged with 12-over-12 lights, had survived in Mills Nos. 6 and 8, but virtually all the sash and some of the frames had been removed form Mill No. 5 (see figure 1).

Design Problem

Appropriate window treatments quickly emerged as the major preservation design problem in this $8.5 million rehabilitation. From the outset it was established that the appearance of the historic windows would have to be retained on all elevations; this meant duplicating such features as the reveal, trim detailing, double-hung configuration, and particularly the multi-pane appearance created by the muntin pattern.

The first step was to evaluate the condition of the original windows that had survived in Mills Nos. 6 and 8 to establish whether the historic windows were repairable. Based on an in-depth inspection, the windows were judged beyond reasonable repair due to their deteriorated condition (see figure 2). Once the decision to replace the historic sash had been reached, consideration was given to replacing them with matching custom-made wooden windows. The developers obtained a quotation of $875 per window for fabrication and installation of 900 matching wooden replacement units, with integral muntins in a 12-light configuration and the addition of an interior storm panel. Due to cost, the developers decided to consider other alternatives.

The decision was reached to evaluate the cost and appearance of a non-wooden, double-glazed, prefinished, single-hung window with applied muntins grids on the exterior rather than integral muntins. The objective was to determine whether a non-wooden commercially available window could closely match the configuration and appearance of the historic windows. To achieve this result, several window manufacturers were invited to install field mock-ups. Six manufacturers responded—

Aluminum Replacement Windows with Sealed Insulating Glass and Trapezoidal Muntin Grids

Charles Parrott
Lowell Historic Preservation Commission

Deteriorated historic windows should be repaired rather than replaced wherever possible. In the event replacement is necessary, the new windows should match the historic ones in design, color, size, configuration, reflective qualities, shadow lines, detail and material. Only where it is not feasible to match the historic fabric should substitute window material be considered for use and only when it is shown through such means as field mock-ups that it is possible to match closely both the detail and the overall appearance of the historic windows.
four aluminum windows were installed as part of the selection process, along with the one vinyl and one aluminum-cladded wooden unit.

The criteria used in evaluating the field mock-ups included performance and cost, but focused primarily upon appearance due to the significant contribution of the windows to the historic character of the building. In considering the various proposed window replacements, criteria established for the window work included:

1. Retaining the historic reveal of the window—the location of the sash relative to the outer wall surface.
2. Matching the double-hung window style and having sufficient depth between the glass planes of the upper and lower sash to create an appropriate shadow where the upper sash overlaps the lower sash.
3. Matching as closely as possible the proportions and the width of the sash members, such as the stiles and meeting rails.
4. Duplicating the glass pattern of 12 lights in each sash.
5. Having an applied muntin grid that was not only permanent but that closely approximated the historic shape and width and that also had sufficient depth to create good shadow lines.
6. Having appropriate paint color.
7. Retaining the appearance of the historic frame and brick molding details.
8. Incorporating energy conservation features.

One of the aluminum window mock-ups did contain real muntin bars, dividing each sash into 12 individual, double-glazed lights. The width of the muntins, however, was far too wide. With the insulating glass, there were technical limitations that prevented the manufacturer from making any major modifications, especially in the size of the muntins.

**Design Solution**

One of the aluminum windows did stand out as the most promising match of the historic units, and with further modifications eventually was selected as the replacement window for the project. The replacement unit was one of the manufacturer’s standard single-hung sash models modified to accept an exterior muntin grid on each sash, creating the appearance of 12 divided lights. The window assembly also incorporated a custom-extruded and curved aluminum pan over the existing wood frame and trim.

**Frame and Brick Molding**

The historic wooden frames were retained and used as a structural sub-frame on which to fasten the new aluminum trim and frame members. A custom extruded aluminum pan was used that fitted snugly around the exposed face of the original frame and maintained the face width and depth of the casing at both jamb and head. The original wooden brick molding (which covers the joint between the masonry and the window frame) was fitted with a custom-extruded aluminum pan (see figure 3).

At the head of the wooden frame, the aluminum pan was constructed in two pieces, both custom extrusions. The flat face of the lower piece was cut on a curve to follow the segmental curve of the masonry opening. The upper piece, which replaced the original brick molding, was custom-bent to the segmental curve and blind attached to the lower piece of aluminum (see figure 4). An additional aluminum pan was fitted tightly to the original wooden window sill (see figure 5).

When the aluminum window frame was inserted, it included its own sill in the place where the bottom rail abutted the sill of the original window. This second sill unfortunately added an element not present in the original window (see figure 6).

**Muntin Grid and Sash**

A new type of applied muntin grid was developed to give the appearance of a 12 light division in each sash. To avoid the flatness of most applied metal muntin grids, the aluminum sections were extruded in a trapezoidal shape to resemble more closely the historic shape of the rabbed wooden muntin and beveled putty seal. The 3/4" wide muntin bar has an exterior depth of 1/2", dimensions nearly identical to those of the original wooden windows. Even though the muntin bar does not extend through to the inside, the field mock-up showed that the shadow lines were sufficiently strong to create from the exterior the overall effect of a 12 light sash.
Figure 3. Horizontal section of both the original wooden window and the replacement aluminum window. Drawings: Penelope Watson

Figure 4. A custom-extruded aluminum pan was installed, duplicating the brick molding detail and, at the head of the frame, custom bent to follow the segmental curve of the masonry opening. Photos: Charles Fisher
Figure 5. Vertical section of both the original wooden window and the replacement aluminum window. Drawings: Penelope Watson
The manufacturer’s stock sash accommodated the muntin grid with only minor modification. The stock sash contained a single light of 7/8” thick insulating glass (two 1/8” glass panes separated by a 5/8” air space) fastened in a 1 1/4” thick sash. As modified for the muntin grid, the insulating glass was narrowed to 1/2” (two 1/8” glass panes separated by a 1/4” air space) to provide the depth for the grid to be contained within the sash. The beveled edge of the muntins was continued around the glass edge of the rails and stiles as well, in order to duplicate the angled putty seal line of the original sash. The grid was securely set into the sash frame as the sash was being assembled.

Visually, the exposed face of the aluminum window is wider than the wooden sash because the face of the new frame and sash are practically in the same plane and read as one. As a result, the face width of the new upper sash stiles (which visually includes the vertical face of the new aluminum frame) is wider (2 1/2” vs. 1 1/2”) than the face width of the historic sash (see figure 4). At the lower sash, the new frame stands out as an additional member not present in the historic windows.

An increase in size also occurs at the meeting rail. The resulting encroachment on the historic glazed area is noticeable, though fortunately the large window opening lessens the visual impact of the heavier meeting rail. Redesign of the meeting rail to achieve a narrower face dimension was not attempted for this project because any change in these extrusions would have necessitated retesting of the window with the new meeting rail to determine its compliance with the standard Architectural Aluminum Manufacturer’s Association (AAMA) specification for this window—a costly and time-consuming process.

**Custom Color**

Windows of Lowell’s textile mills were usually painted light colors—often white—in the 19th century. Through paint research, it was established that an off-white was the original color of the windows at the Suffolk Mills; later in the 20th century they had been painted dark green. In an effort to recreate the light value of the original color without necessarily duplicating the exact hue, a cream color was selected. The thermosetting acrylic enamel paint was factory-applied to the extrusions before window assembly. Due to the large number of windows involved, the cost of the custom color was negligible and did not affect the construction schedule.
Window Fabrication and Installation

The historic window openings were prepared for the new aluminum windows by removing interior sash stops, the parting beads, sash pulleys and exterior brick molding at the head. For each window, the head, jamb and sill panning was then applied using the extrusions custom-made for this project.

The new window units were delivered to the site preassembled. The operable bottom sash was temporarily removed from the new aluminum window unit, and the unit (frame and fixed upper sash) was set into the old sash opening and screwed into the pulley stiles of the old window frame. Finally, the operable bottom sash was installed and all exterior joints caulked. Later, flat wood trim was placed around the interior of the opening to finish the interior joints and complete the enclosure of the original frame.

Project Evaluation

The replacement of the windows at the Wannalancit Office and Technology Center was a pioneering effort in using stock aluminum windows specifically modified for large historic industrial buildings with single-hung sash and multiple divided lights. The results achieved in adapting these existing stock units are noteworthy, including the high cost savings achieved by adapting existing units rather than developing and producing completely new aluminum windows. Both the developers and the preservation review groups involved felt that the performance criteria and visual considerations were satisfactorily met in this case, especially considering the then-prevailing state-of-the-art. Subsequent modifications in similar window systems over the past several years have achieved even a closer match of the visual characteristics of historic windows.

Insulation and infiltration values of the new aluminum windows were considered acceptable by the owner; the modifications made to the stock units only minimally reduced the energy efficiency. The insulation U-value of the window with 1/2" insulating glass measures .62 while the 7/8" insulating glass achievable in the same window without the muntin grid would have been .54. The infiltration rating for this DH-A2.5 H.P. speci-
Figure 7. Replacement window after installation. Photo: Charles Parrott
PROJECT DATA:

Buildings:
Wannalancit Office and Technology Center
Mills Nos. 5, 6 and 8 of the former Suffolk Manufacturing Company
650 Suffolk Street
Lowell, Massachusetts

Owner:
Dobroth and Fryer, Inc.
650 Suffolk Street
Lowell, Massachusetts

Project Date: Spring 1983

Architects:
Perry Dean Rogers, Inc.
177 Milk Street
Boston, Massachusetts

Window Manufacturer:
North American Manufacturing, Inc.
551 Concord Street
Holliston, Massachusetts

Window Installer:
Atlantic Window Co.
15 Carr Road
Saugus, Massachusetts

Preservation Review Agencies:
National Park Service
Lowell Historic Preservation Commission
Massachusetts Historical Commission

Project Cost:
The total fabrication and installation cost was $415 each for 906 windows on Mills Nos. 5, 6 and 8. The supply cost was $240 per window; the remaining $175 included removal of the old window and the installation and trimming of the new window. The per square foot cost was $12.20 on windows 4' wide by 8 1/2' tall. An additional 250 windows will eventually be installed in Mill No. 10.

This PRESERVATION TECH NOTE was prepared by the National Park Service in cooperation with the Lowell Historic Preservation Commission, and the Center for Architectural Conservation, Georgia Institute of Technology. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Coordinator for the PRESERVATION TECH NOTES. Special thanks go to the following people who contributed to the production of this Tech Note: Penelope S. Watson of the Lowell Historic Preservation Commission and Preservation Assistance Division staff, particularly Michael J. Auer, Terry Robinson, Brenda Johnson, and Janet Thomas. Cover Photo copyrighted by Jim Higgins.

This and many of the PRESERVATION TECH NOTES are included in “The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings,” a joint publication of the Preservation Assistance Division, National Park Service, and the Center for Architectural Conservation, Georgia Institute of Technology. For information, write to the Center for Architectural Conservation, P.O. Box 93402, 8 Atlanta, Georgia 30377.

PRESERVATION TECH NOTES are designed to provide practical information on innovative techniques and practices for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures, and standards. This Tech Note was prepared pursuant to Federal tax laws which direct the Secretary of the Interior to certify rehabilitations of historic buildings that are consistent with their historic character; the advice and guidance provided in this Tech Note will assist property owners in complying with Federal requirement for tax incentives for historic preservation.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Preservation Assistance Division-424, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127.

ISSN: 0741-9023

PTN-15
September 1985
BOOTT COTTON MILLS  
(The Boott Mills)  
Lowell, Massachusetts

The complex of buildings which make up the Boott Mills is considered one of the best examples of a large 19th-century New England textile factory. The 3,000 double-hung windows, most of which are 3½' x 7' in size, are a distinguishing characteristic of this interconnected red-brick grouping of nine mills, a counting house, and a cotton storehouse. The point-grid patterning of these windows, rhythmically punched into the multi-story plain brick walls, and the nearly uniform 12-over-12 configuration of lights tightly stretched over the facades, creates an austere yet powerful composition evident not just in the first four mills of the mid-1830s but in the additions that continued until 1899. Rather than being subservient to more richly detailed wall treatment, the windows became the dominant element of detail and decoration for the Boott Cotton Mills. Many other textile mills of the 19th century could be characterized in this way.

The rehabilitation of the Boott Mills complex, located in a National Historic Landmark district, presented the opportunity to arrest decades of neglect and deterioration and to re-establish the important historical and architectural contribution of the windows. This Tech Note will explain the work that led to an innovative solution, combining alu-

Deteriorated historic windows should be repaired rather than replaced wherever possible. When replacement is necessary, the new windows should match the historic ones in design, color, size, configuration, reflective qualities, shadow lines, detail and material. Only where it is not feasible to match the historic material should a substitute be considered and only when it is shown through such means as field mock-ups that it is possible to match closely both the detail and the overall appearance of the historic windows.
The windows are the dominant element of detail and decoration in the Boot Mill Cotton Mills. Photo: Courtesy of the Center for Lowell History

Problem

The projected three-phase, $63 million rehabilitation of the Boot Mill involves 700,000 square feet of space. An appropriate window treatment was foremost among several important preservation design problems. The developer and the historic review committee agreed that one-over-one aluminum replacement windows with exterior muntin grids were not desirable. Because of the significance of the complex, it was established that the windows needed to have true divided lights and that the dimensions and profiles of all visible elements would be near copies of the originals (see figure 1).

Restoration of the existing windows was one solution that was considered. This approach was undertaken on one late 19th century facade where the windows retained structural integrity due to oversize muntins and a mild weather exposure. However, the results of the architect’s survey of the windows concluded that the vast majority of the surviving wooden sash were deteriorated well beyond repair. The historic windows had indeed fared badly in the decades following the collapse of the New England textile industry after World War I. The lack of proper building maintenance beginning at that time has been documented by historians studying the business and labor history of the Boot Mill. The only significant window work during the waning textile operation at the mill resulted in the spot replacement of many of the 12 light sash with 6 light sash. Virtually no work, including painting, had been done on the windows following the cessation of textile production in 1954. The one exception was the replacement of several hundred windows on the exposed river elevations that had been destroyed by an off-site explosion in 1976 and replaced with inexpensive aluminum double-hung, single light sash.

The developer and architect next investigated the replacement with wooden reproduction windows. Several wooden window manufacturers were approached for design and price quotations for a custom window with true divided light sash that maintained the historic sight lines of the visible members of the window. At the same time, the project team investigated the possibility of developing an aluminum true-divided-light sash that would satisfactorily duplicate the historic wooden window while providing for double glazing. A new aluminum window system would result from their efforts.

Window Design

In the fall of 1988 the developer and architect turned to a manufacturer with whom they had previously worked and proposed the development of a vertical sliding aluminum sash window which would contain true divided lights with thin muntins and members with dimensions and finish profiles that match those of the historic wooden window.

Over the next few months, the following basic requirements were established for the new window:

- True-divided lights/integral muntins
- Dimensions and profiles of all visible members that virtually duplicate the historic window
- “Wet” glazing for small divided lights
- Double glazing
- Thermally broken unit
- Aluminum construction with factory-applied paint

Figure 1. The windows are the dominant element of detail and decoration in the Boot Mill Cotton Mills. Photo: Courtesy of the Center for Lowell History

Figure 2. Because of the historic character and significance of the complex, replacement sash needed to have true divided lights and the dimensions and profiles of visible elements needed to be close copies of the originals. Photo: Courtesy of Huygens DiMella Shaffer
7. Conventionally weatherstripped and counterbalanced vertical sliding sash
8. Retention of the historic wooden frame as the receptor for the new window system

Although the latter five requirements are typical of most recent historic building rehabilitations, achieving the first two demanded that a new window system be developed. Recent aluminum replacement windows on historic rehabilitation projects were nearly all based on available window systems, limiting the flexibility to closely match specific windows on a project-by-project basis. In addition, the thin muntins typical of 19th century multiple-light sash could only be achieved through use of an exterior aluminum trapezoidal grid against the exterior sheet of glass. The near-universal industry use of sealed insulating glass necessitated true-divided aluminum muntins that were excessively wide. In the case of the Booth Mills, use of a standard true divided light aluminum window with insulating glass would require muntins over twice the width of the historic 5/8"-wide wood muntins.

In order to permit the use of true muntins of sufficient narrowness at the Booth Mills, it was necessary to limit the muntin-supported glass panes to single glazing, as in a historic window, and to achieve double glazing with a secondary window system (see figure 3). This secondary window consisted of a "piggy-back" interior glazing panel, which left exposed on the exterior the multiple facets of the true divided lights so characteristic of historic multiple-pane windows. The interior glazing panel was attached to the room side of the sash. It was also decided that the existing wooden frames would be retained and used to receive the aluminum sub-frame for the new window. Finally, new aluminum extrusions were to be made for all members to ensure a very close match to the historic units.

The design work evolved into a back-and-forth exchange of full-scale details between the architect, developer, contractor, and manufacturer. First, the architect produced section details of the late 19th-century window at Booth Mills to serve as a basis for sight-line matching. (The early 19th-century windows were similar, but had thinner sash members, a flat-headed masonery opening instead of an arched opening, and generally a smaller overall height.) From these drawings, the manufacturer began to design the new window.

**Window Detailing**

The manufacturer's initial design roughed out the first technical details for the new system, including:

- duplication of the face dimensions of the meeting and lower sash rails;
- duplication of the face dimensions of the stiles and head rail, taking into account the addition of the new aluminum sub-frame;
- vinyl snap-on interior grid to snugly fit the glass against the sealant, provide a thermal break and approximate the appearance of the interior profile of the muntin; and
- extruded reveals in the sash to receive the piggy-back panels so as to conceal the panel frames from the exterior;
- thin sill extension of the sub-frame beyond the exterior face of the lower sash to minimize the introduction of a non-historic double sill; and
- shaft extension of the sash-lock arm to extend below the intruding piggy-back panel of the upper sash.

The first muntin design was an adaptation of the true-divided-light muntin developed by the manufacturer in 1985 for another historic rehabilitation project (see Tech Note Windows No. 12). It
was narrowed and profiled to approximate the beveled glazing bead and sticking of the historic wooden muntins. However, it was found that the technology of the 1985 three-piece muntin system could be reduced only to about 7/8" in thickness. A new two-piece true muntin was then developed by the manufacturer that met the general dimensions and profile of the putty-glazed historic muntin; it provided the needed strength and proved to be simpler in design and less expensive to fabricate. This muntin consisted of an aluminum tee extrusion with a trapezoidal flange and a web terminating in a triangle-shaped point over which a profiled cover of extruded rigid PVC was snapped to hold the glass panes in place. Plastic was used for this cover to provide the flexibility needed to remove the cover in case of glass breakage and to provide the thermal break to insulate the aluminum tee member. The snap cover extrusion was to be made in the pre-selected custom color chosen for the window (see figure 4).

The framing and new muntin designs were supplied to the architect who prepared full-scale sections to show how the new window would be installed in a repaired window frame. To conform more precisely to the visible features of the late 19th-century window, the architect modified the inside edge of the rail and stile extrusions to include the beveled shape of the historic glazing putty. Revisions were incorporated by the manufacturer as the design evolved and further refinements were added.

On the sub-frame, a drip edge that broke the sight line at the head was eliminated as unnecessary. The detailing of the sub-frame was also revised to facilitate installation into the existing frame from the building interior. This resulted in a cleaner interior finish; however, it also increased the height of the sub-sill, making it somewhat more visible on the exterior. The overall depth of the early design was also reduced, resulting in a final depth only about 1/8" larger than the historic window. Because the muntin had to clear the piggy-back panel behind it, the overall muntin depth was to be 1 7/16", just 3/16" less than the historic ones (see figure 5).

Refinements were also made to the piggy-back panel. In the original version, they were clipped into a frame revealing the inner face of each aluminum sash. As revised, the panel frame was fastened more substantially using receptor channels along the rails of both sash and tamper-proof turn buttons fixed into a slot along the stiles. This modification greatly eased panel removal and reinstallation for cleaning and maintenance. It also produced a cleaner, more finished interior appearance.

Before die production was initiated by the manufacturer, a full-scale mock-up of one typical window was custom-built from aluminum stock, duplicating the exterior sight lines of the new extrusions. The window was then compared visually to a repaired and painted existing wooden window, to determine whether the new window sufficiently matched the historic appearance.

After evaluating the mock-up, two additional extrusions were developed at the recommendation of local preservation officials to create a narrower meeting rail for use in certain windows. This was determined necessary since the early 19th-century sash had sight lines much narrower than the later ones—all face widths of sash members were 3/4" narrower. Since this was especially noticeable at the extremely narrow 3/4" meeting rail of these early windows, an alternate extrusion pair was developed that narrowed the meeting rail to 1/8", for use where the early 19th-century sash were to be replaced. The 3/16" was as narrow as technically possible.

**Existing Technology**

Various features of the new window involved relatively standard aluminum window industry auxiliary materials and design techniques. These carefully selected components permitted most of the development costs to address visual requirements. These components included:

- block-and-tackle sash balances for the lower sash—the upper sash is fixed but removable for maintenance;
- an insulating, plastic thermal break between the interior and exterior halves of the sash frame;
- plastic "wool" pile with fin seal (at head, meeting rail and jambs) and vinyl bulb (at sill) weatherstripping held in shallow slots in each extrusion to control air and water infiltration between both moving and fixed extrusions;
- silicone rubber-edge blocks to cushion the glass panes against their rabbets in the aluminum extrusions;
- "wet" sealant (silicone) to glaze the small individual lights; and
- custom-colored, rigid PVC snap covers at the jambs to cover the sash balances and provide a weather seal.

The muntin joinery also applied existing techniques to the problem of creating a structural grid capable of adequately supporting independent glass panes (just as in a wooden multiple-light sash.) As in a wooden window, the vertical muntins are continuous from rail to rail, with horizontal muntins individually pieced in between. The continuous vertical member minimizes the introduction of water into the joint, just as it does in a wooden window. The ends of the horizontal bars are coped to the profile of the extrusion, and the vertical
muntin is drilled to accept a stainless steel pin which is force fit through the connection. An extruded longitudinal hole through the muntin accepts the pin into the horizontal members. Where the muntins intersect the stile and rail extrusions, a welded connection is used to minimize the penetration of water into those members. The interior snap cover is cut and fit in like manner—continuous vertical members with pieced-in horizontal sections coped around the ogee profile.

**Window Fabrication and Installation**

After approval of the mock-up for its ability to reproduce the appearance of the historic wooden windows, cutting of dies and production of extrusions proceeded during the summer and fall of 1989. A full scale window was constructed for performance testing to the standards of the American Architectural Manufacturers Association (AAMA), the industry’s standard-setting body for aluminum windows. The performance evaluation was done by an independent testing laboratory and was certified to meet the specified standards. By spring 1990, the new windows were being installed at the site.

Windows were fabricated in several different sizes according to the dimensions of the sash opening of the existing wooden frames. All new sash had 12 lights or more, replicating the configuration of the original sash.

The aluminum components of the
Costs

In the first two phases of the project, wooden window frames were repaired and new aluminum sash installed in 522 windows. In addition, new wooden windows were installed in a highly visible entrance location of the first floor. Work on another 1,031 windows remain to be undertaken under the third phase of the project. The standard window averaged about 3½' by 7' or about 25 square feet in area.

Because of the large number of windows needing replacement at the Boot Mills, the associated development costs for the new window were within reason—approximately ten dollars per window. Smaller projects can now benefit from the development of this window system. It is estimated by the manufacturer that an order of 100 windows, involving a 12-over-12 light window like that at Boot Mill (3½' x 7'), would cost today around $28 per square foot or $686, plus shipment and installation.

Evaluation

The sash replacement work undertaken to date at the Boot Mills represents an advance in the way in which aluminum windows can be designed to capture more fully the authentic appearance of historic windows in larger buildings while providing good overall performance. The treatment of the muntins and the sash framing elements, the piggyback glazing panel, and the retention of the exposed historic wooden frame all combined to create a window that was aesthetically pleasing and that retained many of the important historic qualities of the original windows (see figure 8).

Particularly notable was the development of a true divided-light hung-sash window in aluminum where the muntins reproduced the narrow widths of the historic wooden sash. The use of the piggyback panel to provide double glazing facilitated matching the appearance of the muntin on the primary glazing. By having the primary glazing set within true muntins, the characteristic nuance imparted by individual panes of glass is visible on the outside of the building.

The relatively small size of these mill windows (3½' x 7') made possible the use of true-divided lights with aluminum muntins that matched the dimensions of the historic ones. For very large windows, additional engineering and testing would be necessary to establish the feasibility of this approach.

Another important component of the overall success of the Boot Mill window approach was that new rail and stile framing components closely matched the sight lines of their wooden counterparts. This is especially important with respect to the narrow meeting rail typically found in historic windows. The retention of the historic wooden frame as a finish element of the window system was also an important feature of this project. This avoided the normal practice when installing aluminum replacement units of either removing the wood frame altogether or sheathing it in break metal or an extruded pan.
With the Boott Mills project, the old wooden frame served as a convenient anchor for the replacement window system. With no technical need to cover the historic frame on the outside, it was therefore possible to preserve all the visual qualities of the original wood frames. For the developer, the achievement of the perceived operating and maintenance advantages of a new aluminum window system ended at the old frame, thus allowing its retention as an aesthetic and historical feature. Although the new design is set up for use in the existing wooden window frame, the lengthening of the jamb and head extrusions and redesign of the frame would permit its use in cases where the wooden frames are missing or severely deteriorated beyond repair.

As with any successful window solution, there are opportunities for refinement. Modification of the glazing vinyl gasket and associated extrusions was subsequently acknowledged as an area for potential improvement, to approximate more fully the historic muntin profile around the sash frame. The sill of the aluminum sub-frame could also have been detailed better, following more the slope of the original wood sill.

This special application of aluminum window technology in response to historic preservation concerns in the rehabilitation of the Boott Mills was the result of a unique combination of individuals and events. Although the cost of this window solution was about the same as a custom replacement wooden window, in terms of historic preservation, it represents a substantial design and technology improvement in aluminum windows (see Tech Note Windows No. 13).

While in many cases the historic character of specific buildings would preclude the use of such a retrofit solution, it has applicability to many large-scale buildings where the existing windows are beyond repair and where replacement with wooden windows, even though upgraded in thermal performance, is not a viable alternative. It illustrates the need for advance planning and the willingness of the developer, the window manufacturer and preservation groups to work together, as they did in this case, to improve the quality of replacement windows installed in historic buildings. In the end, these parties discovered that to achieve a much closer match of a wooden window, the aluminum window had to be built very much like it (see figure 9).

Figure 8. Replacement window sash after installation. Photo: Charles Parrott

Figure 9. The window solution represents an important advance in the way in which aluminum windows can be designed to capture more fully the appearance of historic windows in larger buildings. Right photo shows wood sash in bottom row and aluminum in the upper three rows. Photos: Jim Higgins ©
Developer Representative:
Richard Graf, Vice President
Congress Group Properties

Architect:
Amir Mann
Project Architect
Huygens DiMella Shaffer
Boston, Massachusetts

Preservation Consultant:
William MacRostie
Heritage Consulting Group
Washington, D.C.

Window Manufacturer:
Custom Window Company
Englewood, Colorado

THE PRESERVATION TECH NOTE was prepared by the National Park Service. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as Technical Editor of the PRESERVATION TECH NOTES. Information on the window work at Boott Cotton Mills was generously supplied by Richard Graf, Vice President, Congress Group Properties; Dick Gann and Allan Brown, Custom Window Company; and William MacRostie, Heritage Consulting Group. The following National Park Service staff also contributed to the production of this Tech Note: Ward Jandl, Michael Auer, Timothy Buehner, Theresa Robinson, Robert Powers and Dalhia Hernandez. Cover historical photo: Center for Lowell History, University of Massachusetts at Lowell.

This and many of the PRESERVATION TECH NOTES on windows are included in "The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings," a joint publication involving the National Park Service and the Georgia Institute of Technology. For information write: Historic Preservation Education Foundation, P.O. Box 27080, Central Station, Washington, DC 20038.

PRESERVATION TECH NOTES are designed to provide practical information on traditional practices and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures, and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act Amendments of 1980 which direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Preservation Assistance—424, National Park Service, P.O. Box 37127, Washington, D.C. 20013-7127
ISSN: 0741-9023  PTN 36  November 1991
Sears Roebuck and Company Mail Order Store  
(Landmark Center)  
Boston, Massachusetts

The Sears Roebuck and Company Mail Order Store was constructed in 1928 in the Fenway section of Boston. Designed to meet the needs of traditional catalog sales and the company's rapid expansion into urban retail markets, the eight-story brick clad structure combined one million square feet of warehouse and shopping space. Retail activity was concentrated on the lower levels, while the upper six floors were devoted to processing catalog sales and providing warehouse facilities. The reinforced concrete framed structure has modest Art Deco detailing that is particularly prominent on the eleven story central tower and flanking piers that project above the roof parapet. Over 1,100 steel industrial windows were original to the structure. Placed individually or in groupings of two or three, most featured either a single projecting ventilator or a pair of stacked ventilators set within the multi-light window. Each vent in turn was typically divided into two or three vertical lights.

After more than a decade of disuse, a $100 million rehabilitation was undertaken in the late 1990s to convert the building into a mixed retail-office complex called Landmark Center. Through a process of evaluating the surviving windows and experimenting with various treatment solutions and design proposals, the decision was made to replace the majority of the windows while retaining and repairing units in select locations. A new custom aluminum window featuring true divided lights and insulating glass was developed that replicated both the interior and exterior details of the original units.

Problem

The design and placement of the original rolled steel industrial windows, manufactured by the now-defunct firm of David Lupton & Sons, contributed significantly to the historic character of the Sears building. Utilitarian yet distinctive, the windows reflected the dual function of the structure as warehouse and showroom. Of the building's seventeen window types, almost all shared some variation of the centrally located projecting ventila-

Deteriorated architectural features should be repaired rather than replaced wherever possible. In the event replacement is necessary, the new windows should match the historic ones in design, color, size, configuration, reflective qualities, shadow lines, details and material. Only where it is not feasible to match the historic fabric should substitute window material be considered for use and only when it is shown through such means as mock-ups that it is possible to match closely both the detail and overall appearance of the historic windows.
Repair Options

From the outset, serious consideration was given to repairing the majority of the existing windows and upgrading the units for improved thermal performance. Any repair program had to be accomplished in situ, as the original window frames were embedded directly in the masonry surround without an intermediary subframe. Their removal for repairs or to salvage and substitute windows from one area of the building to another could only be achieved by cutting the frames free from the anchors, a process that would cause considerable damage.

If the windows were retained, energy efficiency could be increased by either of two alternative treatments: reglazing with insulating glass units, or installing interior storms. The former approach was quickly discarded when the thickness of the original steel muntin sections proved insufficient to support the added weight of new dual-pane glass units.

The second retrofitting option appeared more promising. To avoid obstructing the muntin arrangement of the historic windows, the proposed interior storm units had to be fashioned as single sheets extending from the head to the sill of each steel window. Installation of a mock-up, however, pointed out the limitations of the system. Because of the depth of their placement, the storm unit reflected the existing muntin pattern, creating a visually confusing appearance of two distinct grids.

Figure 2. Narrow sightlines, ventilator weathering flanges and mullion boltheads were all distinguishing features of the original steel windows. Photo: Bruner/Cott & Assoc., Inc.
A mock-up of the applied muntin system was fabricated utilizing available extrusions and was temporarily installed in the Sears building. The flat profiles of the stock extrusions did not, in this case, successfully recreate the historic window appearance. Had the applied muntin approach been adopted, it would have been possible to match the outside and inside profiles of the original muntin and such details as the drip moldings and grooves along the operable ventilators through the use of custom extrusions. However, because of the importance of the windows to the building's historic character, it was determined that only a true divided light solution would adequately reproduce the visual qualities of the original windows.

**Solution**

In the search for appropriate replacement units, an aluminum window manufacturer was contacted that had a track record of creating new systems for large historic renovations. The company was charged by the development team with providing an aluminum window that had true divided lights, matching profiles and sightlines, and insulating glass. The replacement system that was designed used a large number of new custom extrusions to replicate the dimensions, profiles and sightlines of the original windows (see figure 3). Individual insulated glass lights provided increased energy efficiency while more accurately recreating the characteristic variations of the original glass panes.

Existing historic windows in areas that were not to be continuously occupied, such as common lobbies and fire stairwells, were retained and repaired in situ. In addition, all of the tall windows on the second level (which would be devoted to retail functions) were repaired and reglazed where needed with historic glass salvaged from other locations in the building (see figure 4).

**Fabrication**

A significant challenge to developing the Sears building replacement window was matching the original narrow muntins. Common industry practice for true divided light aluminum windows was to utilize wider muntins that conceal the spacer bar in the insulating glass unit and protect the edge sealant from light degradation. This approach would significantly encroach into the sightlines of the original windows as a result of the wider muntin and proportion changes to the window. In the case of the Sears building, however, the window manufacturer utilized a narrow spacer bar that permitted an accurate replication of the original 7/8" muntin (see figure 5). Substituting a dark bronze anodize finish further reduced the visibility of the spacer making it appear as a shadow line when viewed from an angle.

Each replacement window developed for the Sears building was fabricated from over forty new aluminum extrusions. The large variety of custom designed elements allowed for a faithful reproduction of the original profiles. At the request of the developer, the replacement windows were not operable, yet their appearance suggested the functional nature of the original projecting ventilators. Tabs were added to resemble the weathering flange closed flush against the fixed outer frame, while drip caps shielded simulated hinges. The muntin, rail, head, sill and jamb profiles were also accurately reproduced. In order to replicate shadows cast on the original frames, the manufacturer included cosmetic bolt heads on the mullions running between each of the paired and tripartite window arrangements.

**The Inside Look**

The inside appearance of the windows was important to the developer in marketing the new office space. A similar effort was made, therefore, to duplicate historic interior details and profiles. As was typical of multi-story warehouses, historic steel windows were glazed on the inside so that the individual panes could easily be replaced when broken. To simulate...
the original interior putty profiles, the fixed-light muntins were tapered to the same 1/8" thickness of the original sections while stepped muntins were used in the central vent where steel beads had originally secured the glazing. Jambs in the replacement units were also beveled to recall the shape of the old glazing putty (see figure 6).

**Testing and Installation**

Being a new window system, the manufacturer had independent firms conduct standard performance tests on both the insulating glass and a mock-up of the complete window. In accordance with ASTM guidelines, tests on the complete window evaluated air infiltration, water resistance, and deflection and structural deformation under uniform load. With the test units meeting required specifications, window fabrication proceeded. Lengths of the new spacer were shipped to a glass fabricator where the insulating glass units were produced with a standard butyl and silicone dual-seal. Completed glass units were then shipped to the manufacturer for final assembly of each window.

While the new windows were being manufactured, a local contractor began the three month long process of stripping, repairing, repainting and reglazing the historic second floor windows and other retained units in stairwells and other non-office locations. As the new windows began to arrive in Boston, the general contractor removed the original units that were slated for replacement and a team of eight to ten workers started installing the new windows.

**Evaluation**

Decisions involving the treatment of the original Sears building windows were reached after understanding the significance of the windows' historic appearance and by evaluating their condition and the requirements imposed by the rehabilitated building's new function. Various proposals were explored to determine how well they reconciled these factors. The process suggested that the most appropriate solution was to retain approximately 18% of the original windows while replacing the remainder with aluminum true divided light units that carefully matched the originals in both detail and general appearance (see figure 7).

The replacement window system used on floors three through eight had two important advantages over earlier design proposals. First, it did not rely upon applied muntin grids that read less as individual glass 'panes.' Second, by developing new custom extrusions, the replacement window successfully matched the dimensions and sightlines of the original muntins.

The design of the Sears building windows demonstrates the degree to which aluminum windows with insulating glass units can accurately replicate historic windows. Attention to seemingly small details such as...
as drip caps and the interior appearance of the window proved crucial to the success of the replication effort (see figures 8 and 9). This understanding led to a new engineered window that met the challenge of combining narrow muntins with insulating glass units and true divided lights.

Although there were many advantages to the window scheme developed for the Sears building several drawbacks should also be acknowledged. One of the most significant disadvantages was the loss of historic material and integrity that accompanies any window replacement. In this case, the loss included steel frames and glazing that were removed as well as the functional nature of the once-operable projecting window.

While the replacement window frames are virtually indistinguishable from the original frames, the uniform, factory-produced nature of the units is in contrast to the look of historic steel windows that have aged over time. Also, the true divided lights, though superior in appearance to large insulating glass units with applied muntins, still have the reflective quality of modern insulating glass.

A final concern, relevant to all dual-glazed replacement windows, involved the integrity of the insulating glass unit seals. Although the dual-seal used in the Sears building replacement windows is currently state-of-the-art, the lifespan of insulating glass units in general has varied widely and is undoubtedly shorter than traditional monolithic glazing. The combined effects of the true divided light design and the narrow spacer bar suggest that the Sears building windows be periodically inspected. Small divided lights significantly increase the perimeter area that is sealed and thus vulnerable to degradation while the narrow spacer reduces the amount of sealant that can be accommodated along that perimeter.

A ten-year warranty is currently being offered by the glass fabricator for the window system.
Conclusion

The Sears project illustrates that a combined approach of window repair and replacement with a custom window designed to match the historic unit is a viable alternative when large-scale building rehabilitation is undertaken (see figure 10). Such a solution provides the opportunity to retain significant historic fabric and a wholly authentic original appearance in the most visible locations. In areas where the original windows have experienced significant deterioration, they are in less prominent locations and where there are no suitable alternative means of enhancing thermal performance, replacement windows that are intended to match the originals in detail and appearance are acceptable. The window solution developed for the Sears building acknowledges modern demands for both a marketable aesthetic appearance and increased energy efficiency while retaining the historic visual appearance of the structure. Already the custom replacement window developed for the Sears building is being installed on other historic buildings with comparable windows that are deteriorated and in need of replacement.

PROJECT DATA:

Building:
Sears Roebuck and Company Mail Order Building
(Landmark Center)
309 Park Dr. & 201 Brookline Ave.
Boston, MA 02215

Owner:
The Abbey Corporation
Boston, Massachusetts

Project Date: 1996-2000
Project Architect:
Bruner/Cott and Associates, Inc.
Boston, Massachusetts

Restoration Consultant:
Leslie Donovan
Tremont Preservation Services
Boston, Massachusetts

Window Manufacturer:
Custom Window
Denver, Colorado

Window Contractor:
JK Glass
Boston, MA

Project Cost:
The project's size and budget were sufficient to absorb the added expense of developing the new window system and its numerous custom extrusions. Engineering time and the cost of tooling and producing new extrusion dies for the Sears project totaled approximately $25,000. As additional $15,000 was spent on mockups and testing, bringing the development cost to approximately $45 per frame in 1998 dollars.

The total expenditure for replacement window work including all development costs, installation labor, perimeter caulking, dealer markup and the 890 window units themselves came to approximately $1.75 million, or $1,966 per window.

This figure does not include expenses associated with removing the original units. Repairing and repainting the two hundred windows that were retained on the second floor and along the stairwells cost an additional $158,000, or approximately $800 per unit. The overall rehabilitation cost for the building was approximately $100 million.

THE PRESERVATION TECH NOTE was prepared by the National Park Service. Charles E. Fisher, Heritage Preservation Services, National Park Service, serves as the Technical Editor of the PRESERVATION TECH NOTES. Information on the window work at the Sears Mail Order Building was generously supplied by Leslie Donovan, Tremont Preservation Services; Henry Moss and Simon Tempest, Bruner/Cott Architects; Edward Bartlett, Custom Window Company; Jim Kfouri, JK Glass; and Alan Aulson, Aulson Company. Thanks also go to Sharon Park and JeEllen Hensley of the National Park Service's Heritage Preservation Services for their review and comments.

PRESERVATION TECH NOTES are designed to provide practical information on traditional practices and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act Amendments of 1980 which direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Technical Preservation Services, National Center for Cultural Resources, National Park Service, 1849 C Street, NW (2255), Washington, DC 20240.
BEATTY'S MILL
(CORAL STREET ARTS HOUSE)
Philadelphia, Pennsylvania

Introduction

In the early twentieth century, the desire of property owners to reduce drafts and offset rising fuel costs led to a thriving market for improving the performance of windows. Storm windows and weatherstripping for old and new windows became commonplace. By the 1920s and 1930s, manufacturers began offering sash with dual glazing that also had functional, integral muntins. This feature is still available in traditional styles with true divided lights and a piggyback interior-glazing panel. It has a practical application in the rehabilitation of historic buildings today.

Early Piggyback Storm Panel

Soon after World War I, wood window sash with two layers of glass were being offered by various local and regional companies. Commonly used in wood windows that had integral muntins for the outer glass, the individual glass lights set within these muntins were glazed in a traditional manner, utilizing glazing putty and metal glazing points. On the room side of the sash, a single-light glass panel, set in a thin metal frame, was mounted flush within the rails and stiles of the wood sash. The metal frame was affixed within the wood sash frame in a manner that permitted it to be occasionally removed when necessary for cleaning the glass. By creating a sash with two sheets of glass, enhanced energy performance was achieved without the need for a separate storm window. It also provided for easier care and use than the traditional combination of an exterior storm window and primary window.

This type of dual glazing was available in a variety of sash styles but appears to be most heavily promoted for double-hung and casement windows. By the 1930s, the dual-glazing feature was part of a standard line of windows made by such nationally known companies

Where the severity of deterioration requires replacement of significant historic windows, the replacement units shall match the old in design, color, texture, and other visual qualities and, where possible, materials.
as the Andersen Corporation and the Rolscreen Corporation (now Pella Corporation).

After World War II, dual-glazed window sash continued to be sold by national, regional and local wood window companies. Although annual sales were never comparable to that of cheaper single-glazed sash, this type of window continues to be marketed today. Technical refinements in gaskets and hardware occurred over time as manufacturers further enhanced the performance of this glazing system.

Even with the growing popularity of sealed insulating glass after World War II and its later dominance in the glazing industry, a market remains today both in new construction as well as rehabilitation work for sash with a piggyback interior energy panel. Several national wood window companies actively promote such a sash, although without true divided lights. This feature permits companies to offer the convenience of “between the glass” window shades and blinds. The removable panel allows access to the blinds or shades as needed for maintenance.

Some regional and local companies that focus on the historic preservation mar-
ket have taken advantage of a different marketing opportunity. By offering true integral muntins for use with the outer glazing, along with the standard single-light for the interior glazing panel, the appearance of many types of historic windows can be duplicated more accurately than with applied muntins. While providing for improved energy conservation, this system of dual glazing also avoids the eventual failure inherent with sealed insulating glass.

**Beatty’s Mill (Coral Street Arts House)**

Beatty’s Mills originally consisted of six interconnected buildings serving as a textile mill complex. The single surviving building is rectangular shaped, five stories in height with details representative of the Italianate style. Constructed in 1886, the brick building is strongly punctuated by repetitive rows of segmental arched windows (see figure 1). This building had changed little over the years and was still being used for textile-related purposes when it was closed around the year 2000.

The New Kensington Community Development Corporation acquired the mill with development plans that combined low-income housing and artist live/work space. The tall ceiling heights, existing hardwood floors, and large window openings lent themselves well to the new use.

**Problem**

The large double-hung wood windows were one of the most prominent features of the mill. Each measured 48" by 96" with 12 lights of glass in both the upper and lower sash. Characteristic of many mill windows of the time, the sash frames were set in the masonry walls so as to minimize frame exposure on the outside. This provided for more light on the interior. It also enhanced fire safety through minimizing exposed wood on the outside, thus reducing the risk of flames spreading from an adjacent building fire (see figure 2). The outer face of the meeting rail was quite narrow.

The building had suffered many years of neglect, which was reflected in the condition of the windows. A condition survey determined that 40% of the sash were in poor condition; 45% were in fair condition; and only 15% were in good condition. Based on the window survey, the development team elected to replace the
Figure 3. Drawings of the historic windows were prepared by the architectural firm based on field measurements to assist in devising an appropriate replacement window. Drawings: Courtesy of Kitchen & Associates Architectural Services.
existing sash with new wood sash. The initial plans included retention of the wood frames, utilizing a combination of dutchman repairs, epoxy consolidation, and epoxy repairs. Upon further investigation, it was determined that even the window frames were too deteriorated to repair.

**Solution**

The location of this building right on a street corner and the importance of the windows to the historic character of the building led the project team to select a window solution that closely matched both the detail and appearance of the historic windows. By selecting a new custom wood window, the narrow site lines of the historic windows could be closely replicated, the historic glass to wood ratio readily maintained, and other historic details easily reproduced (see figure 3).

To help retain the historic sightlines, the deteriorated frames were removed, permitting the new frames to be set close to the masonry (see figure 4). The alternate approach of retaining the existing frames, abutting new frames to them, and covering the outer face of the exposed portion of the older frames would have resulted in reduced glass exposure and a beetter frame appearance to the finished windows.

The small divided-light appearance of the historic windows was initially thought to be difficult to match since energy conservation requirements stipulated dual glazing for the sash. One option, involving a new wood window with true divided lights and a separate interior storm window, was not considered practical in this case. Another option utilizing grids applied onto a sealed insulated glass unit was determined by the project team to be an insufficient match of the historic window.

A third option called for the use of a wood window with true divided lights for the outer glazing and an applied interior single-light glass panel on the inside of each sash. The project’s preservation consultant, Robert Powers of Powers & Company, knew this window approach has been used successfully on historic rehabilitation projects for more than 20 years. This option provided for a close match of the historic window, was affordable, insured ease of operation for residents, and provided dual glazing for energy purposes.

The project team selected the third option, and the architectural firm prepared drawings both of the existing windows and the proposed replacement windows as part of the bid documents. Seaquay Architectural Millwork Corporation, located near Philadelphia, was selected for the window work. The company had manufactured windows for 18 years and made this style of dual-glazed wood
window for both small and large size residential, commercial and institutional buildings.

In matching the exterior appearance of the historic windows, two issues arose that were successfully addressed. First, in order to meet the energy requirements of the various funding agencies, it was necessary to use Low-E glass. By locating the Low-E glass in the interior energy panel and with the energy panel being placed nearly one inch from the outer glass, the color difference of Low-E glass and its slight light distortion were minimized when viewed from the outside. With the Low-E glass, a U-factor of .38 was achieved.

Somewhat more problematic was how close the bottom rail (meeting rail) of the new upper sash could match the narrow width of the existing window. Specifications for the project required that the replacement window meet three ASTM Standards: ASTM E283, the standard test for determining the rate of air leakage through an exterior window; ASTM E331, the test of water penetration; and ASTM E330, the standard test for structural performance of an exterior window. To meet ASTM E330 with the design pressure rating for the window set by the architect, a 1¼" wide meeting rail was needed (see figure 5). This was an increase of ½ inch over the historic sash. Fortunately because of the size of the window, this increase was considered acceptable, as the meeting rail still appeared relatively narrow even with the ½ inch increase.

**Fabrication and Assembly**

All but four of the 192 double-hung windows to be replaced measured 48" wide by 96" high. The upper sash were to have a segmented arch at the top rail and the frame was to have a common brick molding of wood. The ¾ inch wide muntins in the new sash were to match the historic ones and when glazed create a trapezoidal shape on the outside.

Seaquay prepared three-quarter scale shop drawings for the new windows and submitted them for approval to the architect (see figures 4 and 5). Sufficient time was provided to allow the project team to obtain approval from the various historic preservation review agencies. To ensure that the windows would meet the performance specifications set by the architects, a window was fabricated and tested at the company, then sent to an independent testing laboratory.

Following the results of the testing, full production of the new windows commenced using northeast pine for all wood members. Sequoia already had the knives to match the profile of the ¾ inch wide muntin and ran lengths of the sash components through an onsite molder. (Because the company is a custom millwork shop and considering the size
of the project, the cost for new knives to match a historic muntin profile would not have been expensive.) After all the cuts were made and joints prepared, the wood parts were dipped in a water-based preservative that included a fungicide, in accordance with the Window and Door Manufacturers Association’s industry standard for water repellent preservative treatment of millwork.

The windows were then assembled and sanded. The outer glass was installed in the factory after the assembled sash were primed. Exterior glazing putty manufactured by C.R. Lawrence was applied in the traditional manner (see figure 6). Since the upper sash were to be fixed in the operable windows, weatherstripping and block and tackle balances were provided only for the lower sash. Each window was provided with two sweep locks and two sash lifts for the operable lower sash. Of the 188 replacement windows, 111 were single hung and 77 were fixed (see figure 7).

The aluminum frame glazing panels were manufactured by Seaquay using a C Sash aluminum frame also purchased from C.R. Lawrence. The C Sash product has the weatherstripping for the glass and is surfaced on one side with weatherstripping to effect a reduction of air infiltration.

Seaquay delivered the windows to the job site with the aluminum-frame glass panels separate. The aluminum-frame glass panels were attached to the wood sash with metal screws after the windows were installed and had received their final coat of paint on the interior muntin bars. This was the contractor’s choice. The muntin bars could have been painted in the shop in the finish color and delivered complete to the job site.

Several features of the new window were different than the historic windows in order to accommodate the dual glazing. The inside of the rails and stiles of the sash were rabbeted on the room side to a depth that permits the glazing panel to be set flush. To retain the depth of the original muntin and to accommodate the glazing panel on the inside, the thickness of the sash was increased to 1 3/4". In the bottom rail, weep holes were provided between the glazing panel and the outer glass, to allow water to drain from condensation that might on occasion develop between the two layers of glass.

**Project Evaluation**

The new windows in Beatty’s Mill successfully matched the historic units while providing enhanced energy conservation. There is little difference between the new and historic windows in terms of the characteristic features (see figures 2 and 7). The integral wood muntins, individual panes of glass, reflective qualities of the glass, glazing putty, and painted wood surfaces, along with the benefits of using a custom-wood window manufacturer that could duplicate the historic features, all contributed to the successful match.

The aluminum frame for the interior glazing panel can be ordered in a factory applied finish to match the inside sash color, left unpainted, or painted the color of the sash at the job site. In the later case, it is important to first remove the glazing panel, paint, and allow for sufficient drying prior to reinstallation.

Cleaning the glass surfaces in between the two glazing layers will be occasionally needed. For ease in removing and reattaching the glass panel, the use of set screws or latch levers to secure the panel to the sash is recommended. Some conditions may lead to more than occasional condensation forming on one of the glass surfaces in between the two layers. For example in northern climates, this condition may occur in a bathroom or kitchen, especially where mechanical or window ventilation is not properly used. Besides weep holes, some manufacturers install

![Figure 6. The outer glass was installed in the traditional manner, using exterior glazing putty. Photo: Charles Fisher.](image)

![Figure 7. The new window's joinery, individual glass lights, reflective qualities, and painted wood finish all help to capture the appearance of the original units.](image)
An Established Solution for Buildings of All Sizes

The window system described in this Preservation Tech Note has been used in a wide range of historic rehabilitation projects in numerous states. Projects have varied in size from 25 to over 1000 windows. Some other projects by the window company responsible for Beatty’s Mill are illustrated here.

Figure A. Building 10 (headquarters of Urban Outfitters), former Philadelphia Naval Shipyards. New wood windows were made to match the original units, including true divided-lights, while incorporating a piggyback interior energy panel. Photos: Seaquay Architectural Millwork.

Figure B. 61-63 North Arch Street, Philadelphia (commercial and residential). Most of the historic windows were missing or severely deteriorated prior to the rehabilitation of this corner building. Based on surviving units, new non-clad wood windows were milled with matching true divided lights and piggyback energy panels. Photo: NPS file.

Figure C. Anthony Wayne School (affordable senior housing), former Philadelphia school. The predominant window type is a wood unit with four-over-four glass lights as shown in the lower right-hand photograph. The replicated wood window on the right is shown with the energy panels installed, while both sash in the left window have yet to receive the panels shown in the left forefront.
breather holes placed on the sides of the wood sash to help address this issue.

While the origin of the piggyback interior storm panel more than 75 years ago will probably never be known, its use in historic preservation projects is firmly established today (see page 7). This window treatment preserves important features of the traditional true-divided light sash while incorporating dual glazing for energy conservation. Its use at Beatty’s Mill and even larger buildings demonstrates that this type of a dual-glazed wood sash can be a viable window solution for projects of varying size (see figure 8).

Figure 8. Upon completion of the work, the former mill now serves as low-income housing and artist live/work space. The new wood windows provide improved energy performance and enhance the visual qualities of the historic building.

This Preservation Tech Note was prepared by the National Park Service. Charles E. Fisher, Technical Preservation Services, National Park Service, serves as the Technical Editor of the series. Information on the window work at Beatty’s Mill was generously supplied by Larry Knowles, President, Seaquay Architectural Millwork Corporation, and Robert M. Powers, Powers & Company. Thanks also go to Bonnie Wilkinson Mark of the Pennsylvania Historical and Museum Commission, and Rebecca Shiffer and Kaaren Staveteig of Technical Preservation Services, National Park Service, for their assistance. Unless otherwise credited, photographs are courtesy of Powers & Company.

Preservation Tech Notes are designed to provide practical information on traditional practices and innovative techniques for successfully maintaining and preserving cultural resources. All techniques described herein conform to established National Park Service policies, procedures and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act Amendments of 1980 that direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to Preservation Tech Notes, Technical Preservation Services, National Park Service, 1840 C Street NW, Washington, DC 20240.

ISSN: 0741-9023  PTN 50  April 2008
D: Second Floor, South Elev. S218

- Replace molding
- Spall-repair with mortar
- Replace with nine light sash to match upper

E: Second Floor, North Elev. N221

- Replace molding
- Install new glass
- Replace rail or consolidate with epoxy
- Sash weights missing - install new to match; replace all sash cord using sash chain
- Interior - consolidate apron using epoxy

---

E: Second Floor, East Elev. E208

- Replace outer tracks and parting stops

E: Second Floor, South Elev. S211

- Transom missing
- Weatherstripping missing - install new to match
- Interior - fill open joints, repair transom mechanism
- Right transom missing - install new wood transom to match

INTERIOR: Replace soffit of head
FLORIDA STATE CAPITOL
Tallahassee, Florida

The old Florida State Capitol, constructed in the 1840s and greatly enlarged over the years, has recently been rehabilitated for use as museum space and government offices. The neo-classical revival building has been returned to its 1902 appearance and is individually listed in the National Register of Historic Places.

Photographs in the Florida Photographic Archives show that as early as the 1890s decorative awnings had been installed, replacing shutters as sun screens. Wide-striped red and white operable awnings can be seen in postcards as early as 1902. By World War II, air conditioning units had been added to the building, and the awnings had been removed.

When rehabilitation plans were drawn up for the building, the initial intention was not to duplicate the awnings. Energy studies, however, showed that significant cost savings could be achieved by installing the awnings, and today the building stands with this highly colorful feature added.

Rehabilitation Design Problem

The effective use of awnings to reduce solar heat gain can be found on numerous historic buildings during the late 19th and early 20th centuries, and it still is a treatment with practical applications in certain climates. In hot climates awnings can eliminate the need to alter or replace existing historic windows for reasons of improved energy performance while also reducing glare; can provide rain protection for windows opened for ventilation; and can bring a bright, cheerful addition to a building. Given the high visibility of such a window treatment, research should be undertaken to ensure that awnings previously had been used on the building; care should be taken to match the size, design, color, and basic appearance of the historic awnings where possible.

The Florida State Capitol project is a good example where replication of the awning treatment was undertaken primarily because of the cost savings realized through reduced energy usage.

The architect and the mechanical engineer for the work at the Capitol were concerned from the outset about the high cooling load created by the large glass area on the building's facade. The cooling load required to handle the solar gain from the 138 windows that measured 4' by 10' each was calculated at 55 tons. There were also significant air infiltration problems due to a lack of weatherstripping and window maintenance. It was estimated that mechanical equipment with a capacity of 102 tons refrigeration (which includes the 55 ton load for just the windows) would be needed to cool the 46,501 square feet of building area, and concern was expressed that the air velocity from such a system might have created drafty conditions in the smaller offices within the building. An engineering study of two offices on the west facade of the building showed that 72% of

Laura A. Muckenfuss
Center for Architectural Conservation
Georgia Institute of Technology, and

Charles E. Fisher
Preservation Assistance Division
National Park Service

Installing historically appropriate awnings can effectively reduce solar heat gain.
the required cooling load in a typical first floor office and 56% of the load in a typical second floor office was due to exposed glass surface. With the windows contributing to 54% of the overall air conditioning load, some measures were necessary to reduce the heat gain from the windows.

Some of the sash were in good condition, and it would have been possible to add tinted heat-absorbing insulating glass by rabbeting out the existing sash frames. Alternatively, tinted glass could have been installed both in existing sash that were repairable as well as in the numerous sash replacement units needed. There were concerns, however, over such visual changes to the historic appearance of the building; finally, cost considerations were an important factor weighing against the use of insulating and new tinted glass. Rising energy costs and the savings from the reduction in the size of the HVAC system made the installation of the awnings both a practical and economical alternative.

Figure 1. Large awnings were specified for all but the north elevation in order to reduce solar gain. Drawing: Courtesy, Shepard Associates, Architects and Planners, Inc.

Rehabilitation Design Solution

It was determined that installation of the awnings would appreciably reduce heat gain and cut energy consumption during Florida’s long hot weather season and also enable the Capitol project to remain within its $7 million budget. This was possible, despite the purchase cost of the awnings, in part because of the cost savings resulting from the ability to reduce the size of the HVAC system. The size, shape and installation angle of the original awnings as shown in the archival records were duplicated in the new work.

Since the primary facades of the Capitol faced east and west, awnings were needed on the two main floors on all but the north side (see figure 1). Solar heat gain, which originally would have consumed 54% of the required cooling load, was now estimated to be 31.5% of the equipment load, and allowed a downsizing of the HVAC system by 25 tons. In typical first floor offices, the exposed glass surface would now only account for 46% of the required cooling load down from 72%. On the second floor, there was a similar change from 56% down to 30%.

Fabrication And Installation

A decision had to be made on the type of material to be used for the awnings. Canvas awnings had been used on the building from the 1890s through the 1930, but records showed that the canvas lasted only three to four years in the Florida climate. A modern material of acrylic fibers with an eight-year life expectancy was selected instead to reduce the long-term maintenance needs. A local marine products company was located that sold the acrylic fabric.

The awnings were fabricated to the architect’s design of 4’ wide by 4’ deep with a height of 8’-1” and a 9½’ scalloped valence (see figure 2). The 100% acrylic fabric has vertical stripes four inches apart. Regrettably the production of the acrylic weave did not allow for pure color separation, and as a result the striping is in reality red and a very light pink; still the impression of red and white is maintained.

Figure 2. Early photographs were used in determining the appropriate design and size of the new awnings shown in the photograph. Drawing: Courtesy, Shepard Associates, Architects and Planners, Inc.; Photo: Courtesy, Florida Bureau of Historic Preservation.
The awning fabric can be readily removed from the frame for replacement and cleaning. Standard galvanized steel awning frames designed to draw vertically against the window frame were used. Since the windows in the Capitol were sealed shut for weatherization purposes and to keep a more constant load demand on the HVAC system, the pivoting points on the standard frames were easily made rigid, preventing retraction of the awnings. The decision to fix the awnings in a fully opened position did have some cost trade-offs, since solar gain through the windows during the short cold weather season would have been desirable. There also would be an advantage to be able to adjust the awnings to allow natural light when the rays of the sun were not directly shining on the windows. In addition, the viewing area through the window would be permanently reduced in the upper portions of the windows. Operable awnings could have been provided by having the mechanical opening hardware extend through to the inside. This more costly feature was not selected for use in the Capitol.

The hardware for the awnings, including the anchors and attaching devices, were primarily galvanized or zinc plated steel. Prior to installation, the contractor was required to examine the windows and to correct any condition that might have prevented proper installation of the awnings.

Cost

Eighty-four awnings were purchased for the Capitol; eighty-two were installed on the two main floors throughout all but the north side of the building. The remaining two were saved for replacement needs. The cost of material and installation was $26,500—approximately $315 per large window. Along with the benefits of energy savings as a result of reduced heat gain during the long warm weather season, the awnings have eliminated the problem of glare in the main ceremonial spaces of the building. In certain rooms, the awnings also have eliminated the need to purchase and maintain interior shades or draperies (see figure 3). The awnings are proving to be cost effective with a full payback projected within 3 to 4 years (even counting the projected high maintenance cost), largely because of the reduced energy consu- tion and as a result of the downsizing of the HVAC system.

Project Evaluation

The Florida State Capitol project has shown that awnings can be an effective means of reducing heat gain. Commonly used in the past as a passive design feature to keep a building cool, awnings have received renewed interest in the 1980s because of their energy-conserving qualities.

The use of the acrylic fabric as a substitute material for the original cotton duck canvas avoided the problem of shrinking that canvas exhibits. Moreover, acrylic is not affected as badly by mildew. It is also anticipated that the reinstallation of the awning with their protective overhang will provide some additional cost savings through extended life for the windows.

The decision to make the frames rigid to prevent retraction of the awnings on the Florida State Capitol did prove to be unwise, since seasonal high winds, exacerbated by large adjacent new construction, caused greater damage than had been anticipated. To correct this condition, the windows, which had been screwed shut and sealed, were easily reopened; the awnings were rigged so that they can be drawn back in high winds; and various sleeves and pins were removed from the frames, returning them to their original operable condition. Now whenever inclement weather is anticipated or more sunlight is required in certain rooms, maintenance personnel can easily retract the awnings. The awnings now are performing admirably and this highly distinctive historic feature has generated considerable local interest (see figure 4).

Figure 4. While the awnings were installed in order to save on energy costs, the restoration of this highly decorative and colorful feature enhances the historic appearance of the building. Photo: Courtesy, Florida Bureau of Historic Preservation.

Figure 3. By reducing the glare and solar gain, the awnings have eliminated the need to purchase and maintain interior shades and draperies in various offices. Photo: Courtesy, Florida Bureau of Historic Preservation.
PROJECT DATA

Building:
Old Florida State Capitol
Capitol Complex
Tallahassee, Florida

Owner:
State of Florida

Project Date: 1979-1982

Project Team:
Herschel E. Shepard, FAIA
Restoration Architect
Shepard Associates Inc.
Jacksonville, Florida

James M. Hammond
Mechanical Engineer
Evans and Hammond Inc.
Jacksonville, Florida

Jennings Knox
Project Manager
Jack Culpepper Construction Company
Tallahassee, Florida

C. E. Sullivan
Manager
Division of Building Construction
and Property Management
Department of General Services
State of Florida
Tallahassee, Florida

Florida Bureau of Historic Preservation
Preservation Consultants
Division of Archives, History and
Records Management
Department of State
State of Florida

Materials:
Awning Fabric and Hardware-
Jacksonville Ship Chandlery
Jacksonville, Florida

Project Costs:
The 84 awnings cost $26,500; approximately $315 apiece fabricated and installed.
HAMM BUILDING
ST. PAUL, MINNESOTA

Introduced in the 1890s, prismatic glass transoms were a popular and practical means of directing daylight into building interiors. With origins in sidewalk vault lights and glass panels used on ship decks, prismatic tiles had ridges or other raised patterns on their inside surface that refracted sunlight toward the rear of a building. The pressed tiles were usually joined together with zinc or lead in a process similar to that used to create stained glass windows (see figure 1). An alternate, less common approach was to bond the tiles to copper strips during immersion in an electrolytic bath, a process known as electroglazing. At the peak of popularity, over a dozen manufacturers offered varying tile patterns—each “scientifically designed” to increase natural light levels and thereby reduce reliance upon light wells and artificial light sources. Prismatic glass tiles were used both in new construction and to update existing storefronts, until changing tastes and the dominance of electricity led to their functional obsolescence by the 1930s.

Although prismatic transoms were seen most frequently above the display windows and doorways of modest main street buildings, they were also used in larger commercial structures. An example is the Hamm Building in St. Paul, Minnesota. This six-story structure, with shops on the ground floor, offices above, and a theatre on one side, was completed in 1920. The exterior of the building was especially admired for its cream-colored terra cotta with Classical and Renaissance Revival ornamentation.

Another important feature of the Hamm Building exterior was the large band of prismatic glass located just above the storefront awnings (see figure 2). Divided into groups of three and four panels separated by terra cotta pilasters,

Deteriorated prismatic glass transoms should be repaired using historic tiles. When tiles are missing, the transoms should be replicated using glass that matches closely the appearance of the historic prisms.
Figure 1. A typical prismatic tile glazed with zinc came is shown on the left. Tiles on the Hamm Building had a pattern of raised circles on the inside surface. The drawing on the right illustrates a typical storefront with prismatic transom. Drawing: Chad Randl

Figure 2. The Hamm Building featured fifty-six prismatic panels set directly above the awnings. Each panel contained over two hundred individual tiles. Photo shows completed project. Photo: Chad Randl

their placement mirrored the fenestration pattern of the rest of the facade. Each of the fifty-six panels was approximately 4 1/2’ tall by 5’ wide and contained 224 tiles, each measuring 4” high by 4” wide by 1/4” thick. The tiles were made by the Manufacturers Glass Company, one of several prismatic glass producers based in Chicago. Two types of tiles were used in each Hamm Building panel. Most featured uniform rows of raised circles resembling bubbles on both sides of the tile. The other tile pattern had bubbles on the interior face only, with the manufacturer’s trademark logo on the exterior side. (Both differed from a more common prism tile of the time that featured horizontal ribs on the inside surface). In the Hamm Building transoms, the trademark tiles were arranged in a square border along the edge of each panel (see figure 3). The prisms were glazed with zinc came and set within a copper frame. A small pivoting ventilator was located in the center of each panel.

Like many historic transoms today, a large number of the Hamm Building panels were covered over during a mid-twentieth century renovation. Only partially intact when the building was rehabilitated in the 1990s, the prisms were uncovered, removed, cleaned and reglazed. New glass that approximated the historic prisms was used to replicate several missing panels. With modifications that improved their structural strength, the transoms continue to contribute to the visual interest of the exterior and natural light levels in the interior.

Problem

When the Hamm Building was rehabilitated beginning in 1996, plans were made to return the prism glass transoms to their historic appearance. At the time, all but sixteen of the panels were obscured behind plywood sheets (see figure 4). Installed decades before, the covering was probably a response to the gradual deformation of the assemblies and water infiltration that resulted from deferred maintenance. The desire for a more contemporary appearance and more prominent sign space may also have been factors.

After removing the plywood, the individual panels were found to be in various states of disrepair. In approximately 20 percent, the tiles were either completely missing or had fallen to a pile at the bottom of the frame. Most panels that survived were bulging or sagging and had severely pitted and corroded came and cracked solder joints.
Numerous paint layers covered the exterior surface of the panels and several had holes cut to accommodate the addition of air conditioning or ventilation ducts (see figure 5).

Repairing the transoms required a knowledgeable craftsperson experienced in specialty glass assemblies and exterior installations. A source for replacement tiles was also necessary. Both presented challenges, as the skills and materials developed for the prism glass industry became scarce when the popularity of the panels faded. As is the case with many twentieth century materials from plastic laminate walls to Vitrolite storefronts, finding suitable replacement material was a primary obstacle to restoring the transoms successfully (see sidebar). Prismatic tiles had not been mass-produced for sixty years and all of the manufacturers had either folded or were involved in completely different markets. Finding the right craftsperson or workshop also proved difficult. The work required an understanding both of zinc glazing and the structural and environmental demands that accompanied an installation the size of the Hamm Building panels.

Solution

Repair of the prismatic glass transoms involved removing, disassembling, cleaning, and reglazing the surviving panels with original glass tiles, some replacement glass, and new zinc came. Rehabilitation of the transoms also provided an opportunity to increase the strength of the original assembly. Simply rebuilding the panels according to the original design would establish the same conditions that contributed to their initial failure. With this in mind, the rebuilt panels incorporated unobtrusive changes that provided additional reinforcement.

All of the surviving prismatic tiles were used again in the rebuilt panels. The number of surviving tiles, however, was sufficient to rebuild only forty-six of the fifty-six panels. Since the project team was unable at the time to locate an affordable source for newly cast replacement tiles, a textured, or patterned, glass served as a substitute in the remaining ten panels. Purchased in sheets from an art glass dealer and cut to size in the workshop, the appearance of the replacement glass was a close approximation of the original bubble design.

The contract for rebuilding the Hamm Building transoms was awarded to a local stained glass studio. Their previous work with leaded glass windows demonstrated an understanding of structural load issues, expansion and contraction characteristics, and other concerns relating to glass assemblies in exposed locations. The studio owner also had considerable experience repairing and rebuilding smaller prismatic glass installations. After meeting with the studio team and viewing examples of their ear-
Replacement Glass for Historic Prism Transoms

Whether a project involves minor repairs or recreating an entire installation that had been removed and destroyed, work on historic transoms often requires replacement material. Zinc came is still commonly in use, and can be supplied by some of the same manufacturers that produced came a century ago. The ingredients of waterproofing grout, likewise, have changed little. Prismatic glass tiles, however, are harder to come by. There are generally three replacement options: custom cast new glass tiles, textured glass and salvaged historic material. Deciding which approach is most appropriate is dependent upon the amount of glass required, the degree of accuracy desired, and the project budget.

Several companies are capable of producing new pressed glass tiles. Some have historic molds bought from defunct prismatic glass companies; others use computer design software and laser cut graphite dies to create patterns that are identical to the historic material. Though this approach results in the most accurate reproduction material, the expense of custom casting may be prohibitive for smaller projects that require few tiles.

Textured, or patterned, glass is sheet glass upon which a pattern is rolled. Several patterns especially those with linear ridges (such as narrow reeded or ribbed glass) may be acceptable substitutions for original prism tiles. Textured glass can be ordered in sheets and cut into tiles in the glazing workshop. Advantages of textured glass over custom pressed tiles include cheaper costs, virtually immediate availability, and a larger number of suppliers.

Reputable specialty glass collectors and salvage companies may be a source for replacement historic prism tiles. The profusion of manufacturers and tile patterns once available limits the likelihood of locating an exact match. Those working with collectors should ensure that original materials on offer were not removed from existing installations purely for salvage and resale.

The color of the replacement glass may also have to be decided. Originally, prismatic tiles were clear. Until World War I, manganese was added to the process to decolorize the otherwise green glass. Decades of exposure to ultraviolet radiation, however, can cause a reaction in the manganese that then imparts a purple or pinkish tone to the glass. It may be possible to find patterned glass or salvaged tiles in a color that approximates that seen in solarized historic tiles. Exact matching is not likely, or necessarily desirable, considering the fact that the replacement material and the historic tiles would continue to change color at different rates. Because the historic tiles on the Hamm Building had not experienced significant solarization, the architects and transom contractor chose a clear patterned glass.

See [http://www2.cr.nps.gov/tps/ptn44/material.htm](http://www2.cr.nps.gov/tps/ptn44/material.htm) for a list of possible replacement material sources.

Repair Work

After the transom contractor established a temporary workshop in one of the Hamm Building’s vacant storefronts, each panel was removed and disassembled. Because the shop did not include cleaning facilities, the tiles were inventoried, packed, and sent to a furniture stripping company, where they were immersed in a solvent bath to loosen paint and dirt. The solvent used by the stripping company had been previously tested to ensure that it did not etch, cloud or discolor the glass. In the meantime, the transom contractor built plywood jigs and workbenches in the shop that would facilitate precutting came and assembling the panels. When the cleaned tiles were returned to the site, reglazing began.

The majority of the rebuilt panels incorporated prism glass tiles that were original to the building (see figure 7). Both ventilator hardware and the historic trademark prism border were included in the rebuilt panels. The assembly process was similar to that used for stained glass windows. Individual prisms were set in a zinc H-came matrix that was gradually soldered together as more tiles were added. Reinforcement bars were then soldered to the panel. The last major step before reinstallation was to waterproof the assembled panel. A waterproof grout...
made from a traditional mix of putty, boiled linseed oil and lamp black was forced into the spaces between the cameo flange and the glass.

The four reproduction panels containing new glass were reglazed in the same manner. A clear, patterned glass called "moss glass" that resembled the color and bubbled texture of the historic prism tiles was used as a substitute material (see figure 8). Where historic ventilators were beyond repair or missing, the transom contractor fabricated a simulated vent with strips of capping zinc (a material normally used to cover the edge of the transom frame).

Reproduction panels also differed from the historic assemblies in that they did not have a border of trademark tiles along the perimeter. The resulting panels were distinguishable from the historic units up close, but when viewed from the street or the opposite sidewalk, seemed only slightly different from the original panels.

Evaluation

The rehabilitation of the Hamm Building transoms included reassembling over 12,500 prism tiles into fifty-six panels. All of the surviving historic prisms were preserved in the rebuilt transoms. Replacement materials including zinc came and new patterned glass tiles were selected for their similarity to the original materials; modifications were developed that did not significantly alter the historic appearance of the panels.

It was important in this case, for the transom rehabilitation program to address long-term concerns over the structural strength and weather resistance of the original panels. The addition of reinforcing bars counters the tendency of wind and temperature extremes to distort the transoms. Applied on the interior, such a system has the added benefit of being virtually undetectable. The longevity of the panels including their continued weather resistance is best assured through a process of regular inspection and maintenance and, when necessary, regrouting the panels before leaks develop.

Though the Hamm Building transoms were deteriorated to a point where they had to be removed and taken apart, there are occasions where repairs may not require complete disassembly. In cases where the came is in good condition, but a single tile is missing or severely cracked, the panels can be removed to a workshop and the came flange adjacent to the damaged tile opened up with lead pliers. A replacement tile can then be fitted into the channels, and the came pushed back in place by hand and resoldered together. The rigidity of zinc and the difficulty of soldering on a vertical plane make in situ repairs to prismatic transoms extremely difficult.
Conclusion

The Hamm Building prismatic glass transoms are more than a tool for bringing daylight into ground floor shops and entrances; they are an integral feature of the building facade. The preserved prisms impart an openness and visual texture to the storefronts that were important to the building's design and historic appearance. Although the deteriorated condition of the seventy-five-year-old panels necessitated major repair, the work was planned to retain as much historic material as possible. Reglazed panels incorporated historic tiles and vent hardware while adhering to the dimensions, construction and overall appearance of the historic configuration. Where missing or damaged elements required replacement, new materials approximated the appearance of the original features (see figure 9). Lastly, modifications to the transoms improved the strength of the transoms but did not intrude upon the historic appearance of the prismatic tiles and the Hamm Building exterior.

Additional Reading

Introduction

Beginning in the 1850s, sidewalk vault lights became a common feature amidst the burgeoning manufacturing districts of America’s urban streetscapes. These cast-iron panels, fitted with clear glass lenses, were set into the sidewalk in front of building storefronts. They permitted daylight to reach otherwise dark basements (or “vaults”) that extended out beneath the sidewalks, creating more useable or rentable space for building owners.

Each panel was screwed to a cast-iron saddle and the iron framework that spanned the basement vault. They were cast with molded iron knobs around each lens to protect the glass and improve the footing of passers-by. Originally simple glass lenses were set in the panels, usually with a cement grout. Advances in daylighting technology including the development of prismatic glass pendants that refracted the sun’s rays further into basement areas, and the

Deteriorated historic sidewalk vault lights should be repaired wherever possible. Missing panels can be replicated with new panels that match closely the detail and overall appearance of the historic vault lights.
use of reinforced concrete panels made vault lights popular through the 1930s.

Located in New York City within the SoHo Cast-Iron Historic District, 552-554 Broadway is a six-story loft building detailed with Italianate ornamentation on the upper floors (see figure 1). Designed by the architect John B. Snook and originally constructed in 1855 as two separate buildings, 552 and 554 Broadway were joined internally and unified in 1897 with a new two-story, cast-iron storefront and sidewalk vault installation. It is likely that the building's basement was used historically for a combination of light manufacturing and storage.

The original vault lights stretched approximately fifty-four feet across the full width of the ground-floor storefront. They were made up of twenty-one individual panels extending five feet from the building line and varying in width from 1'10" to 2'8" (see figure 2). The cast-iron panels were fit with 1-1/2" diameter glass lenses, typical for historic vault lights. Raised lettering on the panel frame, "Jacob Mark, 7 Worth Street, New York," indicated the foundry's name and address in Manhattan. Over one hundred years of pedestrian traffic, deliveries and environmental exposure took a toll on the vault lights at 552-554 Broadway.

With use of the basement for merchandise storage, the current ground-floor retail tenant initiated a vault-light restoration program in 2002 to return this historic sidewalk feature to its original function and appearance.

**Problem**

At the outset of the project, the vault lights at 552-554 Broadway were in poor condition (see figure 3). As with many old vault light installations, broken glass lenses and deteriorated seals allowed considerable water infiltration through the individual panels and the surrounding framework. A majority of the glass lenses were either cracked, missing or replaced with a variety of materials including wood, concrete and asphalt (see figure 4). Of the twenty-one cast-iron panels, six sections had areas which were cracked or missing altogether. Two original vault light panels had been replaced with steel diamond-plate hatchway doors to the basement and a variety of materials had been applied over the remaining panels in repeated attempts to prevent further leaks. Worn and lacking a protective coating, the cast-iron panels were exposed to the elements. Displaced panels and uneven asphalt and concrete panels presented trip hazards at sidewalk level.

Repairing and restoring the historic vault lights presented a number of obstacles. These included finding an experienced contractor, locating suppliers and fabricators for the glass lenses and missing cast-iron panels, and keeping the overall cost of the restoration program reasonable.

Consideration of building codes, and load requirements in particular, is part of any vault light restoration project. At 552-554 Broadway, loading issues were addressed in 1995 when the current retail tenant took over the space and installed a supplemental steel framing system beneath the deteriorated vault lights. This system involved the installation of a series of beams set beneath the edges of the individual panels and supported by a large girder running parallel to the storefront. To meet stringent New York City loading requirements, other vault light projects have included pulling up the panels for restoration, pouring a recessed concrete slab and setting the restored vault lights on top of the slab at the sidewalk level. This treatment minimizes water infiltration and maintains the historical character of the sidewalk but removes the daylighting function.

Improving performance, safety and appearance were the main goals of the current restoration program. Water leakage into the basement and trip hazards at the sidewalk had produced a dangerous and unacceptable situation. Meanwhile, the deteriorated condition of the vault lights presented an unattractive entrance to the storefront and building.

**Solution**

An investigation of the vault lights and their support structure indicated that the assembly was repairable. Despite the appearance of the vault lights, physical deterioration was limited and the steel structure beneath was in excellent condition. The project architect and preservation consultants contacted a specialist experienced in rehabilitating cast-iron who developed a plan to return the lights to their historic appearance and function.

![Figure 1. A cast-iron storefront was added to 552-554 Broadway in 1897. The storefront included a fifty-four foot long assembly of cast-iron vault lights set in the sidewalk. Glass lenses in the panels allowed light to enter the basement area, increasing rentable space for the building owner.](image-url)
To facilitate treatment and allow the sidewalks to remain unobstructed, the panels were removed and temporary steel plates were installed over the vaults. In the cast-iron contractor's workshop, the surviving deteriorated glass lenses were removed, the cast iron stripped, cleaned and repainted, and new lenses set into the openings. Replacement lenses were cast by a specialty glass manufacturer, Blenko Glass Company. The company had created glass molds for a vault light restoration several years prior and were now a regular supplier of various sized lenses for similar projects. A cast-iron foundry was contracted to fabricate two new panels to match the missing historic panels. Both new and repaired panels were delivered to the building site where the cast-iron specialist reinstalled them.

**Repair Work**

The first step in repairing the vault lights at 552-554 Broadway was to dismantle and remove the panels from the sidewalk. Over two days, a crew of five experienced workers drilled the heads off of the panel bolts and gently pushed them through the holes in the cast-iron framing. After the bolts were removed, one corner was loosened by inserting a chisel between the saddle and the panel. Other chisels were worked around the other sides of the panel. Then, two workers raised the panels, each weighing approximately three-hundred and fifty pounds. Each panel had to be lifted straight up out of its frame because any uneven pressure could have cracked the cast-iron. A tag with an identification number keyed to a drawing was secured to each panel to ensure reinstallation into the same opening after repair. The twenty-one panels were packed upright into the back of a truck and delivered to the repair shop.

The sidewalk at 552-554 Broadway had to remain accessible to pedestrians while the vault lights were restored off-site, so a 3/4" thick plywood sheet topped with 3/16" steel diamond plate was placed over the openings. The temporary covers were tack welded into the corners of each hole and the seams were sealed with a flexible polyurethane-based caulk.

When the vault lights arrived at the repair shop they were placed upside down and the surviving glass lenses were knocked out by hand. A variety of materials, used in the past to fill holes where lenses were broken or missing, were also removed. Next, each panel was sandblasted. This
Vault Light History

Cast-iron vault lights were originally patented by Thaddeus Hyatt in 1845. As envisioned by Hyatt, the system incorporated small glass lenses set into cast-iron panels. The panels were modular, allowing for installation over large areas. Vault lights, sometimes referred to as “Hyatt Patent Lights,” became widespread through the second half of the nineteenth century, paralleling the rapid development of cast-iron architecture (see figures a and b). As detailed in numerous historical trade catalogues of the time, vault lights were marketed to building owners and architects as a safe, inexpensive daylighting system that allowed for the conversion of previously “unusable” basements into “rent-producing, productive work space.” Prismatic pendant (or “saw-tooth”) lenses were often used in place of the basic lenses because the angled projections on the underside of the prism bent light rays, directing them to the inner reaches of the lower levels (see figure c).

Vault lights were also widely employed in the early 1900s construction of New York City’s first subway system (see figure d). Purposefully employed by the designers of the Interborough Rapid Transit Company’s (IRT) subway, vault lights were constructed in the ceilings above the platforms to create an inviting underground space for a public unaccustomed to subterranean travel. Along with decorative amenities and the promise of rapid transit, the subway depended largely on pure, natural light to attract its riders.

Figure a.

With the emergence of Portland cement as a new building material at the end of the nineteenth century, vault lights were increasingly constructed with round, translucent glass lenses set into reinforced concrete. The new concrete-and-glass version improved durability, waterproofing and slip-resistance while producing the same illuminating effect.

Figure b.

cleared off the paint, chewing gum, tar, asphalt, concrete, corrosion, grout and other grime that accumulates on a New York City sidewalk over the course of a century, without pitting or otherwise damaging the cast-iron. Then, workers cleaned each of the panels with small chisels and drills fitted with wire brush attachments to remove any material missed during sandblasting (see figure 5).

At the outset of the restoration program, six of the twenty-one vault light panels were found to be cracked. Rather than replace them with newly cast panels, the contractor chose to repair the damaged units using two different techniques: welding cracked sections and splicing in replacement pieces. Due to inconsistent heating and the presence of impurities in the blast furnace mixture, historic cast-iron is a notoriously brittle material. This brittleness makes historic cast-iron susceptible to cracking and a challenge to weld properly.

The contractor had developed a system for repairing cracked or damaged vault covers. Primary considerations were to ensure that the pieces to be welded were correctly positioned and level and that the cast-iron was properly preheated. Then, using a wire-feed MIG (metal inert gas) welder, the two pieces were joined together (see figure 6). The welded seam was ground down to the level of the adjacent panel surface so that the repair would not be visible after painting. The result was a strong, durable and complete cast-iron panel. When replacement sections were required, the contractor drew from a small stockpile of salvaged panels identical to those at 552-554 Broadway.

When repairs to the cast-iron were completed, two coats of primer were applied, followed by three coats of gloss black paint to match the existing paint color (see figure 7). The contractor used a Benjamin Moore system including an “ironclad” oil-based metal primer and alkyd gloss enamel (Impervo) top coat that offered high abrasion resistance. A rust conversion
coating system would also be suitable. Painting was followed by the resetting of new glass lenses.

After ensuring that the panels were dry and free of oils, dirt, dust and other contaminants, a bead of silicone was applied at the bottom of each of the round openings (see figure 8). This preliminary seal would keep the glass centered during the grout application. Replacement lenses were obtained from a specialty glass manufacturer that has supplied new lenses for a number of vault light rehabilitation projects. The glass lenses were set into place and a two-part epoxy grout was used to seal them in the panel and waterproof the joint (see figure 9). The gray, chemically-resistant material was the same used for grouting floor brick, quarry tile pavers and ceramic mosaics. Workers mixed the compound, placed it in a caulking gun and squeezed it into the areas adjacent to the lenses. Before it hardened, excess grout was removed using a dampened sponge (see figure 10). After twenty-four hours, the grout cured sufficiently to complete the reglazing process. The panels were turned over and workers used a razor blade to cut away excess silicone that had dripped out of the space between the lens and the cast-iron along the underside of the panel. Then, the panels were shipped back to New York City.

**Replacement Panels**

Because vault lights are no longer in regular production, new custom panels had to be fabricated to replace the two missing when the project began. The contractor chose a surviving panel that was in good condition and sent it to a foundry in Alabama for use as a pattern. The foundry, which had worked on a number of vault light projects in the past, cast two new panels using techniques that had changed little in the past century. The original sample was packed in a bed of casting sand to make a three-dimensional mold. To account for shrinkage in the casting process (1/8" per foot), the mold was made slightly larger than the pattern ensuring that all panels, original and new, would be the same size. Vents and gates were created in the mold to allow the flow of molten iron and gas.

Although the method of casting new panels was nearly identical to the historical process, the composition of the cast-iron was altered to improve the material's tensile strength. To produce what is referred to as ductile iron, the iron was combined with a slightly higher percentage of carbon (+/- 3.75% in the new cast-iron versus +/- 3.5% in the historical). Very small amounts of magnesium and graphite were also added to produce a material two to four times stronger than that of historical cast-iron.

Following fabrication, the new panels were shipped to the contractor who set the new glass lenses and transported them to New York City for installation alongside the repaired panels (see figure 11).

**Reinstallation**

The reinstalation of the panels at 552-554 Broadway was straightforward because the substructure that supported the vault lights and saddles had been reinforced with steel members approximately seven years earlier. Where leaking panels had led to the deterioration of the original stringers and support structure, the previous contractor shored up the substructure by replacing the deteriorated stringers with T-beams.
Figure 12. During the installation, each panel was set onto the supporting T-beams that span the vault. A steel supporting girder, running perpendicular to the beams, is visible within the vault opening.

Figure 13. The restored and reinstalled panels prior to repainting the saddles.

Figure 14. The restored panels after work was completed.

spaced beneath each joint between adjacent panels (see figure 12). Additionally, newly cast frame sections were bolted together and installed beneath the sidewalk surface. As part of the current restoration, the contractor examined the substructure at 552-554 Broadway and determined that the previously rebuilt assembly did not require additional strengthening or modification.

To reinstall the panels, a bead of flexible polyurethane caulk was applied around the perimeter of the support frame. The panels were positioned on top of the sealant, in the same order they were set before removal, ensuring that the bolt holes would align (see figure 13). Four stainless steel flat-headed machine screws secured each panel to its framework. A flexible foam backer rod was inserted into the seam around each panel filling much of the gap. The same grout that was used to seal the glass lenses was also applied to the top of the backer rod to form the final surface seal. Again, excess grout was carefully cleared from the joint. The last step was to touch up paint on any area that was scratched during transportation or reinstallation.

Evaluation

Historically, when vault lights deteriorated, a building owner would often cover them over with asphalt or steel diamond plate or replace them with a standard concrete sidewalk. By obscuring or removing vault lights from the sidewalk, an owner eliminated a significant architectural feature from the streetscape.

The project at 552-554 Broadway suggested another, more appropriate alternative: the sensitive repair and replication of the historic vault lights (see figure 14). The result was the return of a historically significant feature that exhibited a high degree of craftsmanship and complimented the building and streetscape. Furthermore, the repaired vault lights once again serve their original function of illuminating basement space beneath the city's sidewalk.

Similar projects that included restoring vault lights have been able to recapture the basement beneath for restaurant, office and storage space, providing additional usable floor area for the owner. This work shows that proper installation techniques and periodic maintenance can ensure the long-term performance of vault lights.

Vault lights can be repaired using relatively simple, traditional technology. The tools and materials are commonplace: sanders, brushes, glass, paint and grout. The cast-iron, though often appearing beyond repair when covered with asphalt and rust, is usually
sound and capable of restoration. Cracked historic panels, can be welded back together or new patches seamlessly introduced. Damaged lenses can be replaced with new lenses cast in custom molds by specialty glass manufacturers. When historic panels are missing, new ones can be fabricated, utilizing the same methods used to cast ornamental iron features and replacement pieces for cast-iron facades.

Stripping the cast-iron and reinstalling the hundreds of glass lenses are labor intensive undertakings that, depending on the size and condition of the panels, can be expensive. Additional costs would be incurred if the substructure of the installation requires reinforcement, repair or replacement. When part of a building rehabilitation, costs associated with the vault light work may be eligible for state or federal tax incentives.

The project described here took eight weeks including removal and reinstallation. It involved a crew of three men to restore the panels offsite and a crew of four to reinstall them onsite.

Part of the reason that the fabrication of cast-iron-and-glass vault lights was discontinued was their propensity to leak. This problem was exacerbated by infrequent, misguided or nonexistent maintenance programs. After any vault light assembly is rehabilitated, it requires regular inspection and periodic maintenance. A small stock of lenses should be kept by the building superintendent. When a lens is cracked, the glass should be removed, the remaining grout cleared from the hole, the surface repainted and a new lens set in the same way as described above. Leaks that develop along the edge of the panel should likewise be repaired with the old material removed and new backer rod and grout applied. Lens and waterproofing repairs can often be completed without removing the panel from the sidewalk, and are neither expensive nor time consuming.

**Conclusion**

Vault lights are an important architectural feature frequently overlooked and under maintained. Considered beneficial for the way they manipulated light and improved dark, potentially usable space, vault lights were also a visual

**Concrete Vault Lights**

Although this publication focuses on cast-iron vault lights, it is also possible to replace deteriorated or even missing historic reinforced concrete vault lights. Beginning in the early 1900s, this type of installation supplants cast-iron panels. When three existing concrete panels in the sidewalk in front of Smith Tower in Seattle, Washington, were damaged by a construction truck, owners turned to a local concrete precaster to replicate the panels. The two inch thick, 4' x 9' panels dated to the first decade of the twentieth century and contained 180 Luxfer glass lights with saw-toothed prisms extending below. To cast new panels, measurements were first taken of the surviving panels and used to build a wood formwork (see figure a). Styrofoam cubes were set in the form to act as block outs for the square glass lights. A quarter inch, twisted square, steel rod was embedded in the original panels to reinforce the concrete. To obtain even greater strength in the new panels, a grid of steel reinforcing bars and standard 4" x 4" wire mesh was secured between the styrofoam blocks. Then concrete was poured into the mold. After the concrete set, workers removed it from the form and dug out the styrofoam placeholders (see figure b). New 1-3/4" square by 1" thick glass blocks with a pinkish tint to replicate the historic solarized lenses, were obtained from a local glass caster and set in the square voids with an epoxy. Then, the panels were transported to the building site and installed with a backer rod and caulk (see figure c and d).
complement to a building’s entrance and facade. Today, whether severely deteriorated, buried under layers of asphalt or missing altogether, this feature need not be lost. As the restoration project described in this Preservation Tech Note shows, sensitively rehabilitated vault lights can continue to provide architectural and historic character to the urban streetscape while serving their original function of naturally illuminating basement spaces.

PROJECT DATA:

Building:
552-554 Broadway
New York City, New York

Project Date:
2002

Contractor:
Rocco V. DeAngelo
Antique Cast Iron, Inc.
Cherry Valley, New York

Replacement Glass Supplier:
Blenko Glass Company
Milton, West Virginia

Replacement Panel Fabricator:
Talladega Foundry and Machine Company
Talladega, Alabama

Cost:
The total cost of the vault light rehabilitation project at 552-554 Broadway was approximately $70,000 or about $318 per square foot. Forty-five percent of this total was attributed to labor costs for sandblasting, hand cleaning, repainting, resetting glass lenses, grouting, touching up the panels, as well as welding the cracked or damaged panels and the two newly cast panels. Thirty percent of the total cost was for dismantling and reinstalling the panels, including transportation. The remaining twenty-five percent was for materials, primarily new glass lenses. This project did not include structural work, which would have added to the overall cost of the project.

Photo of Bleecker Street station in “Vault Light History” sidebar is courtesy of New York Transit Museum Archives, Brooklyn, New York.

Photos in “Concrete Vault Lights” sidebar are courtesy of Fred R. Beyers, Master Precaster Inc., Puyallup, Washington.

All other photos by the authors unless noted.

THIS PRESERVATION TECH NOTE was prepared by the National Park Service. Charles E. Fisher, Heritage Preservation Services, National Park Service, serves as the Technical Editor of the PRESERVATION TECH NOTES. Information on the 552-554 Broadway vault light project was generously provided by Rocco V. DeAngelo of Antique Cast Iron, Inc. Special thanks are extended to Elise Quasebarth of Higgins and Quasebarth, David M. Look at the Pacific Great Basin Support Office of the National Park Service, and Jo Ellen Hensley, John Sandor, Shannon Dodge and Sharon C. Park of the National Park Service’s Heritage Preservation Services for their review and comments. Thanks also go to Alan Weiskopf of Perfilo Weiskopf Architects.

PRESERVATION TECH NOTES are designed to provide practical information on traditional practices and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act, which direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Technical Preservation Services, National Center for Cultural Resources, National Park Service, 1849 C Street, NW, (2255) Washington, DC 20240.

ISSN: 0741-9023
PTN 47
November 2003