Memorandum

Planning Division
Community & Economic Development Department

To: Planning Commission

From: Carl Leith, Senior Historic Preservation Planner

Date: June 2, 2011

Re: **Windows Work Session**

Purpose

The purpose of this work session is to provide the Commission with the opportunity to consider in greater detail the role and importance of historic windows to the architectural integrity of the building, their characteristics and the issues associated with proposals to alter or replace such windows. In doing so the Commission will be able to consider craftsmanship, materials, perceived and structural window condition, maintenance and repair, sustainability issues, energy and acoustic performance, and options for upgrading this performance.

Joining us for the discussion are Susie Petheram, CRSA, and David Richardson, Capitol Hill Construction, bringing their own wealth of experience and insights on issues relating to historic windows.

Background

The pressure to replace original or early windows has increased in recent years as a result of active marketing by the replacement window industry and a universal objective to enhance energy efficiency and reduce energy demands in all buildings, in the face of global warming. Although historic districts comprise a small proportion of the nation's older buildings, the result has been widely regarded, at national and local levels, as a significant threat to the character of cultural resources across the country; the matter attracts no less attention internationally. Organizations such as the National Trust for Historic Preservation and the National Park Service have focused significant efforts towards enhancing the level of understanding of the aesthetic, functional and durable characteristics of traditional windows, and their stewardship.

In the recent past the Commission has reviewed a variety of applications to replace original windows in buildings within all the historic districts in the city. The predominant reasoning presented is that the windows are in poor condition, do not operate or are painted shut, and that they are a notable source of heat loss from the building. In two cases before the Commission this year, these have been variously presented as the reasons to replace. The Commission, at meetings on March 2 and April 6, has identified the need for further understanding of historic window condition and repair. This work session is the first to be devoted to discussion of historic windows, and the issues which arise in assessing their role, condition and efficiency. It should be a valuable resource for future review and decision making. The Commission may wish to consider further work sessions of this nature, on windows and other matters, to allow greater time for discussion and an opportunity to review a wider range of information on aspects of the subject.

Window Characteristics

Assessing the role of the window there are a variety of issues and characteristics to consider. Discussion in this work session should touch on most of these. A summary of these might include the following:

Angles of Approach – Potential Discussion Points

1. The role of windows in defining the character of the building and the district – SLC/NPS/NT
    a. The architectural authenticity, integrity & maturity of the building
    b. Intricate, multi-dimensional, architectural and visual experience – static and kinetic
    c. Sustainability (cultural/environmental/economic) – conservation of existing embodied craft
2. The inherent functional qualities of a traditional window:
    a. High quality of design, materials & construction
    b. Longevity – based on robustness, 'maintainability' & 'repairability'
    c. Energy efficiency – based on function, design quality, construction & durability
3. Issues associated with decisions regarding a traditional window:
    a. Maintenance and state of repair – superficial/structural/mechanism
    b. Energy & acoustic efficiency
    c. Repair skills availability
    d. Characteristics of traditional & replacement windows - comparison
4. Conservation & preservation policy & approach
    a. National
    b. State
    c. City
    d. International

The design of an older window is really a combination of functionality and the concentration of many facets of the character and integrity of the building (composition, design, detailing, materials, craft skills, patina, etc.) It consequently provides a richness of experience, internally and externally, that helps to create the uniqueness of our older neighborhoods – an experience that changes with the light. The design of a new window is driven primarily by functionality, and price.

Resources

Accompanying this Memorandum there are several copies of selected materials addressing various aspects of historic windows (copies of additional documents will be available at the meeting). There is also a list of internet links to a series of information sources, which in turn provide further links to supporting or related material. Information is provided from across the USA, and also from Canada and Europe, where stewardship and energy research and practice have similar issues to address.

This information is constantly growing and being updated. Staff will endeavor to keep the Commission up to date with any additional material and information as this becomes available.

Attachments

This Memorandum has the following Attachments.

A. Agenda

B. List of Internet Resources

C. Selected Documents on Historic Windows

Attachment A

Historic Landmark Commission - Windows Work Session June 2, 2011

AGENDA

1. **Introduction**
   City Staff

2. **Susie Petheram, CRSA**

3. **David Richardson, Capitol Hill Construction**

4. **Discussion**

Attachment B

List of Internet Resources

HISTORIC WINDOWS – RESOURCES AND LINKS

Federal Sites

National Park Service
http://www.nps.gov/index.htm (search windows)

National Park Service, National Center for Preservation
http://ncptt.nps.gov (search windows)

Secretary of the Interior's Standards
http://www.nps.gov/history/hps/tps/tax/guidance.htm
http://www.nps.gov/history/hps/tps/tax/incentives/avoiding_1.htm
http://www.nps.gov/history/hps/tps/

National Park Service Preservation Briefs
http://www.nps.gov/history/hps/tps/briefs/presbhom.htm

U.S Department of Energy
http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/historic_homes_guide.pdf

National Sites

National Trust for Historic Preservation
http://www.preservationnation.org/resources/homeowners/
http://www.preservationnation.org/issues/sustainability/

Alliance of Preservation Commissions
http://www.uga.edu/napc/programs/napc/publications.htm

Association of Preservation Technology International
http://www.apti.org/publications/bulletin-index.cfm (search windows)

State Sites

Missouri SHPO
http://www.dnr.mo.gov/shpo/links.htm

Kansas SHPO
http://www.kshs.org/portal_shpo (search windows)

California State Parks
http://www.ohp.parks.ca.gov (sustainability)

Preservation North Carolina
http://www.presnc.org/Preservation-Answers/Historic-Windows-Resource-Page

International Sites

Northern Ireland
http://www.ni-environment.gov.uk (search windows)

Heritage Canada Foundation
http://www.heritagecanada.org/eng/news/archived/spring2006/windows.html
http://www.heritagecanada.org/eng/news/archived/summer2006/windows.html
http://www.heritagecanada.org/eng/news/archived/spring2007/thermal.html

Scotland
http://www.historic-scotland.gov.uk/gcu-technical-_thermal-efficiency-traditional-windows.pdf
http://www.historic-scotland.gov.uk/caring-for-your-sash-case.pdf

City Sites

Denver, CO
http://denvergov.org/Preservation/DesignReviewCertificateofAppropriateness/Applicationmaterials/tabid/438031/Default.aspx

Albany, OR
http://www.cityofalbany.net/comdev/historic/

San Francisco, CA
http://www.sf-planning.org/index.aspx?page=1825

Cambridge, MA
http://www2.cambridgema.gov/Historic/windowglines_final.pdf

Phoenix, AZ
http://phoenix.gov/HISTORIC/hprehab.html#technical

Boulder, CO
http://www.bouldercolorado.gov/index.php?option=com_content&task=view&id=2033&Itemid=1862

Technical Papers

Saving Energy in Historic Buildings: Balancing Efficiency and Value
http://www.apti.org/publications/Cluver-Randall-41-1.pdf

What Replacement Windows Can't Replace: The Real Cost of Removing Historic Windows
http://ohp.parks.ca.gov/pages/1054/files/replacement_windows%20sedovic%20gotthelf.pdf

The Effects of Energy Efficiency Treatments on Historic Windows
http://www.conservationcenter.org/assets/EffectsEnergyonHistoricWindows.pdf

Testing the Energy Performance of Wood Windows in Cold Climates http://www.ncptt.nps.gov/2008/testing-the-energy-performance-of-wood-windows-in-cold-climates-a-report-to-the-state-of-vermont-division-for-historic-preservation-agency-of-commerce-and-community-development-1996-08/

Research into the Thermal Performance of Traditional Windows: Timber Sash Windows
http://www.english-heritage.org.uk/professional/research/buildings/energy-efficiency/thermal-performance-of-traditional-windows/

Media and Video Links

http://www.kshs.org/p/window-repair-videos/14680
http://www.presnc.org/Preservation-Answers/Historic-Windows-Resource-Page

Old House Journal
http://www.oldhousejournal.com/npsbriefs2/brief09.shtml
http://oldhousejournal.com/Sash_Window_Clinic/magazine/1078

Traditional Building
http://www.period-homes.com/Newsletter/SPR_APRIL_9_09_NEWSLETTER.html

Attachment C

Selected Documents

Standards
Guidelines

Masonry
Wood
Metals

Roofs
Windows
Entrances/Porches
Storefronts

Structural Systems
Spaces/Features/Finishes
Mechanical Systems

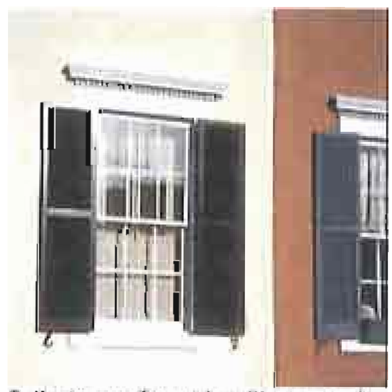
Site
Setting

Energy
New Additions
Accessibility
Health/Safety

Distinctive window design on 19th century building.

Technology and prevailing architectural styles have shaped the history of windows in the United States starting in the 17th century with wooden casement windows with tiny glass panes seated in lead cames. From the transitional single-hung sash in the early 1700s to the true double-hung sash later in the same century, these early wooden windows were characterized by the small panes, wide muntins, and the way in which decorative trim was used on both the exterior and interior of the window.

As the sash thickness increased by the turn of the century, muntins took on a thinner appearance as they narrowed in width but increased in thickness according to the size of the window and design practices. Regional traditions continued to have an impact on the prevailing window design such as with the long-term use of "french windows" in areas of the deep South.



Delicate muntins and multi-pane sash on early 19th c. row houses.

Changes in technology led to the possibility of larger glass panes so that by the mid-19th century, two-over-two lights were common; the manufacturing of plate glass in the United States allowed for dramatic use of large sheets of glass in commercial and office buildings by the late 19th century. With mass-produced windows, mail order distribution, and changing architectural styles, it was possible to obtain a wide range of window designs and light patterns in sash.

Popular versions of Arts and Crafts houses constructed in the early 20th century frequently utilized smaller lights in the upper sash set in groups or pairs and saw the re-emergence of casement windows. In the early 20th century, the desire for fireproof building construction in dense urban areas contributed to the growth of a thriving steel window industry along with a market for hollow metal and metal clad wooden windows

As one of the few parts of a building serving as both an interior and exterior feature, windows are nearly always an important part of the historic character of a building. In most buildings, windows also comprise a considerable amount of the historic fabric of the wall plane and thus are deserving of special consideration in a rehabilitation project.

Windows ....Identify, retain, and preserve recommended.....

Window condition assessment preceding repair work.

Identifying, retaining, and preserving windows--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.

Conducting an indepth survey of the conditions of existing windows early in rehabilitation planning so that repair and upgrading methods and possible replacement options can be fully explored.

not recommended.....

Removing or radically changing windows which are important in defining the historic character of the building so that, as a result, the character is diminished.

Changing the number, location, size or glazing pattern of windows, through cutting new openings, blocking-in windows, and installing replacement sash that do not fit the historic window opening.

Changing the historic appearance of windows through the use of inappropriate designs, materials, finishes, or colors which noticeably change the sash, depth of reveal, and muntin configuration; the reflectivity and color of the glazing; or the appearance of the frame.

Obscuring historic window trim with metal or other material.

Stripping windows of historic material such as wood, cast iron, and bronze.

Replacing windows solely because of peeling paint, broken glass, stuck sash, and high air infiltration. These conditions, in themselves, are no indication that windows are beyond repair.

Windows ....Protect and Maintain

recommended.....

Protecting and maintaining 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.

Making windows weathertight by re-caulking and replacing or installing

weatherstripping. These actions also improve thermal efficiency.

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.

Newly painted double-hung wood windows.

not recommended.....

Failing to provide adequate protection of materials on a cyclical basis so that deterioration of the window results.

Retrofitting or replacing windows rather than maintaining the sash, frame, and glazing.

Failing to undertake adequate measures to assure the protection of historic windows.

Windows ....Repair

recommended.....

Repairing window frames and sash by patching, splicing, consolidating or otherwise reinforcing.

Preparing historic steel windows for repairs and re-finishing.

Such repair may also include replacement in kind--or with compatible substitute material--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.

not recommended.....

Replacing an entire window when repair of materials and limited replacement of deteriorated or missing parts are appropriate.

Failing to reuse serviceable window hardware such as brass sash lifts and sash locks.

Using 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.

Windows ....**Replace**

recommended.....

Replacing in kind an entire window that is too deteriorated to repair using the same sash and pane configuration and other design details. If using the same kind of material is not technically or economically feasible when replacing windows deteriorated beyond repair, then a compatible substitute material may be considered.

Deteriorated lower window sash shown prior to its replacement in kind.

Lower window sash replaced, based on physical documentation.

For example, on certain types of large buildings, particularly high-rises, aluminum windows may be a suitable replacement for historic wooden sash provided wooden replacement are not practical and the design detail of the historic windows can be matched.

Historic color duplication, custom contour panning, incorporation of either an integral muntin or 5/8" deep trapezoidal exterior muntin grids, where applicable, retention of the same glass to frame ratio, matching of the historic reveal, and duplication of the frame width, depth, and such existing decorative details as arched tops should all be components in aluminum replacements for use on historic buildings.

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.

Design for Missing Historic Features

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.

recommended.....

Designing and installing new windows when the historic windows (frames, 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.

not recommended.....

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

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.

recommended.....

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.

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.

not recommended.....

Incompatible new window (lower right), resulting in loss of the building's historic character.

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.

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.

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9 Preservation Briefs
Technical Preservation Services
National Park Service
U.S. Department of the Interior

The Repair of Historic Wooden Windows

John H. Myers

A NOTE TO OUR USERS: The web versions of the **Preservation Briefs** differ somewhat from the printed versions. Many illustrations are new, captions are simplified, illustrations are typically in color rather than black and white, and some complex charts have been omitted.

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. 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.

Windows are frequently important visual focal points, especially on simple facades such as this mill building. Replacement of the multi-pane windows with larger panes could dramatically alter the appearance of the building. Photo: NPS files.

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.

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 proceed with planning appropriate treatments, beginning with an investigation of the physical condition of the windows.

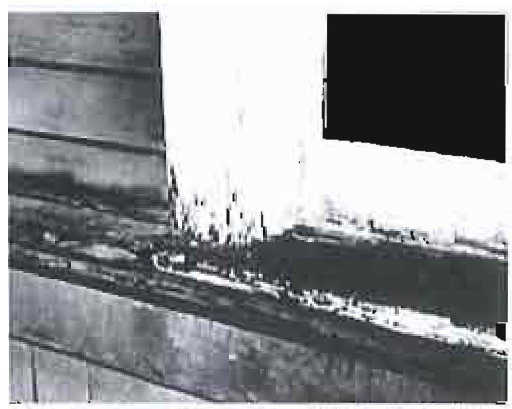
Physical Evaluation

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 runoff, particularly 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.



Deterioration of poorly maintained windows usually begins on horizontal surfaces and at joints, where water can collect and saturate the wood. Photo: NPS files.

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. 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 endgrain 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 section 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.

This historic double-hung window has many layers of paint, some cracked and missing putty, slight separation at the joints, broken sash cords, and one cracked pane. Photo: NPS files.

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 reinstallation of the sash, and 5) repainting. These operations are illustrated for a typical

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. Photo: NPS files.

double-hung wooden window, 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.

Sash can be removed and repaired in a convenient work area. Paint is being removed from this sash with a hot air gun. Photo: NPS files.

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. 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, the glass should be removed or protected from the sudden temperature change which can cause breakage. An 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.

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 weather-tight seal. After the proper curing times have elapsed for paint and putty, the sash will be ready for reinstallation.

While the sash are out of the frame, the condition of the wood in the jamb and sill can be evaluated. Repair and refinishing of the frame may proceed concurrently with repairs to the sash, taking advantage of the curing times for the paints and putty used on the sash. One of the most common work items is the replacement of the sash cords with new rope cords or with chains. 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.

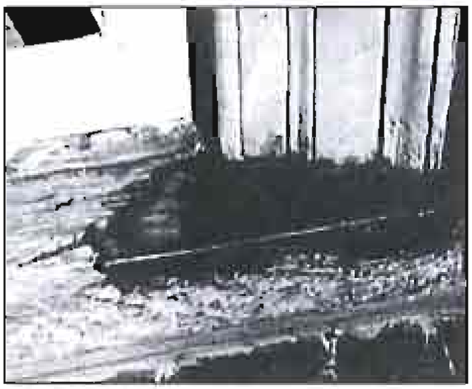
Following the relatively simple repairs, the window is weathertight, like new in appearance, and serviceable for many years to come.Photo: NPS files.

The operations just discussed summarize the efforts necessary to restore a window with minor deterioration to "like new" condition. 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 process 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.



This illustrates a two-part expoxy 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: NPS files.

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 semirigid epoxies which saturate the porous decayed wood and then harden. The surface of the consolidated wood can then be filled with a semirigid epoxy patching compound, sanded and painted. Epoxy patching compounds can be used to build up 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. 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. More information on epoxies can be found in the publication "Epoxies for Wood Repairs in Historic Buildings," cited in the bibliography.

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 other 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, wherever 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 contemporary weatherstripping should be considered an integral 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 accurate, they will usually be viewed as an acceptable contemporary 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 condensation problems must be addressed. Moisture which becomes trapped between the layers of glazing can condense 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 window may clearly indicate replacement. The decision process 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 appearance 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 profiles; **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 understanding of how the window reflects the period, style, or regional characteristics of the building, or represents technological development.

Armed with an awareness of the significance of the existing 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 windows. Continue looking until an acceptable replacement can be found. Check building supply firms, local woodworking mills, carpenters, preservation oriented magazines, 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 successfully 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 window added should thermally outperform a new double-glazed metal window which does not have thermal breaks (insulation between the inner and outer frames intended 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. According 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 replaced 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 element of a building's significance will have been preserved for the future.

Additional Reading

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Washington, D.C. 1981

Home page logo: Historic six-over-six windows--preserved. Photo: NPS files.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Technical Preservation Services (TPS), Heritage Preservation Services Division, National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

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13 Preservation Briefs

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

The Repair and Thermal Upgrading of Historic Steel Windows

Sharon C. Park, AIA

A NOTE TO OUR USERS: The web versions of the **Preservation Briefs** differ somewhat from the printed versions. Many illustrations are new, captions are simplified, illustrations are typically in color rather than black and white, and some complex charts have been omitted.

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 ease 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, insensitively designed replacement windows may diminish--or destroy--the building's historic character.

Maintaining historic steel windows for continued use is always recommended. Photo: NPS files.

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.(1) 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 infeasible. In such cases, the Brief offers guidance in evaluating appropriate replacement windows.

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. 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. 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 by-product 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. Casement, double-hung, pivot, projecting, austral, and continuous windows differed in operating and ventilating capacities. 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, noncorroding 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.

Historic metal windows provide abundant natural light in this rehabilitated industrial space. Photo: NPS files.

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.

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 subframe--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


A severely deteriorated frame, such as this, can be replaced in kind. Photo: Henry Chambers, AIA.

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.

Typical Rolled Steel Windows Available from 1890 to the Present

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.

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.

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.

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.

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.

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.

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.

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 oxyacetylene 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 deg. 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 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 anticorrosive 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.

The historic steel sash is shown in place, prior to its removal and replacement with inappropriate aluminum sash (see below). Photo: NPS files.

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 anticorrosive 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. Anticorrosive primers generally consist of oil-alkyd based paints rich in zinc or zinc chromate.(2) 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. As 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 blowdrier (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.


The historic steel sash (see photo above) was removed and replaced with modern aluminum sash, resulting in a negative visual impact on the building's historic character. Photo: NPS files.

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 re-align 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 x 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 x 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.

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 anticorrosive 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 anticorrosive 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.

Repair in Workshop

Damage to windows may be so severe that the window sash and sometimes the frame must be removed for cleaning and extensive rust removal, straightening of bent sections, welding or splicing in of new sections, and reglazing. These major and expensive repairs are reserved for highly significant windows that cannot be replaced; the procedures involved should be carried out only by skilled workmen.

As part of the orderly removal of windows, each window should be numbered and the parts labeled. 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 labeled 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 anticorrosive 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 oxyacetylene 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.

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.(3)

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 ventilator, and the fixed frame come together to reduce perimeter air infiltration. 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 insure 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, 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 midpoint, the thin sections 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 (27 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.

Appropriate Types of Weatherstripping for Metal Windows

SPRING-METAL comes in bronze, brass or stainless steel with an integral friction fit clip. The weatherstripping is applied after the repaired windows are painted to avoid galvanic corrosion. This type of thin weatherstripping is intended for windows in good condition.

VINYL STRIPS are scored and fold into a "V" configuration. Applied adhesive is necessary which will increase the thickness of the weatherstripping, making it inappropriate for some situations. The weatherstripping is generally applied to the window after painting.

Closed cell **FOAM TAPE** comes either with or without an adhesive backing. It is effective for windows with a gap of approximately 1/4" and is easy to install. However, this type of weatherstripping will need frequent replacement on windows in regular use. The metal section should be cleaned of all dirt and grease prior to its application.

SEALANT BEAD. This very effective type of weatherstripping involves the application of a clean bead of firm setting caulk on the primed frame with a polyethelene bond breaker tape on the operable sash. The window is then closed until the bead has set and takes the form of the gap. The sash is then opened and the tape is removed leaving the set caulk as the weatherstripping.

Thermal Glazing

Historic steel sash can be fitted with dual glazing to improve thermal efficiency. Photo: NPS files.

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 windows); 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.

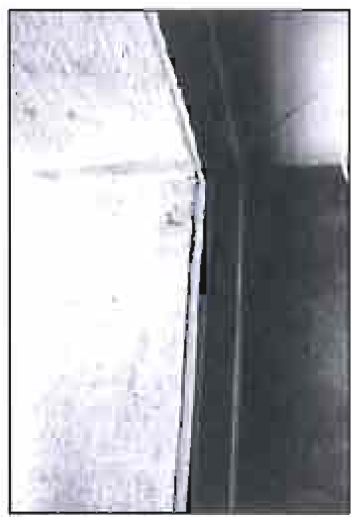
The least expensive of these options is to install a clear material (usually rigid sheets of acrylic or glass) over the original window. The choice between acrylic and glass is generally based on cost, ability of the window to support the material, and long-term maintenance outlook. If the material is 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. 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 a 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 then 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.

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.



This is a successsful replacement in kind of the deteriorated frame shown above. Photo: Henry Chambers, AIA.

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 reflective quality 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. 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.

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 boxlike 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.

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.

NOTES

(1) 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 nonferrous metals, such as bronze, Monel, or aluminum, refer to *Metals in America's Historic Buildings* (see bibliography).

(2) Refer to Table IV. Types of Paint Used for Painting Metal in Metals in America's Historic Buildings, p. 139. (See bibliography).

(3) 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 1.3. Adding storm windows to the existing units or reglazing 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).

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Acknowledgments

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. Kleyle. 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.

Washington, D. C. September, 1984

Home page logo: Metal casement window from "Hope's Metal Windows and Casements, 1818-1926." Photo: Courtesy, Hope's Windows, Inc.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Technical Preservation Services (TPS), Heritage Preservation Services Division, National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

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KDW

Replacement for Missing or Non-historic Windows

Many buildings have inappropriate replacement windows or missing windows. Although installing a replacement window that replicates the original historic window may be desirable, documentation of original windows may not be available. The minimum requirement is that the new windows be consistent with the historic character of the building.

Above: Replacing these existing incompatible replacement windows (left) with similar units would not meet the Standards. New windows installed in a rehabilitation project should be compatible with the historic character of the building. In this case, new windows (right) that convey the general appearance of industrial steel windows that were historically on the building were the appropriate choice for this building. Photos: NPS files

Glazing

Unless the property is a mid 20th-century building, historic glazing is unlikely to be tinted or reflective. Unlike contemporary tinted glass, most clear low-e coatings currently in use have very little visual effect and may be used on historic buildings. It is recommended that a sample of glass be submitted for review if other than clear glass is being proposed. Where the historic glazing was not clear, such as the obscure glass found in many industrial buildings, a replacement other than clear, may be considered.

Left: The transparency of glass is critical to the function of a shop window. The introduction of reflective glass here is inconsistent with the historic character of this building. Photo: NPS files

Windows

Windows are a significant part of the exterior envelope of most buildings and are important in defining the historic character of a building--both inside and out. Historic windows should always be retained, when possible. Yet, owners frequently propose replacement of existing historic windows. When window replacement is appropriate, selecting new windows that are compatible with the building's historic character is one of the most common and difficult issues in rehabilitation.

To meet the Standards for Rehabilitation, missing, non-historic, or severely deteriorated windows that cannot be repaired should be replaced with windows that match the historic windows in material, size, muntin configuration, and reflective quality.

Repair

Where historic windows exist, they should be repaired, where possible. Repair may include incremental replacement of individual elements such as sills or sash. Lead abatement or thermal performance may be accomplished without the loss of historic windows and is not justification for replacement.

Thermal upgrade

Storm windows have been a traditional means of improving efficiency for over a century. They also protect the historic window itself. When detailed to minimize their visual intrusiveness, they are an acceptable addition to a historic window. Another option possible in some cases is the modification of existing historic windows to allow reglazing with insulated glass.

The historic wood windows (left) were repaired and exterior storm windows added (right). This approach meets the Standards for Rehabilitation. Photos: NPS files

The extensive deterioration of this historic metal window justifies its replacement with a matching new window. Photo: NPS files

Replacement of Severely Deteriorated Windows

Any replacement other than a custom-crafted replica involves some measure of change in appearance. Even a wood window, if it is a modern manufactured product, will have profiles and details that vary from historic windows. The acceptability of any replacement is based on the overall visual effect of the new window as compared to the historic window.

Documentation

Deterioration justifying replacement needs to be documented with good close-up photographs. When possible, a trial repair, photographed and evaluated, is an excellent way to determine whether or not repair is reasonable.

An alternative to scale drawings is a mock-up or sample installation photographed together with an existing window. A mock-up may be particularly helpful in determining the importance of variations between the deteriorated historic window (left) and the proposed replacement window (right). Photos: NPS files

Substitute materials

Much of the character of a window derives from its materials. Using a substitute material for a replacement window adds another element of change. On small-scale residential buildings or any building where the interior appearance of the window is important to the character of the building, wood windows may be the only appropriate replacement for historic wood windows. A substitute material is not appropriate if it does not permit the profile and dimension of the historic window to be reproduced accurately.

Clad wood windows generally have the same profiles as other manufactured wood windows, but a clad window will be noticeably different if the cladding is applied with joints that do not match the lines of typical wood window joinery. Also, clad windows do not offer the range of profiles necessary to match some windows, particularly very large windows.

Muntins

True divided lights are desirable, but accurately matching the size and profile of the historic muntins is just as important. Beaded and ogee-shaped glazing beads are a poor match for the simple putty bevel of a historic window. Exterior applied muntins--when backed up by between-the-glass spacers and/or interior muntins--may adequately convey the effect of divided lights on high upper floors. On lower floors, the historic windows should be retained and preserved.

A new sample muntin (above), with its shallow, irregular profile, looks very different from the simple, deeper profile of the glazing putty on the historic window. The new muntin would not be an acceptable replacement. Photo: NPS files

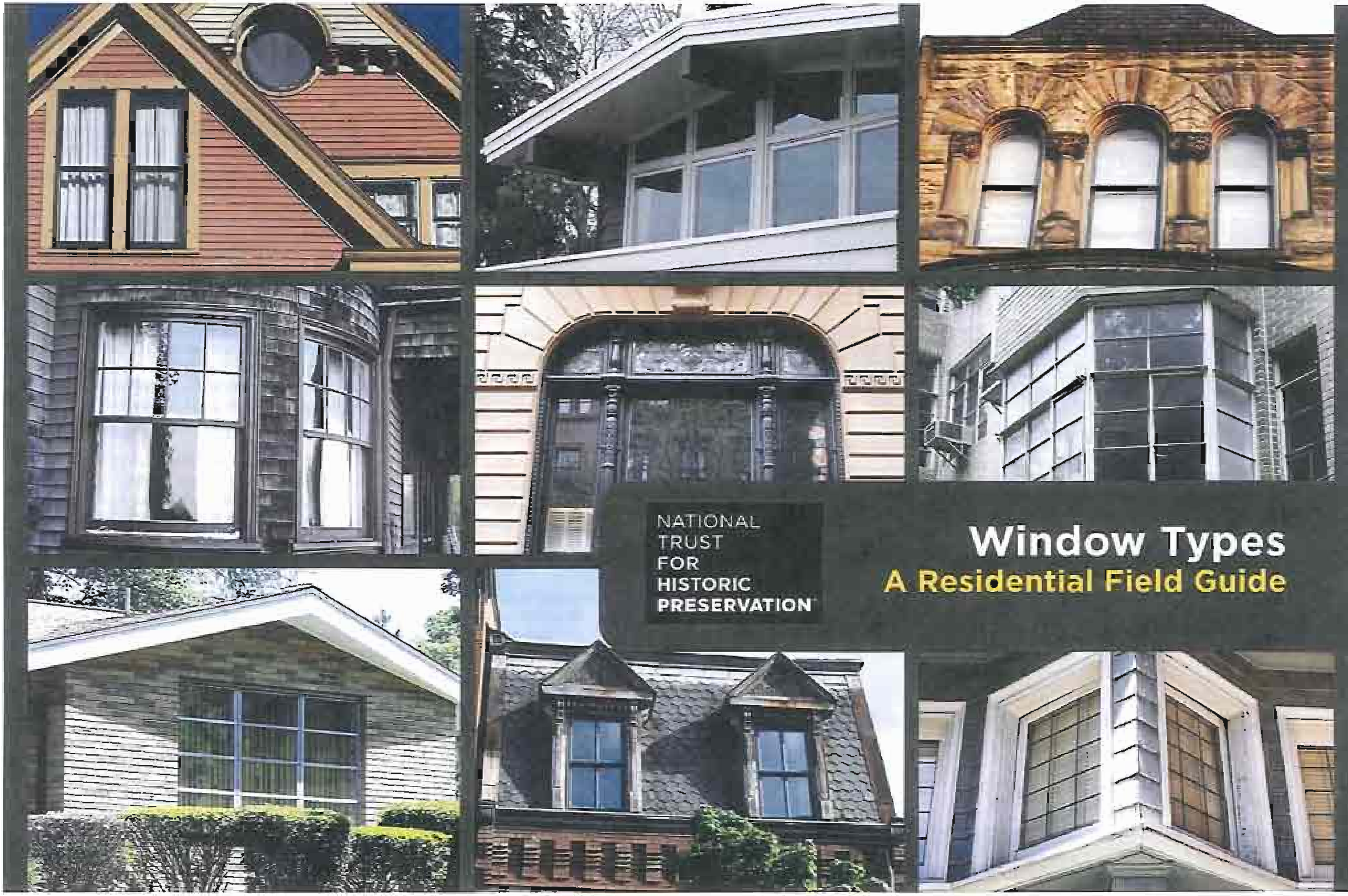
Installation

Successful replacement windows depend not only on the match of the windows themselves, but also on the way they are installed in the wall. The relationship of window to wall plane should not change when a window is replaced. Installing a full replacement unit without removing the existing jambs will usually reduce the glass size and unacceptably compromise the match.

Operation

The way a historic window operates is a major component of its appearance. While a replacement window should capture the visual effect of that operation, it does not have to operate in the same way or at all.

Right: The heavier frame of the pivot sash in this historic industrial building creates a distinctive pattern in the overall grid of muntins. This visual distinction can clearly be reproduced in any replacement window, regardless of how or whether the window operates.
Photo: NPS files



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Window Types

A Residential Field Guide

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Residential Window Types

The character of older and historic homes are often defined by their windows, whether an 1880s Queen Anne or a 1950s Split-Level. While they vary in size, shape, materials and proportion, windows also give scale to a house and provide depth. The proportion, divisions and materials of a window are essential elements of design. In most cases, windows are the most dominant visual element of an older and historic house.

Like architectural styles, there are a wide range of window types. Windows have evolved as technology has advanced. From the early multi-pane double-hung sash to the modern plate glass picture window, they have also changed along with the popularity of different residential architectural styles.

As a homeowner of an older and historic residence, you may want to learn more about your windows, why they are unique and, most significant, how to ensure they are maintained and energy efficient. The weatherization of windows, as part of a whole-house strategy, is important. Homeowners have choices. Older windows can always be retrofitted to be more energy efficient through a variety of methods, depending on the type of window.

This guide is intended as a resource to help get you started by identifying some of the most common window types found in older and historic residential architecture. A series of online links are provided for many of the window types so you can learn more.

For more information...

Go to **www.PreservationNation.org/Weatherization** to find additional resources on windows and much more for your older and historic building.

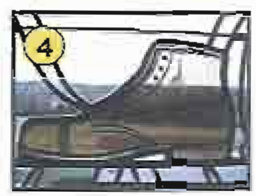
About the Guide

Bay and Bow

Casement

Gothic

Leaded and Stained Glass



Modern

Oriel

Patterned

Queen Anne

Single, Double and Triple-Hung Sash

Additional Window Types

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Bay and Bow

Bay and Bow
Angular and projecting from the wall, bay windows can be found on any story of a building and on many building types. A bay window will allow more daylight, provide more views and offer better air circulation.

Bay - This window is usually made up of three individual window units (though sometimes it can be more). The side units will project outwards from the wall and the center window will join them together. Generally, angles may be 30, 45, 60 or 90 degree angles. Windows will be combined often with operable and inoperable units.

Bow - Like a bay, this window combines a more rounded curve than the angled step style of the related bay window type. Generally there will be four or five window units to make up the curved bow window.

A Bay with metal casement windows on Tudor style house.
B Art Deco apartment building in Brooklyn, NY, with metal casement windows.
C Bay with one-over-one wood double-hung sash window
D Bay with single metal casement windows on Tudor style house.

Wood-frame Victorian cottage with prominent bay window
Manchester, New Hampshire

Adrian Scott Fine/NTHP

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Casement

Casement

Casement windows are often a defining element of residential architecture. These are widely used in both traditional and contemporary design. Casement windows are typical of the Tudor, Arts and Crafts, Art Deco styles. These windows are hinged on one side and may swing out or in. They can be arranged as a single window or paired and the frames may be wood or metal (rolled steel). Metal casement windows can be made more energy efficient by caulking around the masonry openings, adding weather stripping and installing storm windows (interior and/or exterior).

A, B Streamlined casement windows were popular in the 1930s and 40s for Art Deco and Art Moderne architecture.
C Traditional casement designs were often used in the 1920s and 30s for cottage and Tudor style residences.
D Central fixed casement with transoms on apartment building in Denver, CO.
E Brass casement, hinged so that it swings in.

Resources (click title for link):
- The Repair and Thermal Upgrading of Historic Steel Windows. National Park Service. Sharon C. Park, AIA.
- Steel Casement Window Repairs. City of Phoenix, AZ.
- Metal Windows. Building Conservation Directory. Peter Clement

Streamlined Art Moderne house with metal casement windows
South Bend, Indiana

Adrian Scott Fine/NTHP

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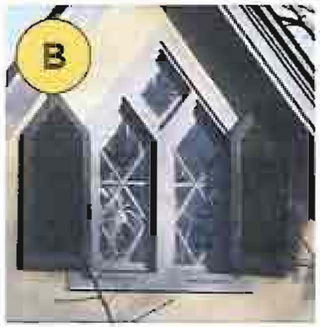
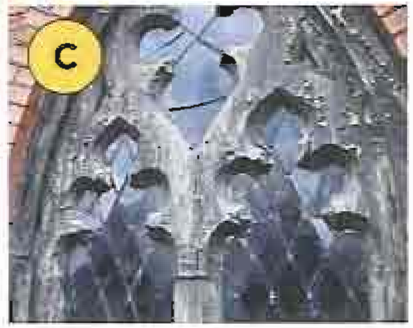
Gothic





Gothic

Commonly pointed, may be paired or have additional windows flanking the center window. Windows may be angular or feature a lancet arch — a tall narrow window with pointed arch at the top, shaped often like a spear. An architectural motif found often on religious structures, placed singularly or in pairs. Appears in early Gothic period of architecture and later Gothic Revival style of nineteenth century. Features detailing and elements also often referred to Carpenter Gothic residential architecture. Found often in picturesque rural settings.

- A Paired windows with lattice-style fenestration and drip mold, designed to protect the window from water — directing it out and away from the sash.
- B In this example, note how the functional shutters are designed to match the profiles of the primary sash.
- C The use of scroll saw allowed the application of elaborate wood moldings, in this case, over leaded-glass.
- D Paired one over one double-hung sash Gothic window.
- E Singular two over two double-hung sash Gothic window.

Resources (click title for link):

- Guide to the Alexander Jackson Davis Papers.
- Lyndhurst, America's preeminent example of residential Gothic Revival architecture, Tarrytown, NY.

Gothic Revival house with paired lancet arched windows
Windsor, Vermont

Adrian Scott Fine/NTHP

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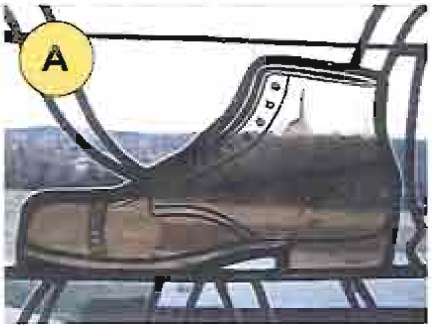
Leaded and Stained Glass



Leaded and Stained Glass

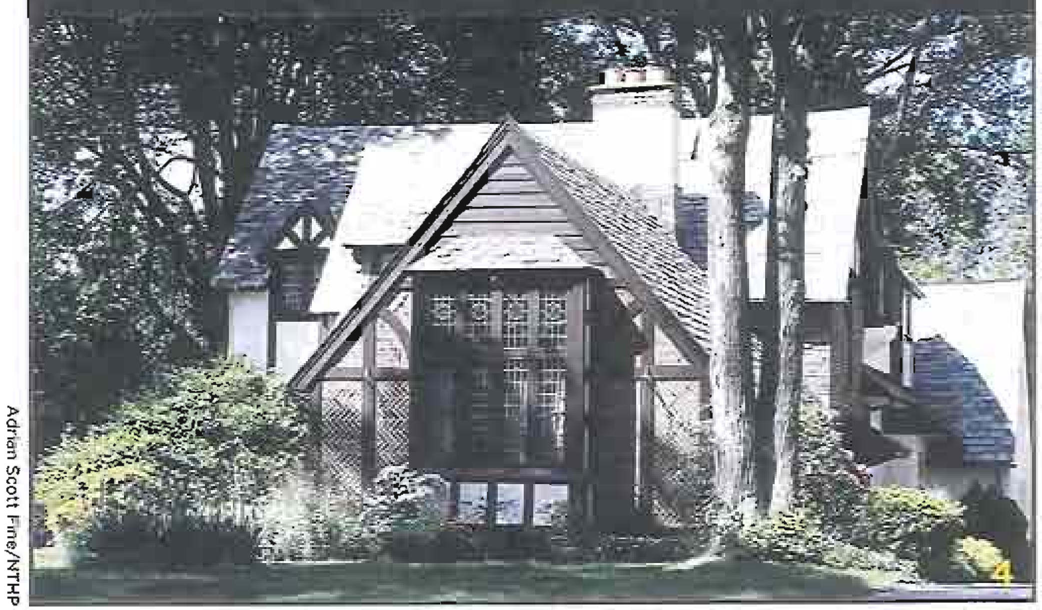
Although colored or beveled glass is often referred to as leaded and/or stained glass, there are varieties and different types despite the interchangeable use of terminology. This highly decorative glass can be colored, painted, enameled or tinted and held together by lead, copper or zinc cames. Residential architecture of all styles often incorporates this form of window.

A Detail of shoe from window in the Shoe House in York, PA.
B Round arched double-hung sash window with elaborate design.
C Transom with leaded and stained glass on Brooklyn, NY, row house.
D The richness of detail is visible in this window.
E Oval-shaped fixed stained glass window.

Resources (click title for link):

- Conservation and Restoration of Stained Glass — An Owner's Guide. Virginia Raguin.
- Scientific Examinations of Historical Stained Glass. Manfred Torge, Wolfgang Muller and Karin Adam.
- Stained-Glass Protection: Ventilation Specifications for Protective Glazing. Ron Bovard.
- The Preservation and Repair of Historic Stained and Leaded Glass. National Park Service. Neal A. Vogel and Rolf Achilles.

Tudor Revival house with projecting, leaded-glass bay window
Philadelphia, Pennsylvania



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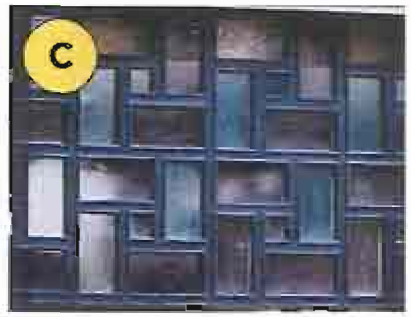
Window Types — Residential Field Guide

Modern



Modern

Like earlier architectural styles, windows are important in helping to define modern, mid-century house types, from ranch houses to split levels. The sizes, types, arrangements and materials of windows during this period were largely experimental and often mass produced. Oversized plate-glass fixed windows, clerestory and the 'picture window' are some of the innovations. Modern windows can be made more energy efficient by caulking around the masonry openings, adding weather stripping and installing storm windows (interior and/or exterior).

- A Irregular and oversized fixed plate glass windows.
- B Picture window with fixed plate glass at center and operable jalousie windows flanking at each end.
- C Distinctive stained glass wall on ranch house in Savannah, GA.
- D Angular clerestory windows.
- E Curved glass blocks.

Resources (click title for link):

- Atomic Ranch magazine
- Historic Preservation Guidelines for Village Grove 1-6 Historic District. City of Scottsdale, AZ.
- Little Boxes. North Carolina Signature
- Retro Renaissance. Alaska Airlines Magazine.

Ranch style house with large steel-framed picture window
Dallas, Texas

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Oriel

Oriel

These projecting bay windows, usually on an upper story, do not extend to the ground. They originally developed as a form of porch, popular in Gothic Revival style buildings. Typically its walls are supported by a corbelled or bracketed base.

A Oriel with three brackets on brick Queen Anne residence.
B Metal-sided oriel with curved glass sash and leaded glass transoms.
C Two-sided oriel on Queen Anne style residence in Sacramento, CA.
D Oriel with copper base at gable of Queen Anne style residence in Harrisburg, PA.
E Queen Anne residence in Wilmington, DE, with wood-frame oriel.

Resources (click title for link):
- Oriel Windows: A Pattern Book for Newquay.

Tudor Revival house with leaded glass oriel window over entrance
Drexel Hill, Pennsylvania

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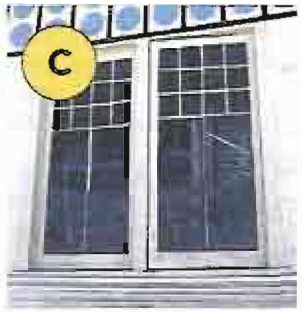
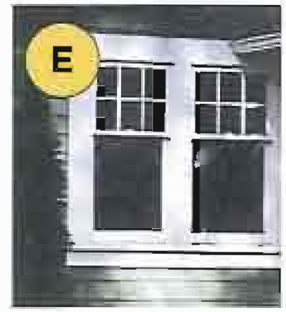
Patterned





Patterned

The Arts and Crafts, Prairie and Queen Anne architectural styles often feature windows with very distinctive and unique patterns. These are usually casements or double-hung wood sash windows. Sometimes the upper sash will be divided into multiple panes of glass with a lower sash as a single piece of glass. Usually these are in the form of grids or diamond/lattice style patterns. Often the window surrounds and casings will be very wide, and grouped as ribbon windows, especially with the Arts and Crafts and Prairie styles.

A Lattice patterned sidelights and Dutch door.
B Twenty-one-over-one Craftsman style double-hung sash.
C Pair of twelve-over-two, wood casement windows on 1930s residence in New Orleans, LA.
D Diamond patterned double-hung sash window and fixed transom.
E Six-over-one double-hung sash windows with wide surround.
F Fixed center window and two casement windows.

Resources (click title for link):

- Craftsman Style Guide, City of Glendale, CA.

Queen Anne house with diamond pattern upper sash windows
Seattle, Washington

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Window Types — Residential Field Guide

Queen Anne

Queen Anne

These windows vary widely, but larger square or diamond panes of glass surrounded by small glass squares were popular. Generally, windows are double-hung sash with wood frames. The small squares were often stained glass, using textured glass or bevel-cut panes. Like their windows, the Queen Anne architectural style is elaborate, often with excessive detailing.

- A Diamond detail of one-over-one double-hung sash window on San Francisco, CA, residence.
- B Round arched Queen Anne style upper sash windows and transom.
- C Multi-colored stained glass and elongated diamond pattern characterize these windows on a bay in Chicago, IL.
- D Arched Queen Anne double-hung sash window with fixed semi-circular windows at gable of house in Gettysburg, PA.
- E Queen Anne double-hung sash window on row house.

Victorian era house with a variety of Queen Anne windows types
Milford, Delaware

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Single, Double and Triple-Hung Sash

Single-hung sash, Double-hung sash and Triple-hung sash
In single-hung windows, only the bottom sash moves. In double-hung windows, which evolved from the single hung sash, both the top and bottom sash are moveable. In triple-hung windows, each sash may move or the center may be fixed.

A Two-over-two. Each sash has two panes of glass. These windows became popular as glass-making technology improved, making individual pieces of glass larger and more affordable.

B Six-over-six. Multi-light windows are named according to how many panes of glass are in each sash. Other common arrangements are nine-over-twelve, and nine-over-six.

C One-over-One. Each sash has just one pane of glass. The windows in this example have arched upper sash. One-over-one windows became increasingly common after the last quarter of the nineteenth century.

D Six-over-six, triple-hung sash. Unique design that offers good floor to ceiling ventilation. This example features decorative stained glass motif in upper sash.

Resources (click title for link):
- How to Restore Sash Windows. Old House Journal.
- Restoring Window Sashes. Fine Homebuilding. David Gibney.
- Sash Windows. Winchester City Council.

Queen Anne cottage with one-over-one double-hung sash windows
Indianapolis, Indiana

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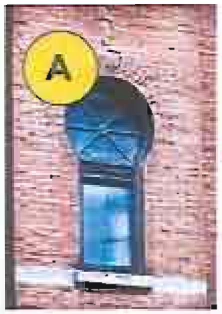
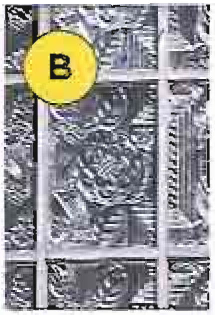
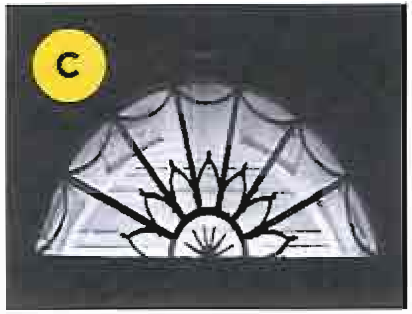
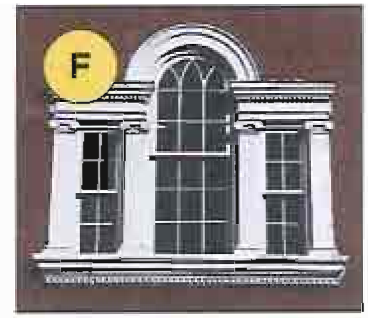
Additional Window Types









Additional Window Types

Most residential architecture is vernacular, incorporating a variety of architectural styles and features, including window types. Some of these are based on historical precedents, such as the Palladian window, named for 16th century architect, Andrea Palladio. Others are often a combination of traditional and modern interpretations.

- A Keyhole window with fixed pin-wheel upper sash.
- B Bevel-cut glass window with floral detail
- C Semicircular fanlight window, located above doorways.
- D Modern interpretation of sidelights with glass block on house in Portland, OR.
- E Aluminum picture window with casements on Lustron house.
- F Palladian style window on residence in Harrisburg, PA.

Resources (click title for link):

- Andrea Palladio 1508-1580. Italian Heritage & Culture Committee of New York, Inc.
- The Lustron Home

Arts and Crafts bungalow with casement and double-hung windows
Savannah, Georgia

Adrian Scott Fine/NTHP

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The National Trust for Historic Preservation (www.PreservationNation.org) is a non-profit membership organization bringing people together to protect, enhance and enjoy the places that matter to them. By saving the places where great moments from history—and the important moments of everyday life—took place, the National Trust for Historic Preservation helps revitalize neighborhoods and communities, spark economic development and promote environmental sustainability. With headquarters in Washington, DC, nine regional and field offices, 29 historic sites, and partner organizations in all 50 states, the National Trust for Historic Preservation provides leadership, education, advocacy and resources to a national network of people, organizations and local communities committed to saving places, connecting us to our history and collectively shaping the future of America's stories.

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www.PreservationNation.org/Weatherization

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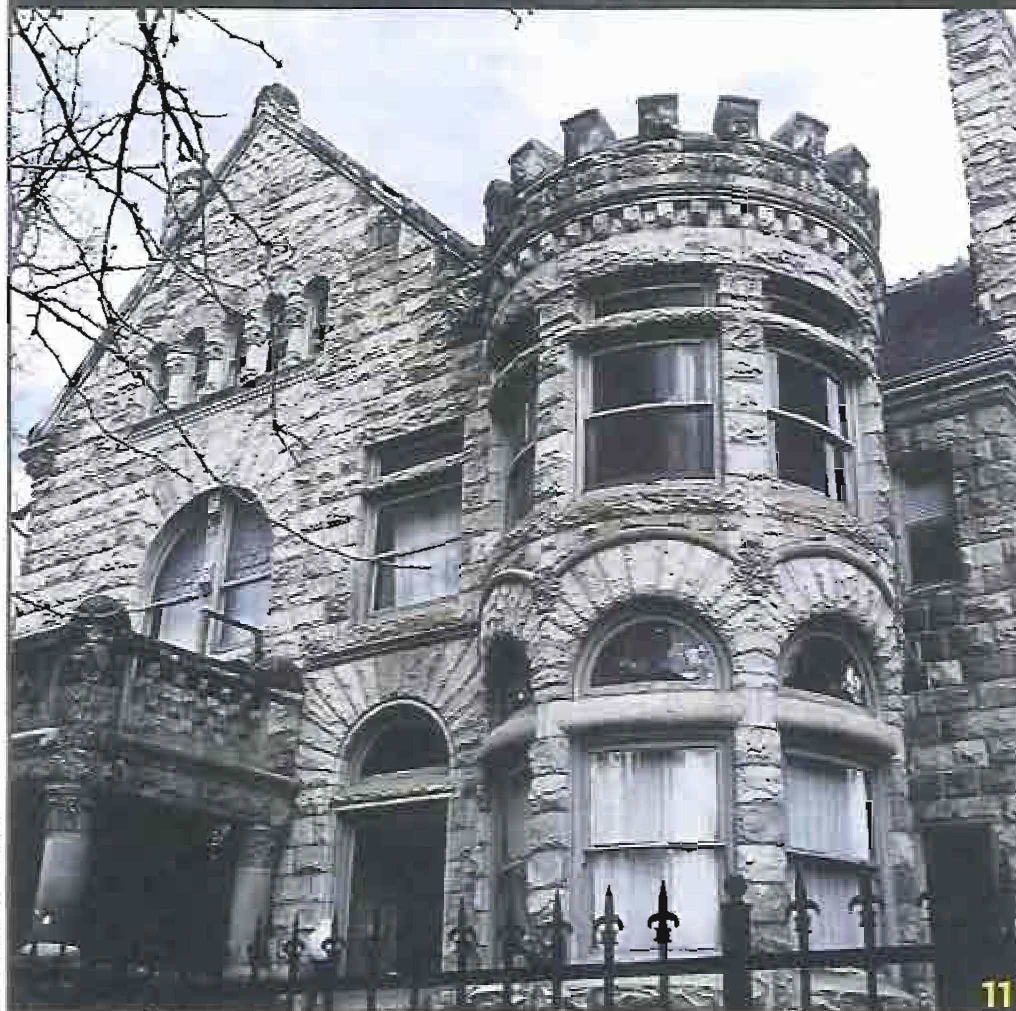
Window Types — Residential Field Guide

Romanesque Revival house with leaded and curved glass windows
Denver, Colorado



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Historic Wood Windows

A tip sheet from the National Trust for Historic Preservation

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This tip sheet on historic wood windows was developed as part of the National Trust for Historic Preservation's Sustainability Initiative.

About the Initiative:
Historic preservation can – and should – be an important component of any effort to promote sustainable development. The conservation and improvement of our existing built resources, including re-use of historic and older buildings, greening the existing building stock, and reinvestment in older and historic communities, is crucial to combating climate change.

Learn more about Preservation and Sustainability on the web:
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Introduction

There is an epidemic spreading across the country. In the name of energy efficiency and environmental responsibility, replacement window manufacturers are convincing people to replace their historic wood windows. The result is the rapid erosion of a building's character, the waste of a historic resource, and a potential net *loss* in energy conservation. Typically replacement windows are vinyl, aluminum, or a composite with wood, and none will last as long as the original window. Repairing, rather than replacing, wood windows is most likely to be the "greener option" and a more sustainable building practice.

Research shows that most traditionally designed wood-frame buildings lose more heat through the roof and un-insulated walls than through the windows.[1] A historic wood window, properly maintained and fitted with a storm window, can be just as energy efficient as a new window.[2] Replacing a historic single-pane window also may not save you much money in the long run. While the exact figure will vary depending on the type of window installed and whether or not a storm window is used, studies have found that it could take 100 years or more for a replacement window to pay for itself in energy savings.[3] According to information published in a recent *Old House Journal* article, it could take 240 years to recoup the cost of replacing a single-pane window-storm window combination with a low-e glass double-pane thermal replacement window.[4] Also, a historic wood window can easily last more than 100 years, while a new window may not last 25.

Not every wood window can be repaired and there are situations where replacement is appropriate. However, many historic wood windows can and should be repaired, especially if the windows were manufactured before about 1940. Wood windows made before this time were constructed with individual parts, each of which can be repaired or replaced. The wood itself is denser and of higher quality than what is grown today, and it is generally more rot- and warp-resistant than modern wood.

Historic windows are among the most important elements of a building. Simple repairs and routine maintenance coupled with storm windows make for energy efficiency that in most cases matches, if not exceeds, the efficiency of replacement windows. Workshops throughout the region have taught building owners easy ways to care for their historic windows. At the Woodlawn Museum in Ellsworth, ME, a grant from the National Trust for Historic Preservation helped fund a window repair workshop. *Photo courtesy of the Woodlawn Museum*

These are just some of the practical reasons to repair rather than replace historic wood windows. In addition, repairing the historic window helps maintain a building's authenticity. Once original material is removed from a building, it is gone forever. There are many more benefits to repairing your wood windows, so keep reading.

---

1. Rypkema (2006); James *et al* (1996); Klems (2002). 2. James *et al* (1996); Klems (2002). 3. Sedovic (2005); *e.g.* research by Keith Heberern, calculations available at www.historichomeworks.com/hhw/education/windowshandout/windowenergyanalysis.pdf. 4. "Let the Numbers Convince You: Do the Math." *Old House Journal* 35 no. 5 (September/October 2007).

Wood Window Basics

Using this 12-over-12, double-hung wood window as our example, here are the basic terms used for wood window parts. This window is called 12-over-12 because there are 12 panes of glass in each sash. Both sashes are moveable so it is called double-hung. If only the bottom sash moves, it is called single-hung.

Jamb (the wood that frames the window opening)

Top Sash (upper section of window, may slide down to open)

Meeting Rail or **Check Rail** (the rail where the two sash come together)

Bottom Sash (lower section of window, typically slides up to open)

Sill (exterior, horizontal piece at the bottom of the window frame, commonly wood, stone, or brick)
Stool (interior shelf-like board at the bottom of a window against which the bottom rail of the sash rests)

A c. 1846 wood window in the former Robbins and Lawrence Armory, now the American Precision Museum in Windsor, VT.

Rail (horizontal part of sash)

Stile (vertical part of sash)

Muntin (horizontal, vertical, diagonal, or curved pieces that frame and provide mounting surface for the lights) The shape, or profile, of the muntin provides a clue to the window's age.[1]

Light/lite/pane (glass, held in place by glazing putty and metal glazing points)

1. Garvin (2002).

My Windows Are Old and Drafty, Why Shouldn't I Buy New Ones?

1. **More heat is typically lost though your roof and un-insulated walls than through your windows.** Adding just 3 and 1/2 inches of insulation in your attic can save more energy than replacing your windows.[1]
2. **Replacement windows are called "replacement" for a reason.** Manufacturers often offer lifetime warrantees for their windows. What they don't make clear is that 30% of the time, a replacement window will be replaced within 10 years.[1]
3. **Replacement windows that contain vinyl or PVC are toxic to produce and create toxic by-products.** Installing these in your house is not a 'green' approach.[2]
4. **If your wood windows are 60 years old or older, chances are that the wood they are made of is old growth**—dense and durable wood that is now scarce. Even high-quality new wood windows, except for mahogany, won't last as long as historic wood windows.
5. Studies have demonstrated that a **historic wood window, properly maintained, weatherstripped and with a storm window, can be just as energy efficient as a new window.**[2]
6. According to studies, **it can take 240 years to recoup enough money in energy savings to pay back the cost of installing replacement windows.**[3]
7. **Each year, Americans demolish 200,000 buildings. That is 124 million tons of debris, or enough waste to construct a wall 30 feet high and 30 feet thick around the entire U.S. coastline.**[4] Every window that goes into the dump is adding to this problem.
8. With a little bit of practice, **it can be easy—and inexpensive—to repair and maintain your wood windows.**[5]
9. Not a DIY-er? There are people near you who can do it for you. **Hiring a skilled tradesperson to repair your windows fuels the local economy and provides jobs.**[1]
10. **Historic wood windows are an important part of what gives your older building its character.**

1. Rypkema (2006). 2. Sedovic (2005). 3. *e.g.* Calculations by Keith Heberern available at www.historichomeworks.com/hhw/education/windowshandout/windowenergyanalysis.pdf. 4. Hadley (2006). 5. *e.g.* www.historichomeworks.com

Lead continued

6 mil plastic taped to the floor.

- Eating a nutritious diet rich in iron and calcium will reduce the amount of lead absorbed by your body if any does happen to be ingested.
- For more tips on how to work lead-safe, see "Lead Paint Safety: A Field Guide for Painting, Home Maintenance, and Renovation Work" available at www.hud.gov/offices/lead/training/LBPguide.pdf and the National Park Service Brief #37, "Appropriate Methods for Reducing Lead-Paint Hazards in Historic Housing" at www.nps.gov/history/hps/TPS/briefs/brief37.htm.
- John Leeke's website www.historichomeworks.com also has practical tips on lead-safer work practices.

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This list is a place to start—it is not intended to be comprehensive, nor does the inclusion of a business or organization serve as an endorsement.

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Additional Help

With nearly half of greenhouse gas emissions attributed to the construction and operation of buildings, older and historic buildings are central to our efforts to address climate change. The **National Trust for Historic Preservation's Sustainability Initiative** promotes the reuse of existing buildings, reinvestment in existing communities, and green retrofit of older and historic buildings to help lower carbon emissions. For more information visit www.preservationnation.org.

Additional help may be available from your **State Historic Preservation Office** (SHPO). Find your SHPO at www.ncshpo.org/. **Private statewide and local preservation groups** serve as the network centers and representatives of local preservation activities within their states. The nine **Regional and Field Offices** of the **National Trust for Historic Preservation** (NTHP) bring the programs and services of the NTHP to preservationists within their regions. Find your nearest NTHP Regional Office and state and local preservation organizations at www.preservationnation.org/about-us/partners/statewide-local-partners/contacts.html

Basic Maintenance

There are many good, practical books and magazine articles to guide a handy person in the basic maintenance of wood windows. Several publications are listed in the references section of this tip sheet. To get you started, here are some of the keys to many years—and generations—of life with older wood windows.

1. Keep the exterior surfaces painted, including the glazing putty. Paint protects the wood and putty from water and extends their service life. Be especially attentive to horizontal surfaces where water may collect.

2. Glazing putty will eventually dry out and is meant to be periodically replaced. You can do spot repairs initially, but eventually it will be easier to re-glaze the whole sash.

3. Keep movable surfaces, such as the inside jamb, free of paint build-up so that the sash can slide freely.

4. If your sashes are hung with cord, keep the rope free of paint. This will improve the window's operability. Cord will eventually dry out and break but can be replaced. When replacing the cord you can also re-hang the weights so that the sash will be balanced.

Winter Tips

Most of the heat transfer occurs around the perimeter of the sash rather than through the glass. So the tighter the seal around the window and between the upper and lower sash, the more energy efficient the window will be. Here are some tips to help you save on your heating bills.

Check the lock. Most people think the sash lock is primarily for security. It does help with security, but the lock's most important job is to ensure that the meeting rails are held tightly together. A tight fit greatly reduces air infiltration.

Weather stripping—add it or renew it. Adding weather stripping to your window can increase the window's efficiency by as much as 50%. It's an inexpensive way to boost your window's efficiency. There are many different kinds from which to choose. Refer to the articles listed at the end of this tip sheet. The staff at your local hardware store should also be able to assist you.

Storm windows—use them! There are many styles from which to choose, including storms that can be fitted on the interior of the window. Many studies have shown that a wood window in good condition fitted with a storm window can be just as energy efficient as the more expensive replacement window. Due to the thermal exchange properties of wood, there is also a growing interest in traditional wood-framed storm windows as they transfer less heat than metal-framed storms.

Condensation. If you find condensation on the inside of your primary window, cold air leaking through the storm window is likely the culprit. If the condensation is forming on the inside surface of the storm window, warm air from the building interior is leaking in around the primary window. When warm and cold air are present on opposite sides of glass, condensation forms (think of a cold glass of lemonade on a hot day). When condensation forms on your window glass, water can collect on the horizontal wood parts of the rails, muntins, and sill, which can lead to paint failure and rot. To reduce condensation, you need to limit the amount of leaking air. Add or replace weather stripping, make sure the sash are meeting properly and that the sash lock is tight, and check the seal around the exterior of the storm window and caulk if necessary. When caulking around the perimeter of exterior storms it is important to leave weep holes at the bottom so that any condensation or infiltration that does occur can drain out.

What About Lead?

If your windows retain paint that was applied prior to 1978, chances are there is lead paint on them. Just because there may be lead paint on the windows does not mean they are unsafe or that they need to be replaced. There are steps you can take to protect yourself and others if you suspect lead paint may be present. **Before beginning work, consult your local or state ordinance to determine the legal method for handling and disposing of lead paint in your area.**

- Children and pregnant women should not be allowed in the work area.
- Do not smoke or eat or drink in the area you are working in and wash your hands and face before doing so.
- Wear disposable gloves and eye protection.
- Use a respirator if there is friable paint, or if you are scraping or sanding paint.
- Use a wet sanding technique to minimize dust.
- Vacuum using a HEPA filter.
- Wash your work clothes separately from your household laundry. You can also wear a tyvek suit to protect your clothes. Take it, and your shoes, off before you leave your work area.
- Place tarps under your work surface to collect loose paint. Seal off the work space from other rooms and from HVAC systems. Cover any furniture and other items in the work area with

(Continued on page 4)

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10 Reasons to Repair Your Old Windows

Replacement windows are called "replacement" for a reason. Manufacturers often offer lifetime warrantees for their windows. What they don't make clear is that 30% of the time, a replacement window will be replaced within 10 years. *Rypkema, 2006*

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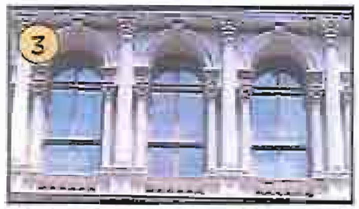

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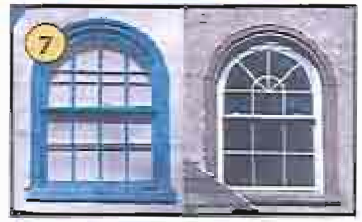
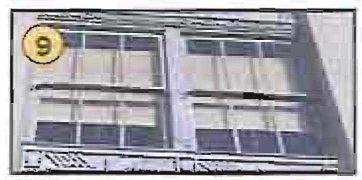
According to studies, **it can take 240 years to recoup enough money in energy savings to pay back the cost of installing replacement windows.** *Calculations by Keith Heberern available at www.historichomeworks.com/hhw/education/windowshandout/windowenergyanalysis.pdf*



Replacement windows that contain vinyl or PVC are toxic to produce and create toxic by-products. Installing these in your house is not a 'green' approach. *Sedovic, 2005*

Historic windows are an important part of what gives your older building its character.



With a little bit of practice, **it can be easy—and inexpensive—to repair and maintain your windows.**

Not a DIY-er? There are people near you who can do it for you. **Hiring a skilled tradesperson to repair your windows fuels the local economy and provides jobs.** *Rypkema, 2006*

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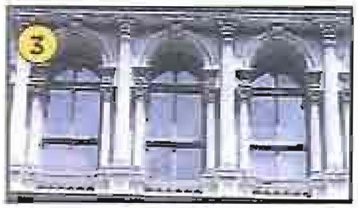
10 Reasons to Repair Your Old Windows

Replacement windows are called "replacement" for a reason. Manufacturers often offer lifetime warrantees for their windows. What they don't make clear is that 30% of the time, a replacement window will be replaced within 10 years. *Rypkema, 2006*

More heat is typically lost though your roof and un-insulated walls than through your windows. Adding just 3 and 1/2 inches of insulation in your attic can save more energy than replacing your windows and will likely cost less. *Rypkema, 2006*



If your wood windows are 60 years old or older, chances are that the wood they are made of is old growth, dense and durable wood that is now scarce. Even high-quality new wood windows, except for mahogany, won't last as long as historic wood windows.

Studies have demonstrated that a **historic wood window, properly maintained, weather-stripped and with a storm window, can be just as energy efficient as a new window.** *Sedovic, 2005*

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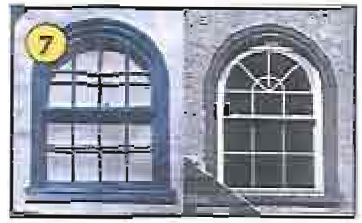

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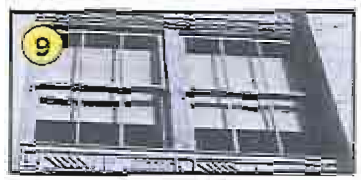

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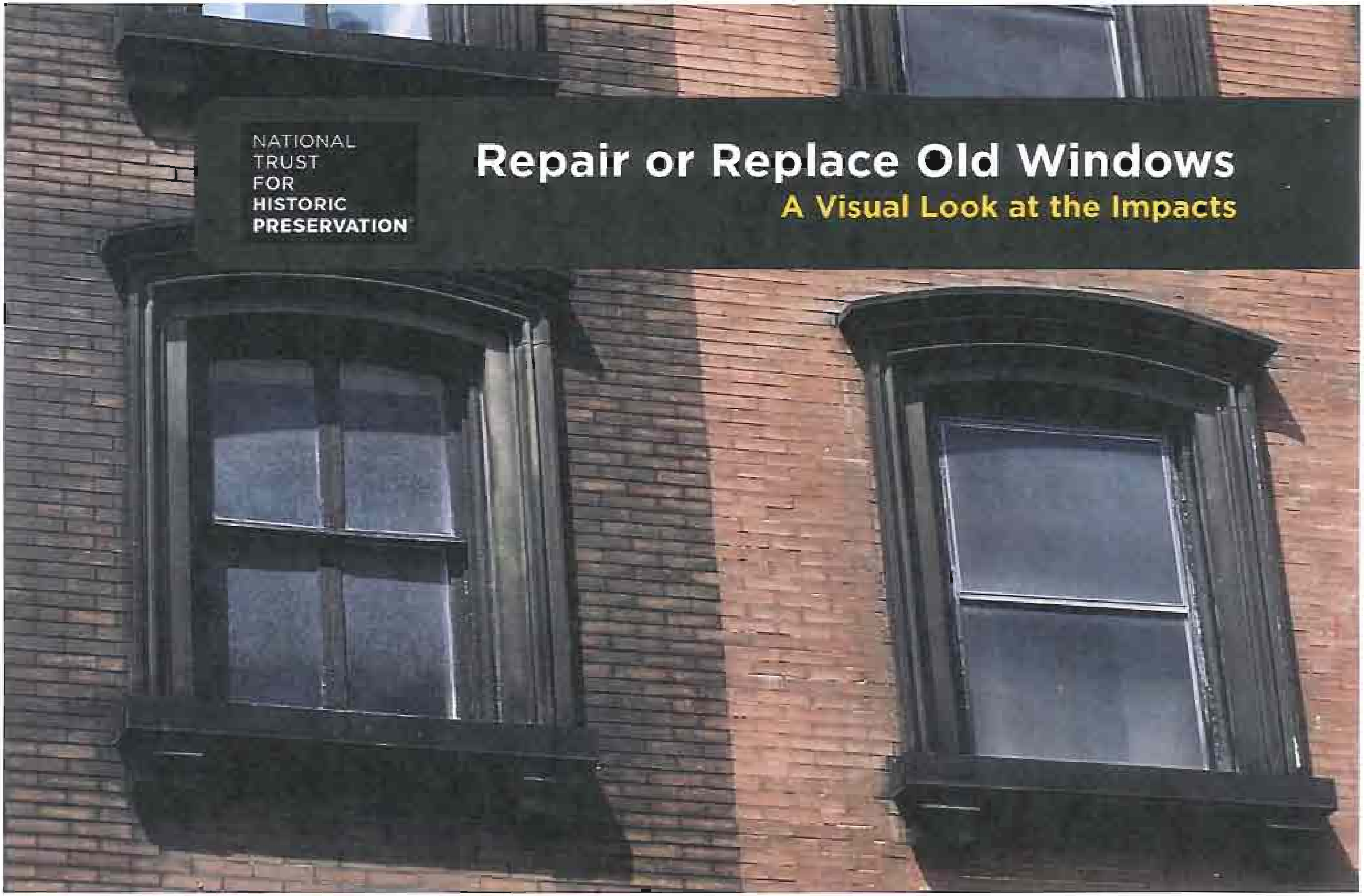
Repair or Replace Old Windows

A Visual Look at the Impacts



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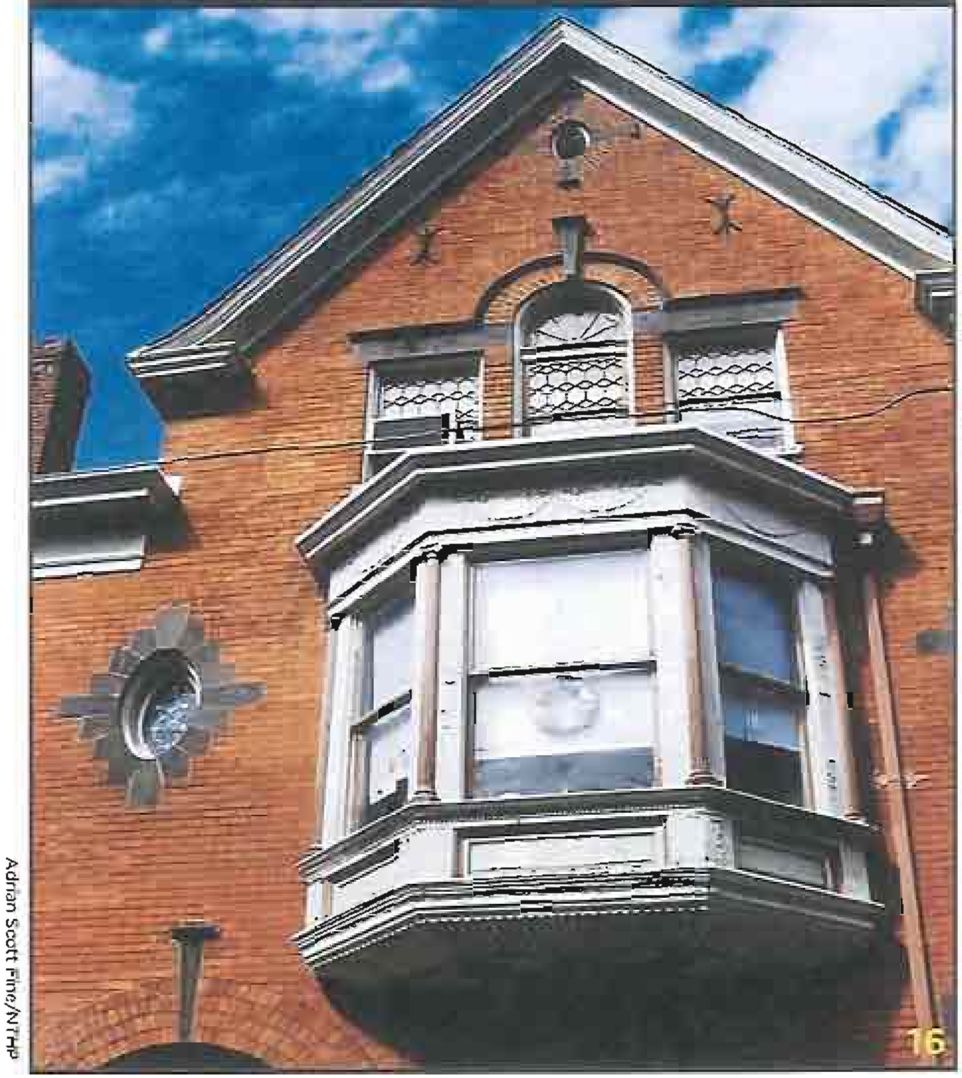
Repair or Replace Old Windows

Early 20th century Queen Anne style house
Original windows help define the character of older buildings



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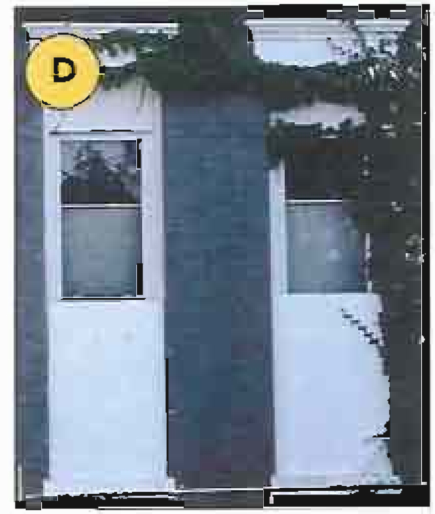

CASE STUDY: Putting Windows in Context

When a homeowner chooses to alter features, such as replacing windows, this may inadvertently also change the character of the larger neighborhood and context, especially when it happens in a domino pattern. Over time, as changes take place house-by-house, the distinctive character of the neighborhood can be diminished.

A, B Two simple Shotgun style homes that were once nearly identical, to each other, and throughout the neighborhood.

C Original two-over-two double-hung windows are a very prominent feature of these homes, directly relating to the size of the main entrance.

D. The original windows were replaced, the openings reduced, and stock windows installed that are no longer in scale to the proportions of the house.

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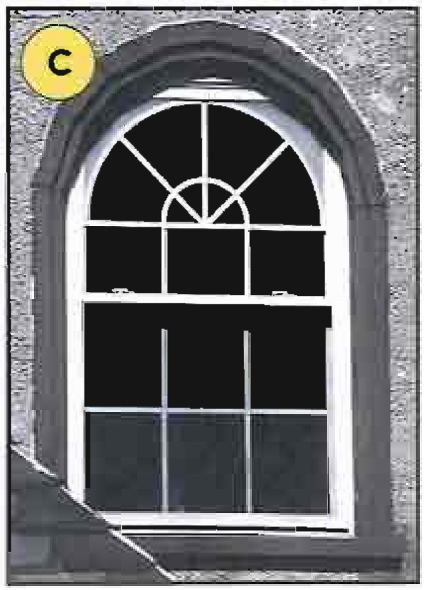
CASE STUDY: One Window, Multiple Replacements
Most older and historic neighborhoods were built, at least in part, by a few developers often employing similar architectural designs and features, such as windows. This example of a simple round arched, wood window clearly shows how different replacement windows can be from one another.

A This eight-over-eight double-hung sash window with wood casing and sill is a common feature on houses in this neighborhood.
B This replacement window attempts to replicate details of the original. However, it is not a true divided-light, the casing is wrapped in aluminum and the upper sash is flat and not round arched.
C. This replacement tries to look like a round arched window but is instead flat, features a completely different muntin pattern, has casing wrapped in aluminum and is not a true divided-light.



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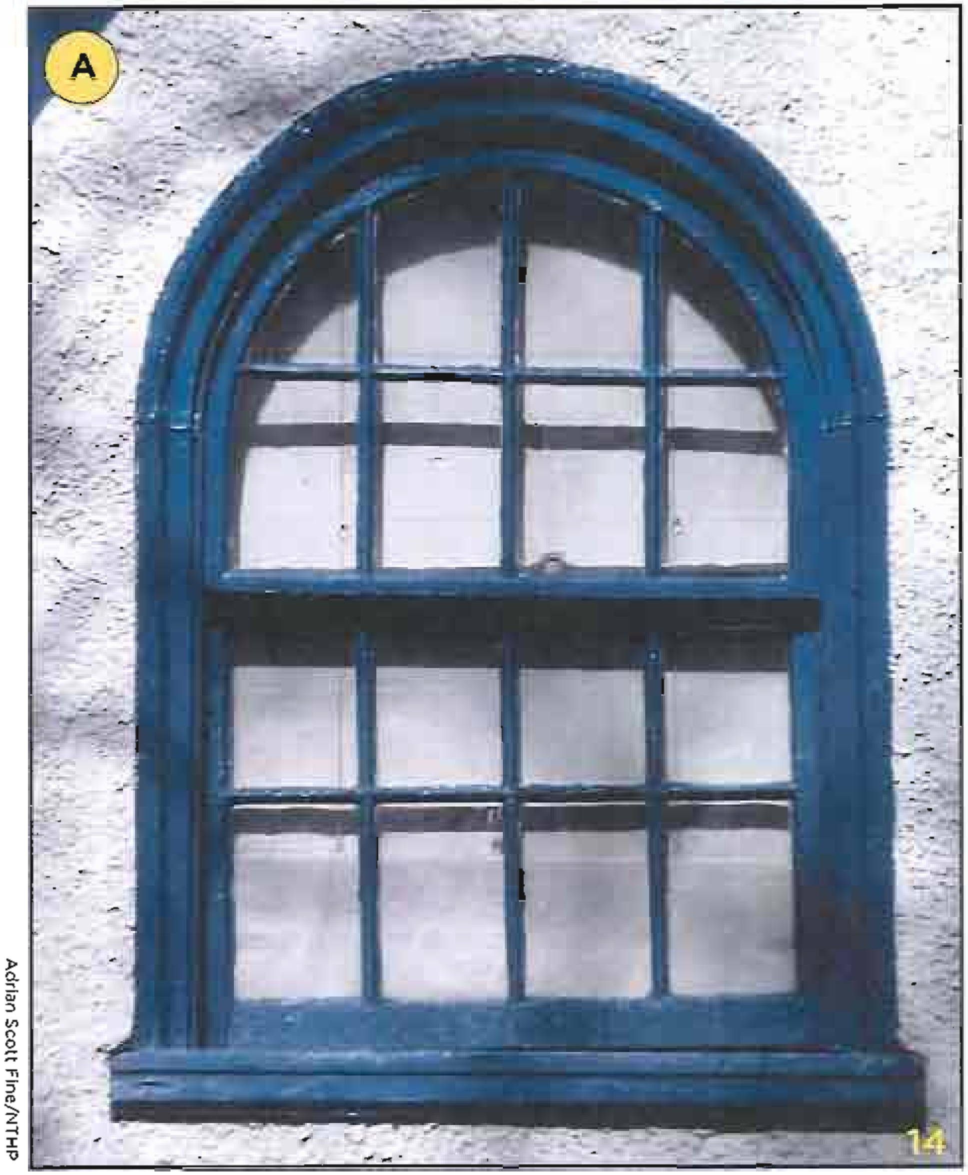

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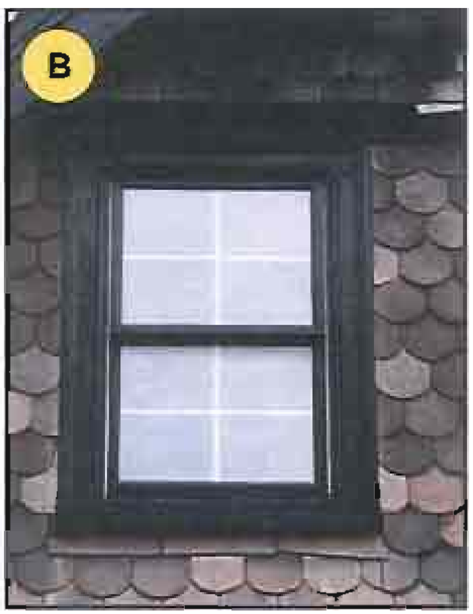
CASE STUDY: Authenticity Counts

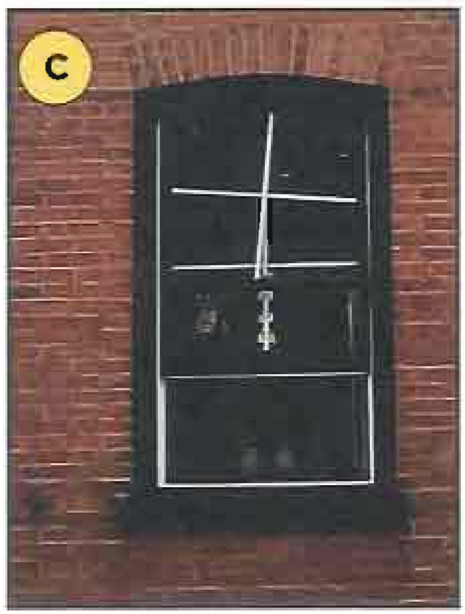
Most older windows are true divided-light, with muntins that are solid, dividing the individual panes of glass. As opposed to a solid piece of glass, a true divided-light window is much more rich in detail and architectural character. Many replacement windows, however, are not true divided light and instead feature muntins that are applied, 'sandwiched' in between glass or clipped on from the inside. This example illustrates.

A A former carriage house, rehabilitated and preserved for a new use, features replacement windows that attempt to look like true divided-light windows.

B This four-over-four double-hung sash still has its original wood casing with a replacement window with clipped on interior muntins. There is little dimension or depth with this design and instead looks like a one-over-one sash.

C This shows how clipped on interior muntins can loosen or fall off.





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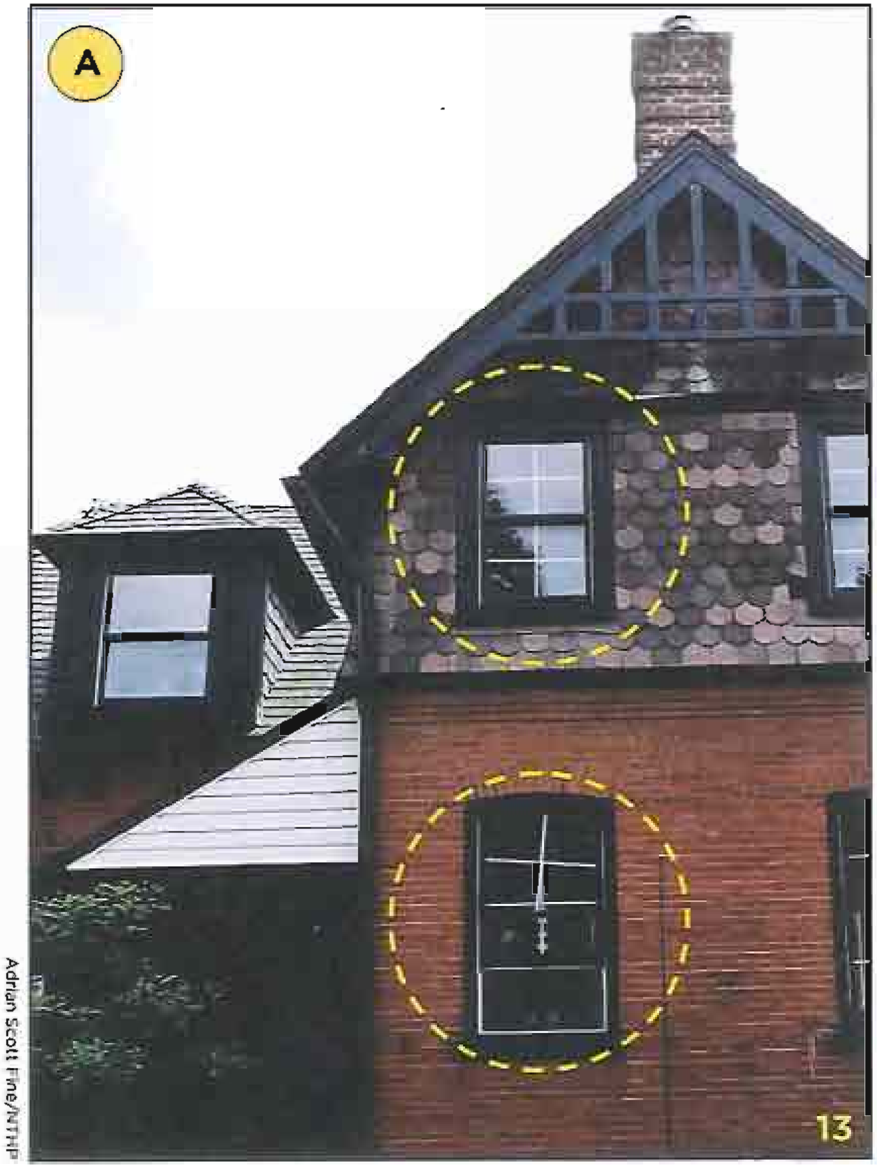

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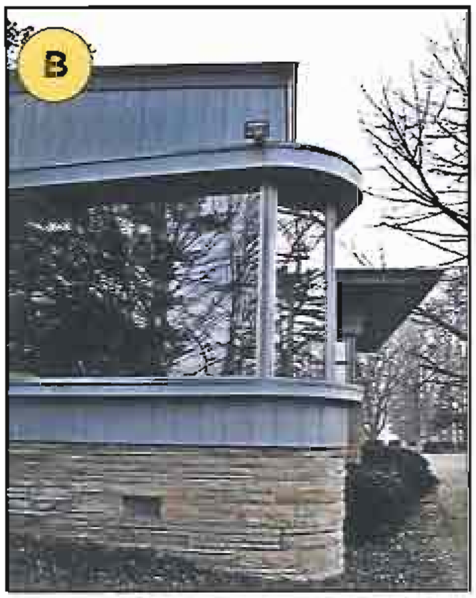
CASE STUDY: A Modern Dilemma

Buildings dating to the second half of the 20th century challenged earlier architectural practices and design, featuring experimental materials and introducing new concepts, such as the 'picture window.' Today, some of these materials are failing, difficult to maintain, and may fall short of optimal energy efficiency goals. As important character-defining features, repair is optimal as finding replacements that match will be difficult. These examples illustrate the challenges.

A — Original, character defining windows and corrugated stainless steel detail are being removed on this 1950s office building, replaced by dark tinted fixed windows that do not match.

B, C — Large spans of single pane and plate glass require innovative solutions, such as custom designed storm windows.



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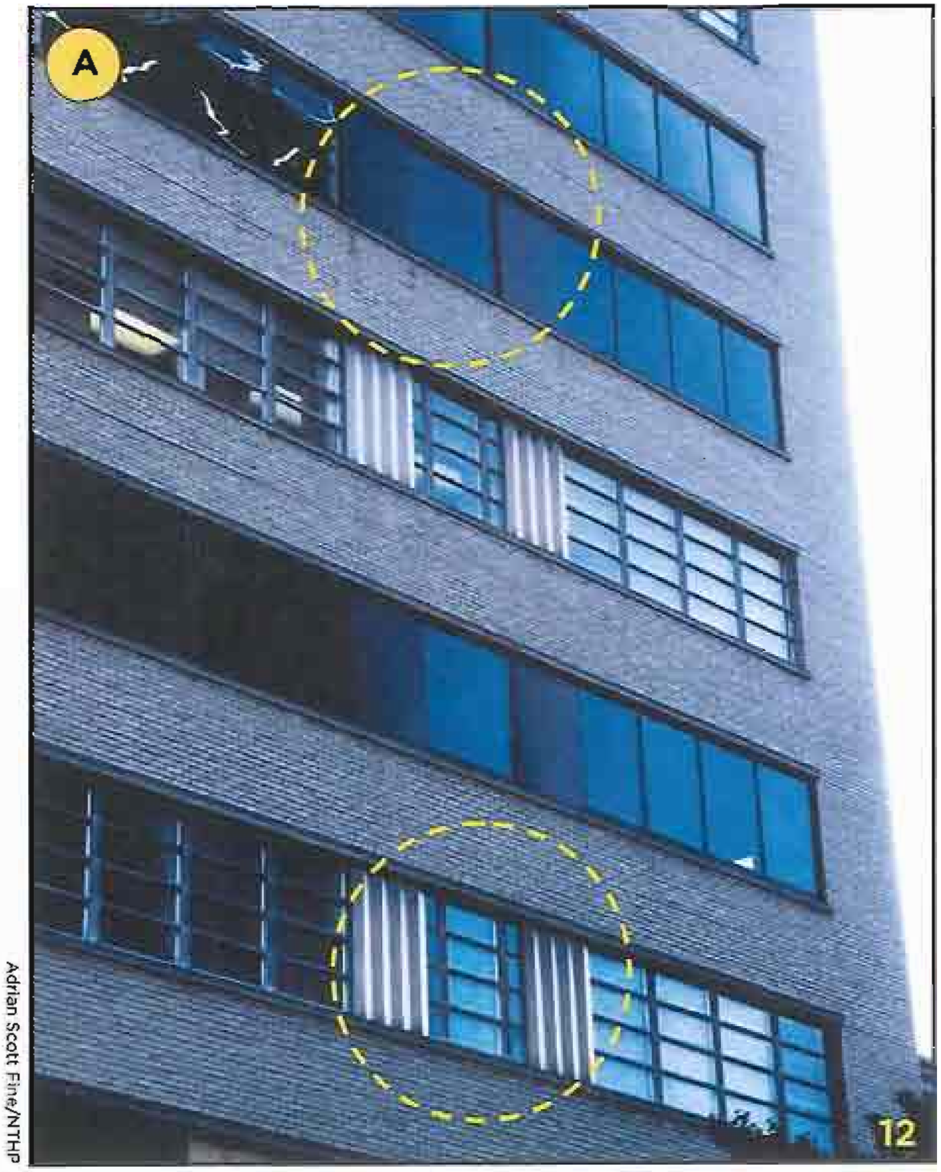

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CASE STUDY: Impersonating the Original

Some window manufacturers claim they can replicate and closely match the details of original windows. Most often, replacement windows fall short of duplicating the look and rich detailing of original windows. These examples clearly illustrate this problem.

A An early 1940s apartment building designed in the Art Deco style features corner, steel casement windows. The slender profile of the muntins and casing is a character defining feature. The replacement double-hung sash window, at the bottom, attempts to match the lines of the original, yet the muntin pattern and width of casing are much different.

B Two double-hung sash replacement windows on side-by-side row houses demonstrate the subtle, but noticeable differences in design. While original windows were identical, these are different in terms of depth, muntin size and pattern and width of casing.

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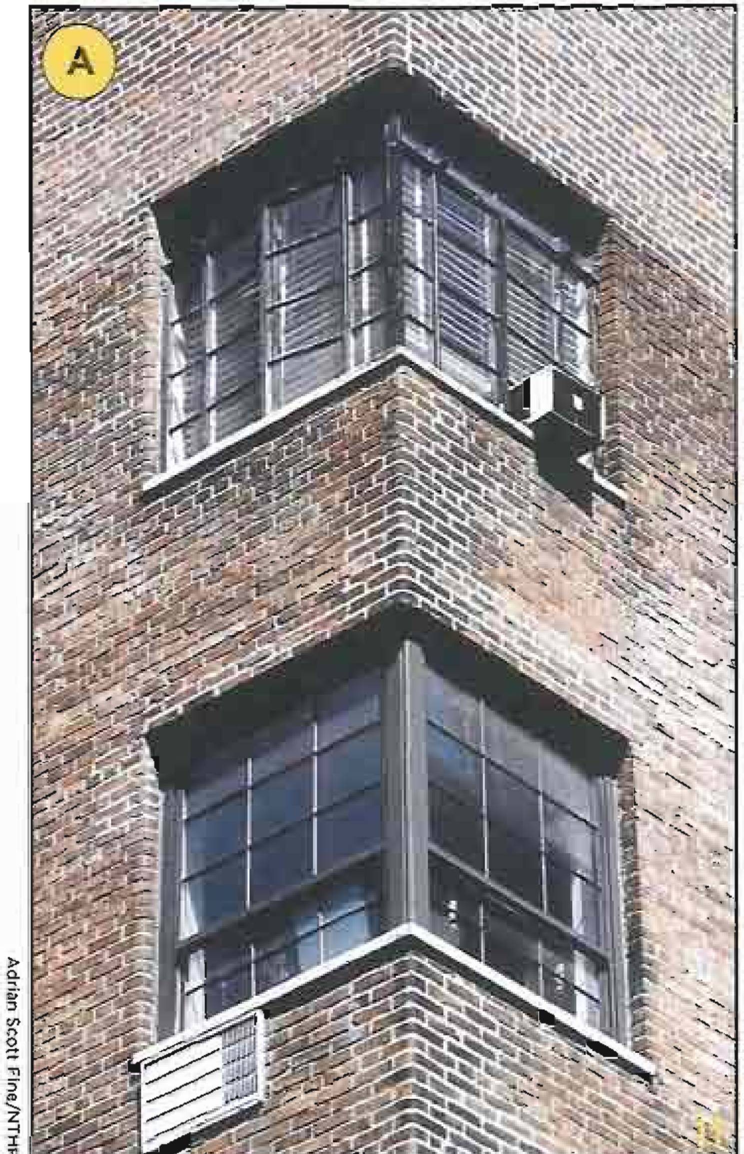

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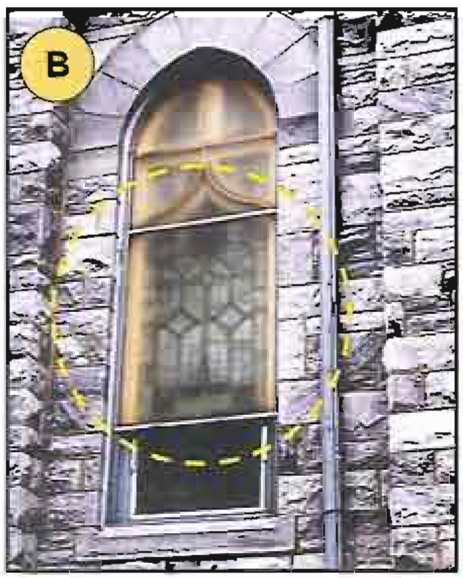
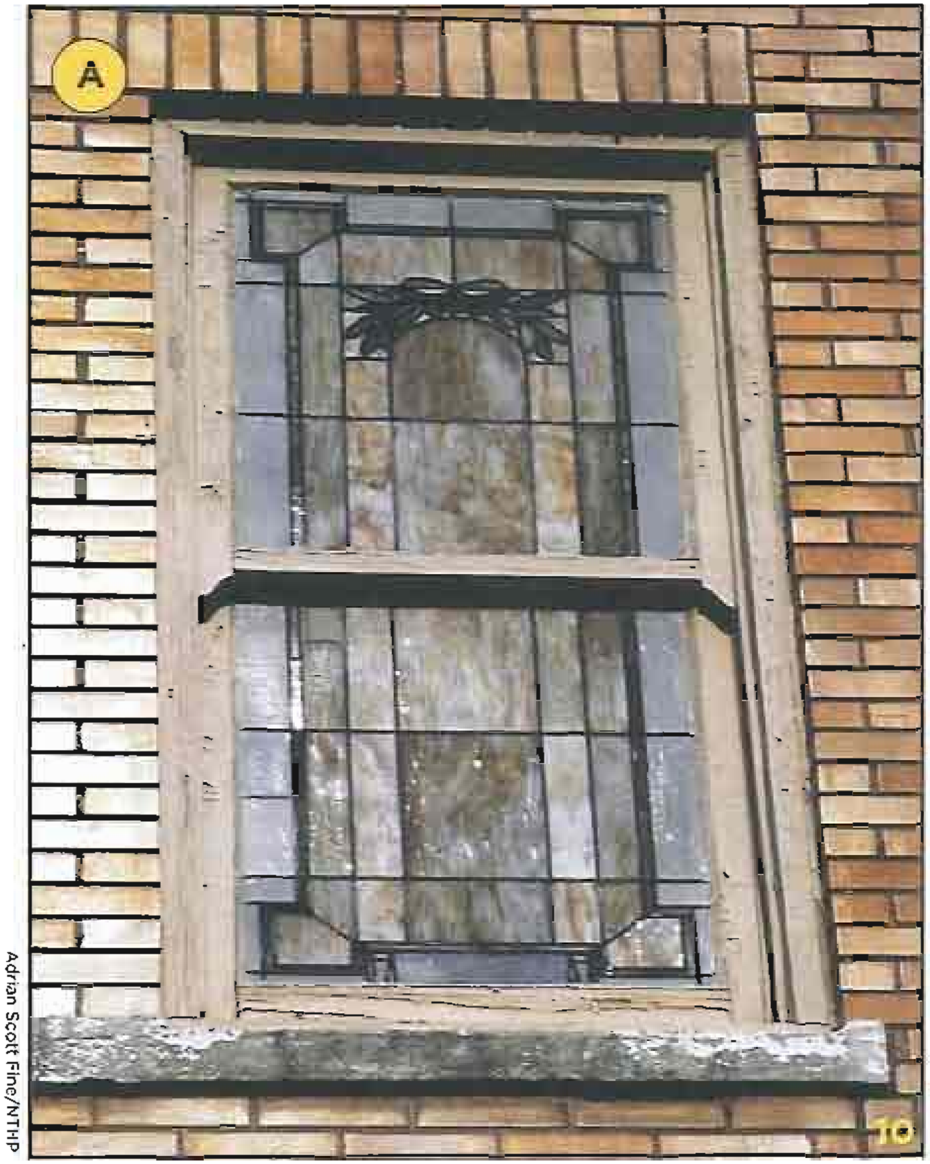
CASE STUDY: A Blurry View

Stained, leaded, slag and other types of decorative glass were meant to be seen from the inside and out-of-doors. In efforts to protect the fragile glass from vandalism and exposure to the elements, protective glazing systems are sometimes used, especially on religious properties. When improperly installed and inappropriate materials used, these systems can not only distort and obscure the look of the windows but also cause more damage than if left exposed. When unvented, moisture from condensation is trapped leading to wood rot and often severe deterioration of the window frames.

A Exposed original one-over-one double-hung slag glass window .
B Plastics (Lexan or Plexiglass) are impact-resistant and nearly shatterproof but tend to yellow and get hazy over time.
C Windows are obscured and the pattern is dramatically altered with new aluminum rails as part of this protective glazing system.





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CASE STUDY: Close, But Not Enough

Two similar houses, both Tudor Revival style and dating to the 1920s or early 30s. Both featured steel casement windows, whereas only one retains the original windows today.

A Steel casement windows with fixed transoms and side-lights, featuring interior storm windows. These windows are a character defining feature of the house.

B Replacement windows attempt to match with casement style units yet the proportion, pattern, width and lack of a true divided-light miss the mark.

C, D The differences between the original and replacement are readily seen, where the wider casing and surround are much prominent on the replacement windows.

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Repair or Replace Old Windows

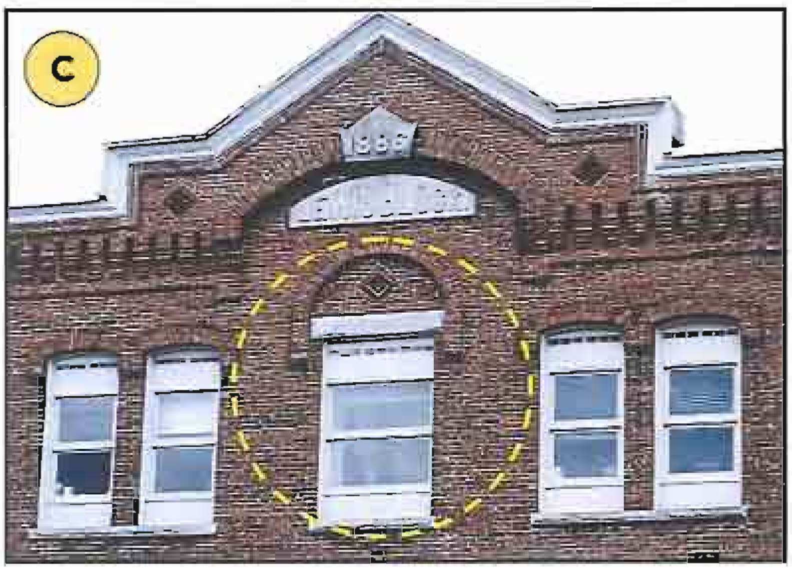
CASE STUDY: Size Matters

In these two examples, original windows were replaced and the openings were reduced to accommodate a much smaller replacement window.

A Two, arched nine-over-one double-hung sash windows are in disrepair with loose meeting rails and paint build up. They can be easily repaired and still maintain the character of the building.

B An identical building with replacement windows. Stock units were used with aluminum in-fill around the opening. The difference in character between A and B is dramatic.

C The upper story windows of this Main Street commercial structure were replaced with stock units with in-fill at the top and bottom.



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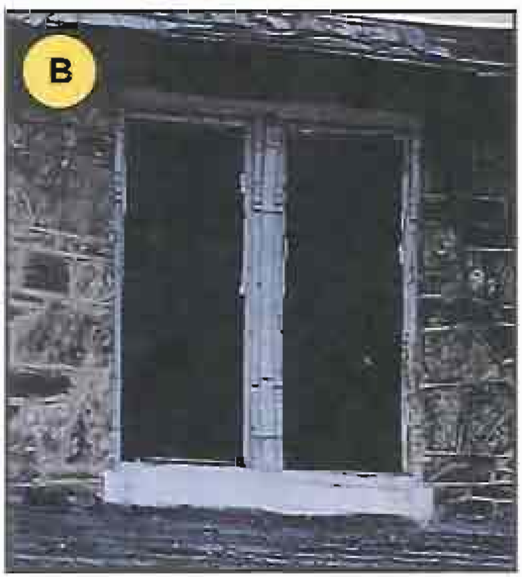
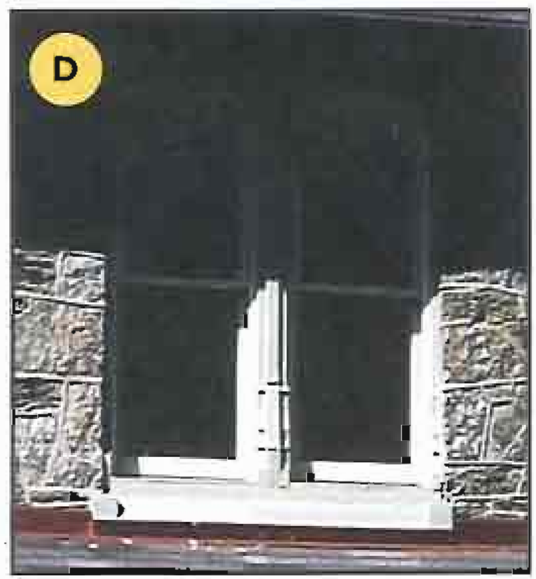
CASE STUDY: In-Kind Replacement

In this dramatic before and after transformation, a severely deteriorated and abandoned duplex was recently rehabilitated. The project preserved important character-defining features, including replicating original windows with new replacement units. The original windows — simple wood one-over-one double-hung sashes — had long disappeared as the building fell into decline and years of vacancy. When replacing a historic window, it is important to retain original window casings and trim when possible. These details often have stylistic features associated with the building's architectural style. In this example, the decorative carved wood casings were intact even though the windows were not.

A, B Original windows are missing but decorative casings and openings remain.

C, D As part of the rehabilitation project, new wood double-hung sash windows were chosen to fit the original openings and the decorative casings were repaired and retained. New windows replicate the originals in terms of size, type, proportion and materials.





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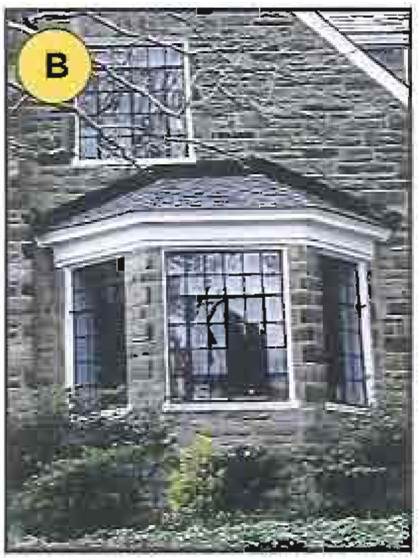
CASE STUDY: A Material Issue

A series of 1930s duplexes in this neighborhood were designed in the Tudor Revival architectural style. Each features large window openings, prominent bays as a central focus, and original steel casement windows. Original windows are a primary character defining feature.

A, B Both sides of this duplex feature original rolled steel casement windows with interior storm window inserts.

C, D Both sides of this duplex have replacement windows. The one to the left more closely mimics the lines and details of the original steel casements, though the new windows are a mixture of fixed and double-hung sash units and the proportions are not an exact match. The unit to the right also features fixed and double-hung sash replacement windows. In this case, the result is less successful with white vinyl casing and a central picture window missing any muntin pattern.



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Repair or Replace Old Windows

Do Window Details Matter?

Yes. Even when maintaining the original opening and general size of the old windows, replacement windows can sometimes miss the mark when details and overall design are off. To the greatest extent possible, new windows should match originals as closely as possible. These examples of replacement windows show how even subtle differences, even minor changes in design, can have an impact on the overall character of an older and historic building.

A Replacing an original double-hung sash window with a casement and fixed transom dramatically changes the look and architectural character of this historic building.

B Modern interpretation of an arched window alters the pattern and overall design on this monumental civic building. If original windows are no longer intact, this approach may be acceptable as windows clearly reflect their own era.

C Replacing a round arched double-hung sash window is a one-over-one double-hung sash with fixed transom. This illustrates using stock windows to fit an opening that often requires a custom or more costly replacement window.

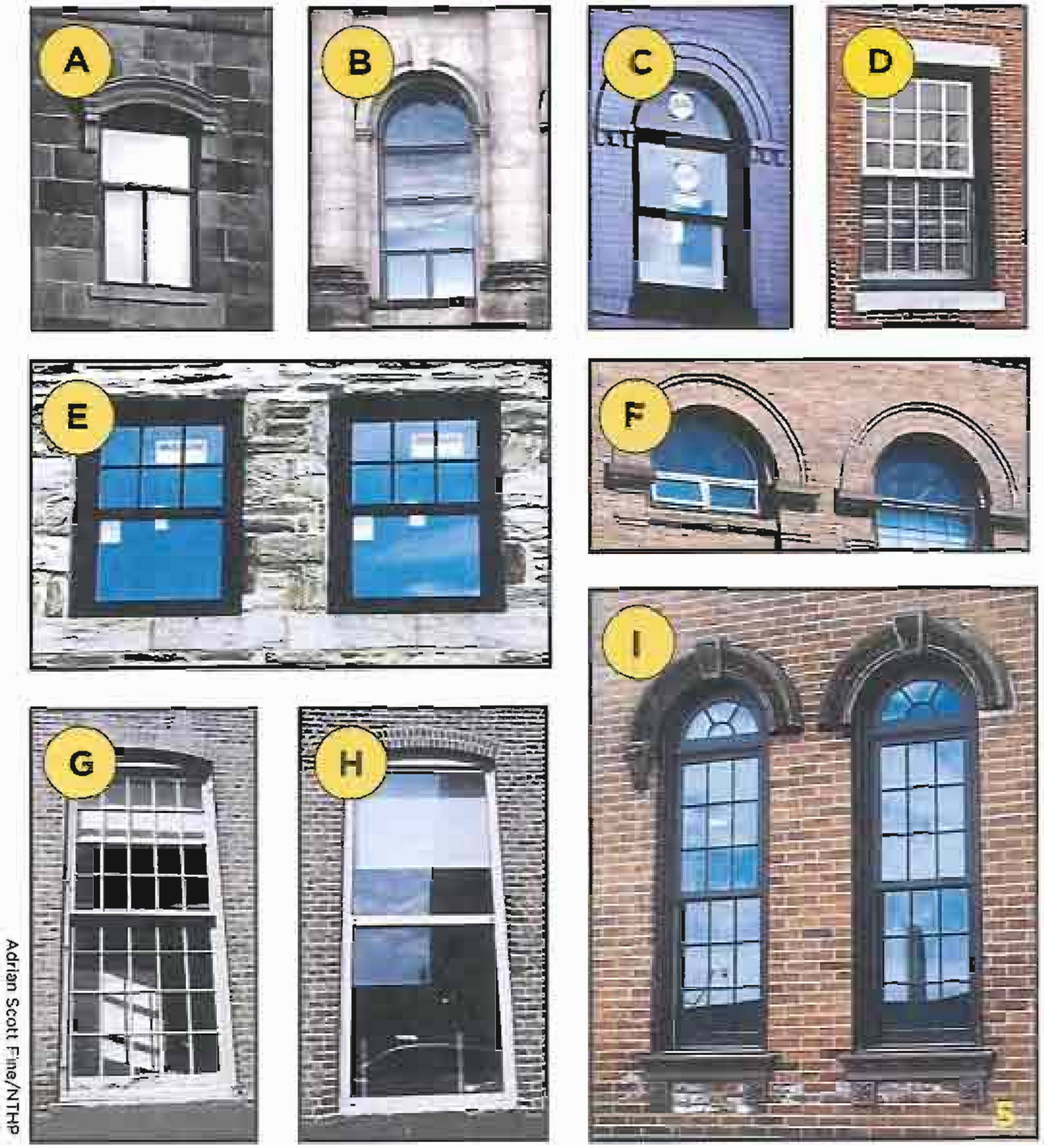
D The thickness of muntins as well as their profile can make a difference. This window is not a true divided-light design, instead featuring applied, flat muntins.

E New windows will often require 'building out' and enlarging the casing and surround to accommodate a stock replacement unit, effectively reducing the size of the window in comparison to the originals.

F The introduction of a hopper window completely alters the look of this window.

G, H Window G features the original twenty-over-twenty double -hung sash window. The replacement, window H, is a fixed one-over-one unit. The design, profile and depth are altered in the process.

I New windows attempt to replicate originals, though the casing and surround is wider and the fixed fanlight does not match originals.



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Repair or Replace Old Windows

When Replacing My Windows, What Not To Do?

Original windows were custom designed to fit your older and historic building. You cannot say the same for replacement windows. Often, off-the-shelf replacement window units do not match originals closely enough in design, overall appearance or fit. As original windows play an important role in defining the character of a building, installing windows that do not match — especially in terms of size and shape, type and color of frame, tint of glazing — can make a significant difference in how the building looks.

Changing the Size

Reducing or enlarging the window opening to accommodate a new replacement window is particularly harmful. It completely changes the entire proportions of a building, not to mention reducing daylight and potential air circulation. If you do choose to replace your original windows, do not eliminate window openings, in-fill or alter them to accommodate smaller or larger windows. These examples illustrate the dramatic change in appearance.

A Italianate style row houses, side by side. Building to the right retains original arched one-over-one double-hung sash windows. Building to the left has smaller replacement windows and in-fill panels installed in the original opening.

B Industrial building converted for housing with reduced windows and in-fill openings.

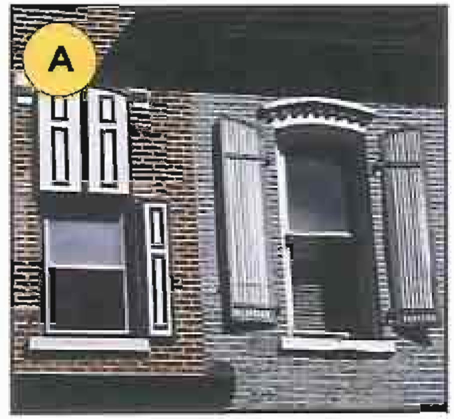
C Main Street commercial building with upper floor windows removed, openings reduced down and much smaller replacement windows that do not match.

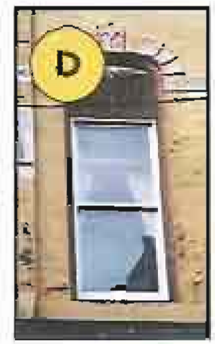
D A stock, smaller window unit was used to replace a larger double-hung sash window.

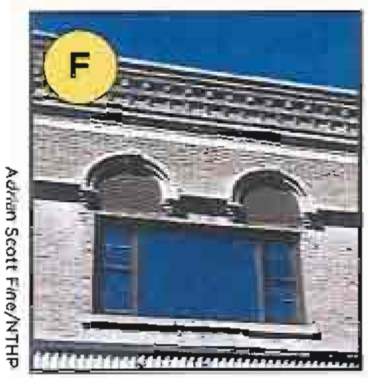
E Brick was used to in-fill the original opening of the round-arched window.

F Two round arched windows were removed and replaced by one larger picture window, completely different in design and period to the historic Main Street building.

G Three vertically-oriented Gothic style windows were reduced and replaced by horizontally-oriented hopper type windows.







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Repair or Replace Old Windows

Do the Benefits Outweigh the Costs?

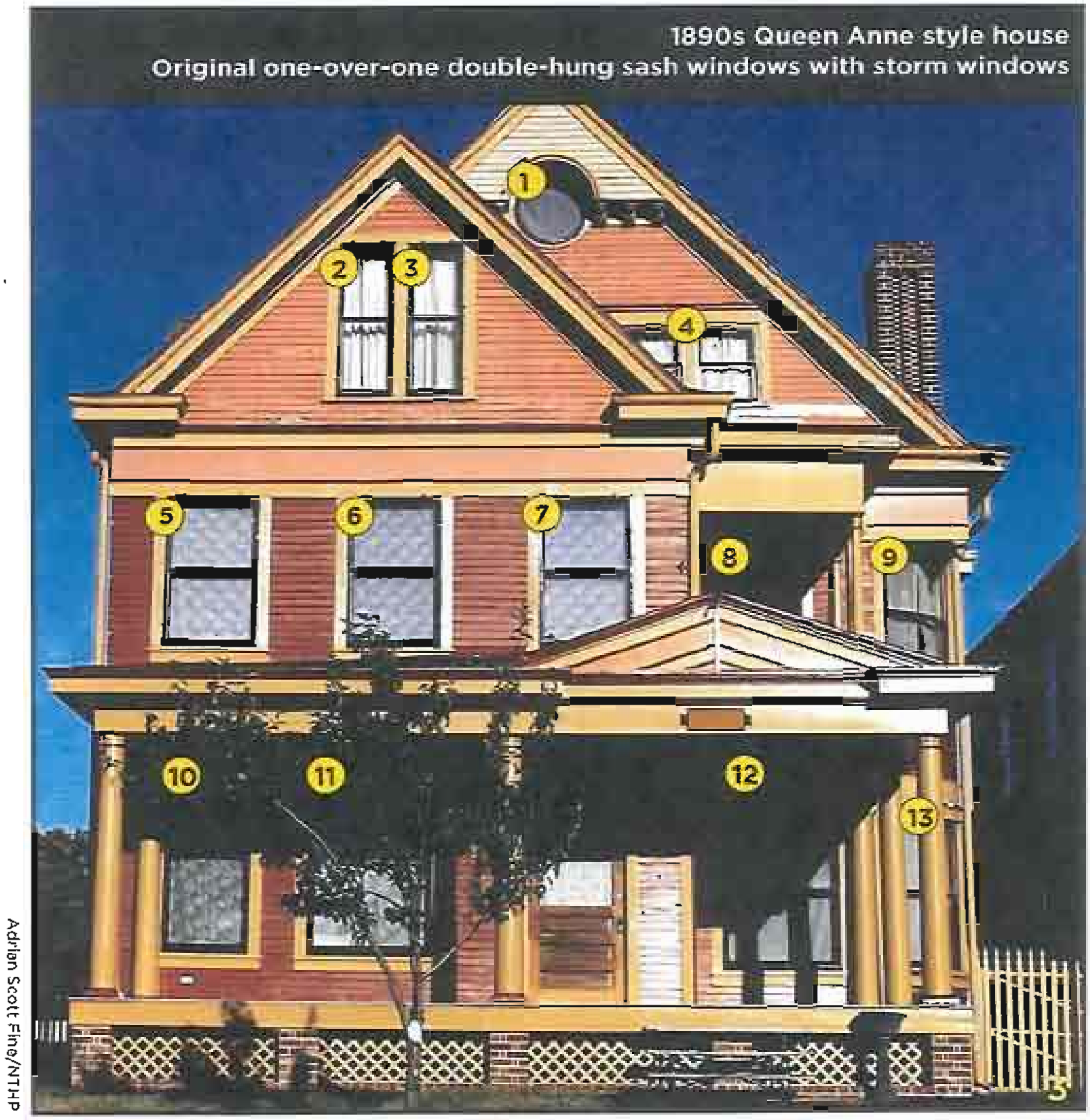
As a homeowner you have to assess the cost-benefit analysis or 'payback' that comes with repairing or replacing your windows. Does replacing windows make economic sense? Can I achieve similar energy savings by repairing windows?

Although data varies, somewhere between 10 and 25% of heat loss is actually attributed to windows. Most heat is typically lost through your roof and un-insulated walls. Given that an average house has between 24 and 30 windows, and a typical replacement window unit costs between $500-1,000 each, does an investment of $12,000 or more make sense? On the flipside, the cost to restore an existing window and add storm windows (where appropriate) will generally be much less (depending on if you do it yourself or hire a contractor), approximately between $125 to 800 each.

Many window replacement manufacturers claim greater savings than actually occur. Since windows account for at most 25% of heat loss, the payback and time to recoup your investment in terms of energy savings could take between 40 and as much as 200 years, based on various studies. A study from Vermont shows the savings gained from replacement windows as opposed to a restored wooden window with a storm is only $.60. The added problem is most replacement windows will not last as long as 40 years, much less over a hundred years. And some are being replaced only after 10 years of service.

Do The Math

- 13 windows on the front of the house (in total 35)
- $500-1,000 for each replacement window unit
- Total costs for new windows: $17,500—35,000
- Average savings gained from replacement windows (in comparison to similar, restored windows with storms): $25.00—50.00 per month
- The payback will take about 60 years



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Repair or Replace Old Windows

When Are Replacement Windows Necessary?

A selling point of replacement windows is that they are maintenance free. In truth, based on their materials, components and relatively short life expectancy, you, and subsequent owners, will probably be looking at replacing your replacement windows in less than 20 years. However, the selling point of old windows is most have been on the job for 50 to 100 years or more, and can continue to do so.

Not every old window should be saved. Sometimes it is necessary to replace a window due to extensive deterioration or missing components. An entire window may need to be replaced or sometimes selectively just components, such as retaining the frame while installing new sashes. When replacing windows, remember to match the originals as closely as possible. New windows should replicate originals, in terms of size, glazing (tint), proportions, width, dimension of components (muntins, frame), profile of sash, depth and materials.

- A Six-over-six double-hung sash with loose meeting rail, missing glass — can be repaired.
- B Queen Anne windows needing paint, re-glazing — can be repaired.
- C Two-over-two double-hung sash with loose bottom rail, needing paint, re-glazing — can be repaired.
- D Arched double-hung sash windows missing glass and frames — replacement likely.
- E One-over-one double-hung sash windows and fixed transoms with detached meeting rail, needing paint and re-glazing — can be repaired.
- F Queen Anne window in poor condition, detached from frame and missing glass — borderline, requiring extensive repairs.
- G Queen Anne window missing glass and subject to structural settling of the building — borderline, requiring extensive repairs.

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Repair or Replace Old Windows

Should I Repair My Old Windows?

Whenever possible, repair an original window, rather than replace it. Any window over time will deteriorate with the exposure to the elements. Most older windows, especially wood windows, can be easily repaired by a DIY-er or by hiring a qualified contractor. It also will be far more economical than purchasing all new replacement windows. Older windows perform well when maintained. Problems arise from a lack of maintenance, water and condensation damage, and ultra violet light degradation. Layers of paint buildup may also make windows difficult to operate and unattractive. Most older windows can be made more energy efficient by sealing gaps with caulk, replacing glazing compound, fixing broken glass, repairing loose wood parts and installing weather stripping. An appropriate storm window may also help reduce heat loss while retaining original windows.

Ask Yourself Two Questions

1. How important are windows in terms of architectural significance and the character of my building? Usually windows play an important role, especially those at the front and on sides that are highly visible from the street.
2. Are the windows really beyond repair? Often windows in disrepair look worse than they actually are and can be easily repaired and retrofitted for greater energy efficiency at a significantly lower cost than replacements.

A, B Two eight-over-eight double-hung sash dormer windows. Both are in disrepair; window A will need to be rebuilt or replaced to match window B.
C Broken glass on these architecturally distinctive windows can be easily replaced and windows repaired.
D A coat of paint and routine and preventive maintenance can restore windows to their original appearance.
E Unique roof monitor with well-maintained and character defining six-over-six double-hung sash windows.
F Group of six-over-six double-hung sash windows with transoms, only needing paint.

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Repair or Replace Old Windows

A Visual Look at the Impacts

Windows are a big part of older and historic buildings, from Main Street commercial structures to modernist mid-century residences. Original windows comprise about one quarter of the surface area of exterior walls. Windows often help identify the architectural style, design and give scale to a building. Just as windows define the character of a building, they also contribute to the larger context of neighborhoods and downtowns and their character. The visual impact and appearance of new, replacement windows that do not match or replicate features can be dramatic. Even minor changes to the appearance of windows can alter the way a building looks. Original material is lost and thrown away. And some buildings may no longer be considered 'historic' in terms of integrity and eligibility for historic designation. When choosing between repairing or replacing old windows, a lot needs to be factored in, including the visual impacts. This resource, divided into the following sections, is intended to help you look at your old windows, building and think about all options before making a decision.

Should I Repair My Old Windows?

When are Replacement Windows Necessary?

Do the Benefits Outweigh the Costs?

When Replacing My Windows, What Not To Do?

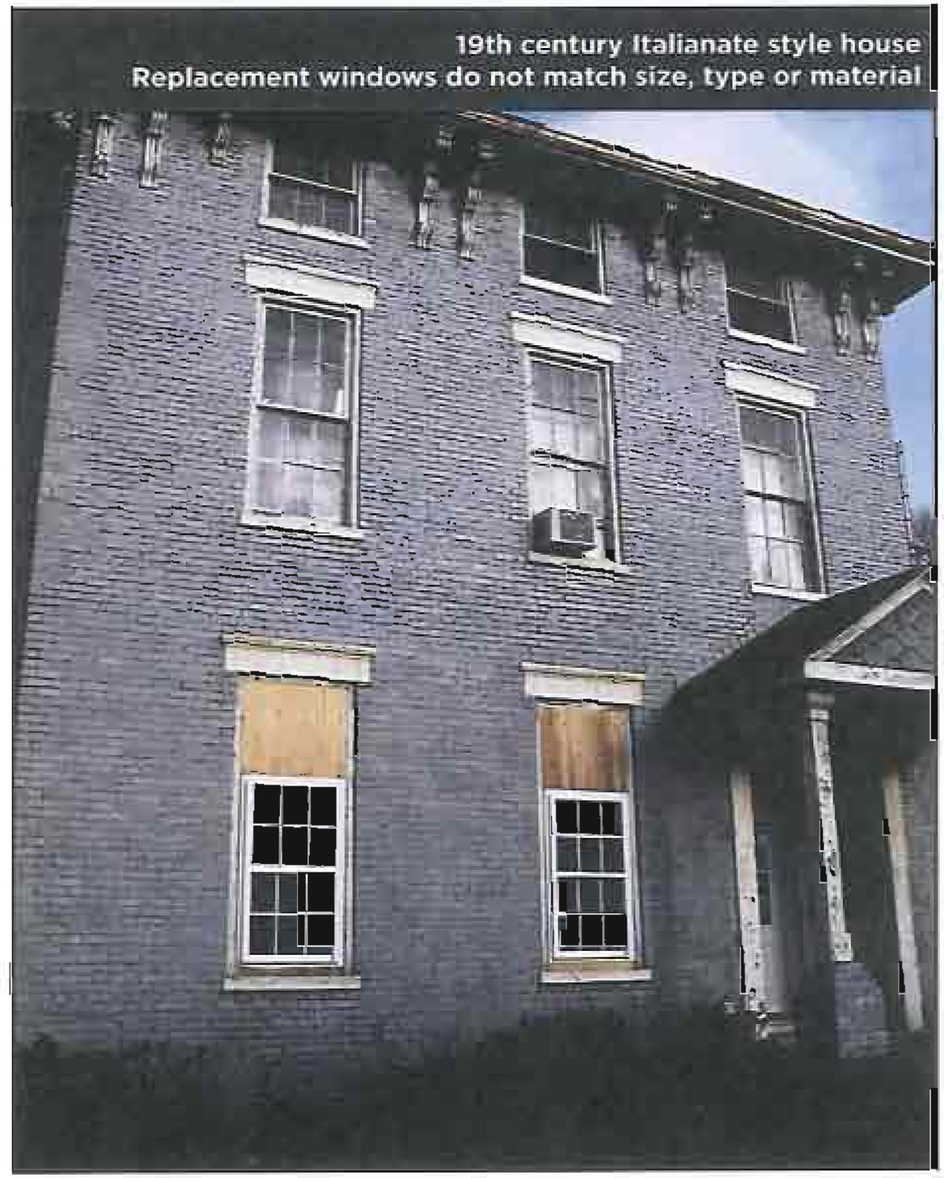
Do Window Details Matter?

Case Studies:

- A Material Issue
- In-Kind Replacement
- Size Matters
- Close, But Not Enough
- A Blurry View
- Impersonating the Original
- A Modern Dilemma
- Authenticity Counts
- One Window, Multiple Replacements
- Putting Windows in Context

For more information...

Go to **www.PreservationNation.org/Weatherization** to find additional resources on windows and much more for your older and historic building.



Historic Landmarks Foundation of Indiana

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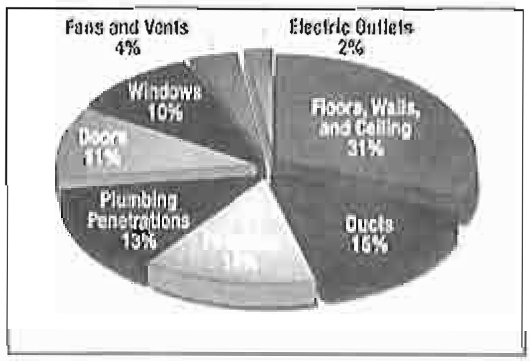
Popular Window Replacement Myths

The Myth: "Vinyl is Final"

"Maintenance free" is a popular term used by vinyl window manufacturers; but with a product that is susceptible to seasonal fluctuations, weathering, and constant operation, how can anyone truly guarantee this claim? Vinyl windows are made with stock parts that quickly become outmoded, making them difficult, if not impossible, to repair if a spring or other suspension component breaks (the same holds true for wood replacement window parts). Vinyl is also prone to warping and fading in high temperatures. Want to repair a historic wood window? Tools, parts, and materials can found at your local hardware store!

The Myth: Old Wood Windows = Astronomical Heat Bills

Replacement window manufacturers will often compare their product to a historic wood window that has **not** been restored or maintained – a window that fits this description will undoubtedly be drafty and inefficient. In most cases, however, a fully-restored, tight-fitting, properly functioning, weatherstripped wood window combined with a quality storm window will have the same insulating properties as a double-glazed replacement window. Other steps can be taken to reduce heating bills, such as insulating attics and floors; the U.S. Department of Energy notes that 31% of air infiltration is at floors, walls, and ceilings, and only 10% at windows: http://www1.eere.energy.gov/consumer/tips/air_leaks.html



The Myth: Replacement Windows Look Just Like Historic Wood Windows

A property owner or replacement window salesman will often make this claim when the snap-in grids or simulated divided lites in the replacement model match the existing muntin configuration of the original wood windows. First of all, snap-in grids or simulated divided lites have a much different profile than the traditional putty profile on old wood windows, which is difficult to replicate. Secondly, materials such as vinyl or synthetic cladding are shiny and glossy and present a much different look than traditional wood. Third, installation details for replacement windows typically involve additional framing that reduces the rough opening of the window. Lastly, replacement window glass is significantly different than the wavy look of historic glass.

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The Myth: Replacement Windows are the "Greener" Option

With all of the talk of global warming and LEED (Leadership in Energy and Environmental Design), replacement window manufacturers often tout the energy savings associated with their product and that a replacement window is a "green" choice. While this claim may correspond to newly-constructed, LEED-certified buildings, the argument that a replacement window is "greener" than a restored wood window is highly debatable. As discussed previously, a properly restored wood window combined with a quality storm window will address energy concerns. A product with a "green" label must also be sustainable. Historic wood windows, constructed of old-growth lumber and superior craftsmanship, will last up to 5 times longer than replacement models, namely because the wood is durable and they are easily repaired. The same can't be said for vinyl or new-growth wood replacement windows with plastic parts. Moreover, the insulating glass found in double-glazed replacement windows will eventually fail and the whole window will have to be replaced.

The Myth: Old Wood Windows are Highly Susceptible to Rot

Wood windows will rot if they are not maintained. Any natural material that is exposed to weathering and sunlight will be impacted. However, proper maintenance will ensure a long-lasting window, whether it be priming and painting or installing a quality storm window. Oftentimes, a wood window may appear to have rot, but is actually just badly weathered and needs some T.L.C. Remember, historic wood windows have a high quality of craftsmanship and were constructed from old growth lumber; they were built to last.

The Myth: "It's pointless to restore an old wood window when it will just be covered up with a modern storm window"

While it's true that modern storms can conceal the character of historic window sash, a few facts need to be addressed. First, storm windows have been around for over 100 years, originally made of wood, of course. Although some modern (and cheap and flimsy) storms might be an eyesore, there are quality models on the market that are more appropriate for historic buildings. Second, a metal storm window is a small price to pay for preserving original materials and character, and storm windows *can* be painted. Third, the installation of a storm window is reversible, while the removal of a historic wood window is not. Furthermore, as a bonus, a properly installed, quality storm combined with a restored wood window will be just as energy efficient as a double-glazed replacement window!

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The Myth: "It is more expensive to restore an old wood window than to replace it."

The cost of restoring a historic wood window obviously varies due to many factors, and there is no guarantee that restoring a window will be cheaper than replacing it. Studies have shown, however, that the payback period for new replacement windows can take decades. In that span of time, it is likely that these windows will have to be replaced again, since most replacement windows only have a lifespan of 20 years. Historic wood windows that have lasted 100 years will last another 100 years if properly restored and maintained. Therefore, the payback period of a restored wood window equates to a much better bargain.

The Myth: "Old wood windows have lead paint and should be discarded"

While any house built before 1978 might contain lead paint, it is possible to remove lead paint from historic sash without posing serious health hazards. Local municipalities often have guidelines for safe and effective de-leading, including windows, but it needs to be done by a professional. An experienced contractor or window restoration specialist should be able to identify unstable lead paint (the most hazardous condition) and treat it appropriately. Oftentimes, stable lead paint can be encapsulated with lead-free paint to comply with state laws. With proper precautions and safety measures, historic wood windows with lead paint can be remedied. For more information on lead paint hazards in historic buildings, refer to *Preservation Brief 37: Appropriate Methods of Reducing Lead-Paint Hazards in Historic Housing* from the National Park Service:
http://www.nps.gov/history/hps/TPS/briefs/brief37.htm

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Essential Online Window Articles

(Note: These and many other links can also be found on the National Trust for Historic Preservation's "Window Links and Resources" page at: http://www.preservationnation.org/issues/weatherization/resources/windows.html)

1. "Testing the Energy Performance of Wood Windows in Cold Climates: A Report to the State of Vermont Division for Historic Preservation."
   http://web.archive.org/web/20060425110158/http://www.ncptt.nps.gov/PDFfiles/1996-08.pdf

2. "Creating Windows of Energy-Saving Opportunity"
   http://homeenergy.org/archive/hem.dis.anl.gov/eehem/97/970908.html

3. "Wiser Window Retrofits "
   http://homeenergy.org/magazine.php?year=2002 (registration req'd)

4. "What Replacement Windows Can't Replace: The Real Cost of Removing Historic Windows"
   http://www.apti.org/publications/Past-Bulletin-Articles/Sedovic-36-4.pdf

5. "Preservation Brief 9: The Repair of Historic Wooden Windows"
   http://www.nps.gov/history/hps/tps/briefs/brief09.htm

6. "Still no Substitute"
   http://www.period-homes.com/Previous-Issues-06/NovFeature06b.html

7. "Window Restoration"
   http://findarticles.com/p/articles/mi_qa3922/is_200010/ai_n8926741/?tag=content;col1

8. "Historic Windows and Energy Efficiency"
   http://www.presnc.org/Features/Historic-Windows-Energy-Efficiency

9. "What Should I Do About My Windows?"
   http://www.bestofbuildingscience.com/pdf/What%20should%20I%20do%20about%20my%20windows%20HEM_19-4_p24-31.pdf

10. "Why Old Windows are Green Windows"
    http://planetgreen.discovery.com/home-garden/green-windows.html?campaign=daylife-article

Saving Energy in Historic Buildings: Balancing Efficiency and Value

JOHN H. CLUVER AND BRAD RANDALL

Energy modeling and life-cycle costing can help identify simple steps to make a historic building more energy efficient, addressing both preservation and sustainability concerns.

By now the slogan of the National Trust for Historic Preservation that "the greenest building is the one already built" is widely known. In an era of increased environmental awareness and rising fuel prices, however, the question is how can historic building stock be made more energy efficient in a manner respectful of its historic integrity and character. The other challenge is to find those improvements that, in the quest to save energy (and, by extension, money), do not in the long run cost more than they save. There are an increasing number of "sustainable solutions" in the marketplace today, but not all are good investments, provide tangible benefits, or are appropriate approaches for historic buildings. Often common sense, trained historic and/or aesthetic judgment, and the studies and assurances of those marketing the solutions are used to determine what interventions are appropriate. In addition, practical and objective analysis tools are needed in the process, and that is the benefit of including energy modeling and life-cycle costing in assessing potential changes. These calculation tools can help all of those involved in a project to understand which solutions truly offer energy and operating-cost savings.

Fig. 1. Swift Hall at Vassar College. Originally built in 1902, the structure retains much of its original appearance and building fabric. Image by Voith & Mactavish Architects, LLP.

Energy Modeling

The use of computers to simulate annual energy consumption began as a result of the energy crisis in the 1970s. After the United States Department of Energy (DOE) was created by President Jimmy Carter, algorithms were developed to simulate the annual energy consumption of a building. These calculations were refined and further developed over the years, with the DOE-2 simulation algorithms gaining wide acceptance in the industry throughout the 1990s. Currently, use of these energy-modeling tools has become standard for any project that is pursuing Leadership in Energy and Environmental Design (LEED) certification from the United States Green Building Council. There are many energy-modeling software programs in use today, including Energy Plus, developed jointly by the University of Illinois and the Lawrence Berkeley National Laboratory.[1]

The basic concept of the energy model is to virtually create (or, in the case of preservation, recreate) a building, delineating not only its physical form but other performance and usage variables. The simulation process includes a virtual model of the building geometry, the building materials and their characteristics, and the types of mechanical systems and lighting, along with other systems that may consume energy. The patterns of the occupants and their activity levels are added to the virtual model, and finally the weather-data files that reflect the particular locale are referenced for a complete hour-by-hour simulation of a typical meteorological year.[2]

Depending on the size of the building, creating this baseline model can be a process that takes 40 hours for a small, straightforward building, such as a suburban office building, to hundreds of hours for a large, complex edifice, such as a monumental campus building. Regardless of project size, the process is typically the same, although larger buildings tend to leverage the effort and cost of the model to greater effect since the improvements can produce larger energy savings. Once the baseline information has been entered and an existing-conditions model created, it is then possible to calculate the building's current energy-use footprint and to track what percentage of that consumption can be attributed to each of the building's components.

Before performing any analysis, however, this initial calculation should first be cross-checked against any energy bills or other records that may exist to help normalize the model to the actual operation of the building and to allow for more accurate predictions in the future comparisons.[3] For example, energy loss through air infiltration can constitute a sizable percentage of the overall total, ranging anywhere from less than 5 percent in a newly constructed building with careful air-barrier detailing to 40 percent or more in an old, poorly maintained building that has numerous gaps and openings at such locations as foundations, sill plates, windows, doors, sheathing, flues, and eaves.

Next, it is appropriate to start the process of creating scenarios to understand the energy-use implications of various improvements that could be proposed. The most beneficial approach is to first select a series of potential interventions and model each of them individually, so as to understand the independent impact of each accurately. Since it takes time to generate the model and run the simulation for each variable, project budgets typically require judiciousness in selecting each option. Some of the more common scenarios to explore include:

- replacing the lamps, fixtures, and/or controls for lighting.
- replacing the mechanical plant with new methods of heat generation and distribution and/or upgrading the system controls.
- installing insulation in the attic, between roof rafters, in walls, dormers, and the basement and sealing locations of air infiltration.
- restoring or replacing single-glazed windows or supplementing them with storm windows.

While running individual models can give an excellent perspective on the effectiveness of various improvements compared to the existing conditions, the additional step of creating combination scenarios is critical to properly determine the impact that a series of improvements may have on the energy consumption in a rehabilitated historic building. These combined scenarios look at the overall effect of several simultaneous interventions, showing how these changes work together. Some combinations will create increased energy savings, while others may work in opposition to each other. For example, converting light fixtures from old incandescent lamps to efficient fluorescent fixtures with electronic ballasts will greatly reduce electrical demand for lighting and could reduce summer air-conditioning costs but will also increase the need for winter mechanical heating to compensate for the loss of heat generated by the old lamps. Once the combination scenarios are created and simulated, the project team will have a truer understanding of the approximate energy savings that can be generated by the proposed improvements and can do so in a manner that does not inadvertently bias the results for the first few improvements that are modeled in an additive process.

Life-Cycle Costing

The energy simulation is only one part of the larger quest of finding the appropriate project scope that achieves energy savings in a manner that is both cost effective and respectful of the historic character of the building. These goals can best be achieved by employing the process of life-cycle costing, which incorporates the results of the energy-simulation modeling into a cost analysis of a proposed project over an extended period of time. Life-cycle costing is a version of life-cycle assessment, which had its beginnings roughly 40 years ago, although it could be said that informal, common-sense versions of it have existed for much longer.[4] The basic concept is to determine the true cost of installing a particular material or system when projected through the expected life span of the building. While there are other sources for more complete information on life-cycle costing that detail the process even further, the following are the four most important factors in endeavoring to answer this question:

- *Cost of manufacture and installation.* Otherwise known as the "first cost," this is the typical construction cost that is carefully scrutinized during design to find the lowest-cost option for meeting a particular need and budget. The first cost includes the harvesting of materials, their fabrication into the final product, installation in the building, and their transportation during all of the stages. Many projects consider only this cost in selecting a material or system for a project.
- *Cost of operation.* Some systems consume electricity or burn fuel, and some are more efficient than others in their use of that energy. Some also require personnel to operate or monitor the equipment, and this labor carries a dollar value. Costs of operation are a regular, ongoing expense that should be predictable, although recent experiences with fuel costs, for example, show that it is susceptible to some degree of uncertainty.
- *Cost of maintenance.* All systems and objects require some level of maintenance and repair, with an associated cost for both the materials and labor, either for in house staff or contracted servicing. These costs do not always occur on an annual basis, but for the purposes of life-cycle cost analysis they can be normalized to an annual frequency in order to predict the anticipated costs related to maintenance.
- *Cost of replacement.* Many elements of a building must be replaced at

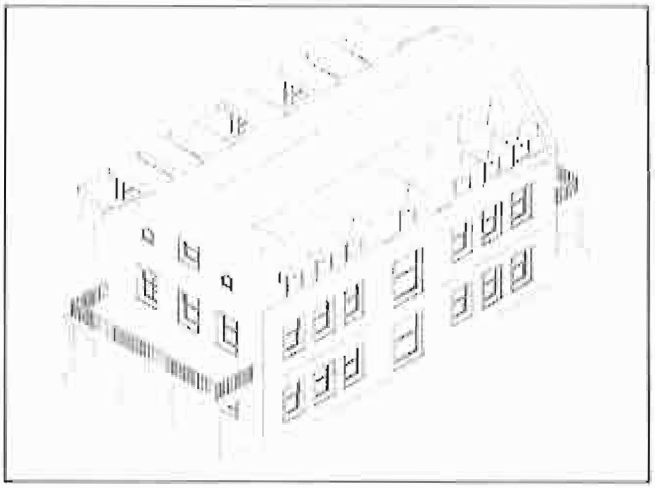

Fig. 2. An axonometric wire diagram of Swift Hall. The wire diagram allows the designer to confirm that the parameters used in the energy model match the existing conditions. Image by Bruce E. Brooks & Associates.

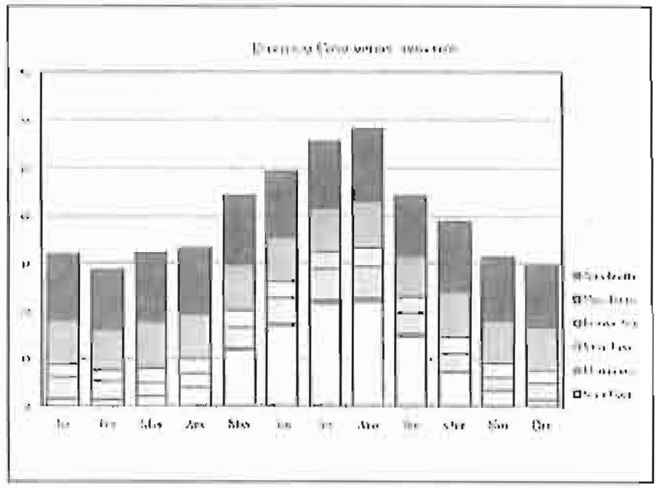

Fig. 3. Monthly energy use patterns can be broken down by equipment, month, fuel type, and other parameters to help analyze possible areas for energy savings. All images by the author, unless otherwise noted.

some point (or several points) in its history. Depending on what is being replaced, the cost of this work can be substantial, including not only the new material and the labor to install it, but also the cost of temporary provisions during the work, potential lost productivity, and disposal of the defunct item. The choice of materials can have a great impact on the frequency of those replacements, as, for example, asphalt shingle roofing may have a lifespan of 25 years, whereas slate roofing can last for more than 100 years.

An important variable in the life-cycle cost analysis is the time period under consideration. Different groups will have their own criteria when determining the life cycle and will define it to suit their situation. For example, a developer may not care that a hot-water heater must be replaced in its eleventh year, whereas the facilities department at a university may work under a 30-year planning cycle. In contrast, the preservationist may have the longest perspective of all, considering ways to help the historic resource last as long as possible, which could include several life cycles for various materials. It is common, however, to look at periods of 25 years or more when doing an analysis, so that maintenance and replacement costs over the full life cycle of the equipment or system are taken into account.

Case Study: Swift Hall at Vassar College

The following case study serves as a useful illustration not only to demonstrate the practical application of the above concepts but also to point out the roughly half-dozen improvements that can be performed in a historic building to achieve the triad of energy efficiency, cost effectiveness, and protection of historic integrity.

Swift Hall at Vassar College in Poughkeepsie, New York, dates to 1902, when it was built to the designs of the noted architectural firm of York and Sawyer as the college infirmary (Fig. 1). It consisted of three floors of wards and private rooms, along with a kitchen, dining room, and parlor on the first floor, all occupying roughly 6,100 square feet of climate-controlled space. In 1941 the building was converted for use as departmental offices and classrooms for the history department, which has occupied it since then.

Very little has changed in Swift Hall from the original design. While some of the third-floor wards were divided to create offices and some of the bathrooms converted into small offices, the building basically retains its original configuration and materials, thus maintaining its historic integrity. The building is solid masonry construction with stone foundations and 12-inch-thick brick walls. The interior plaster is applied directly to the brick and lacks any insulation. The mansard roof is punctuated with numerous dormers and covered with slate and asphalt shingles installed over wood sheathing. There is a low attic beneath the central part of the roof, which is uninsulated. The 60 windows in the building retain the original, single-glazed, six-over-six double-hung wood sash; they lack any type of weatherstripping or storm windows. Heat is provided by steam radiators and convectors connected to the campus's central steam system. Controls are limited to localized, non-electric control valves. Cooling is restricted to a limited number of window-mounted air-conditioning units. Lighting is a combination of incandescent and fluorescent fixtures of various ages and architectural styles.

As a result of these conditions, it is difficult to maintain a consistent temperature in the building; it varies not just seasonally but also from room to room. Despite this and other functional limitations, the building is a much-loved and central part of the history department, and the college's desire was to rehabilitate the building in a historically sensitive manner to improve its energy efficiency and basic comfort requirements while also better meeting life-safety requirements and the department's program needs.

Energy Modeling

The simulation of the annual energy use for Swift Hall — including the esti-

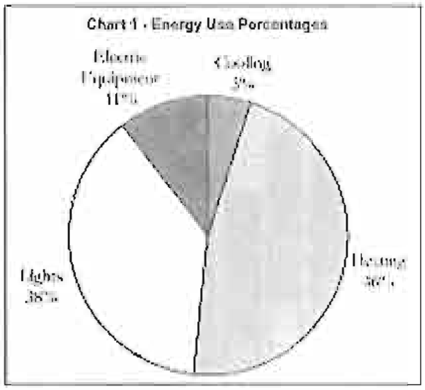

Fig. 4. Energy usage at Swift Hall broken down by building systems.

mated annual fuel consumption used to create steam for heating and annual electricity consumption for lighting, power, and cooling — resulted in an annual energy cost of $2.66 per square foot (Fig. 2). This amount is significantly higher than the United States average for this type of building. According to the Energy Information Administration, which provides the official energy statistics for the U.S. government, the Northeast regional average is $1.74 per square foot for all commercial buildings and even less for educational buildings.[5]

The energy simulation also provides information about where the energy is being used (Fig. 3). For example, the output indicates that for the existing building, the two primary consumers of energy are lighting at approximately 38 percent and heating at 46 percent of the annual energy use (Fig. 4). Air-conditioning is a very low value of 5 percent, due to the reliance on a limited number of window units and reduced summertime occupancy. Therefore, a reasonable conclusion is that the best areas to focus on reducing energy consumption is with the lighting, either through more efficient fixtures and/or reducing the hours lights are used, and with the heating, either by improving the efficiency of the mechanical system and/or the building envelope.

Several scenarios were simulated in order to determine how much savings would be possible for each potential intervention. For each of these scenarios, an hour-by-hour simulation of operations allows an objective analysis of the impact, rather than reliance on the designer's traditions or rules of thumb. It is important to simulate each scenario in the model because the focus is on the performance of the entire building, not just that of a particular element, so the overall impact on an annual basis can be used to compare the cost and savings of various options.

The model not only will show the changes in the total energy consumption for each scenario compared to the baseline existing condition but also can show the amount of change in each energy category (Fig. 5). While typically considered on an annual cycle, the model can also provide information broken down into other groupings, such as seasonal consumption of different fuel sources, to help explain how use patterns during a typical school year can impact energy consumption. Based on the scenarios considered for this building, the most promising measures to improve energy performance, along with other subjective benefits including improved occupant comfort, were upgrading lighting controls and fixtures, insulating the attic and spaces between the rafters on the top floor, improving the zone control of the heating system, and refurbishing the historic windows.

The improvements to the lighting system were simulated through two scenarios. The first would involve the addition of lighting controls, such as occupancy sensors to keep the lights off unless people are in the room. The addition of these controls alone resulted in an anticipated annual energy savings for the building of approximately $2,250, or 14 percent. The second scenario would involve replacing older lighting fixtures with newer fluorescent fixtures with a few exceptions, such as the lobby chandelier, combined with more efficient controls. This more extensive intervention resulted in a predicted reduction of 50 percent of the lighting bill, representing an annual savings of nearly $3,350, or 22 percent over the total-energy-bill baseline.[6]

Addressing the issue of reducing the annual cost of heating the building while improving its overall comfort level for occupants was pursued along two parallel tracks — the efficiency of the heating system in producing and controlling the heat and the ability of the building envelope to retain the heat supplied. The existing heating system, which uses the campus's central steam plant, is reasonably efficient in converting fuel into useable heat (in the low 70 percent efficiency range), but it has limited controls. The lack of controls creates an unevenness in distribution that causes significant occupant discomfort and wasted energy. For example, it is not uncommon in older buildings with steam systems for occupants to resort to opening a window in the winter to compensate for a surplus of heat in a room, thereby negating any gains made in the efficiency of the window. The efficiency of the existing heating system could be improved either by upgrading the controls and zone dampers, which would improve comfort levels along with a modeled savings of $1,200, or 7.5 percent, in annual energy costs, or by replacing the entire system with a high-efficiency hot-water system, resulting in calculated savings of $2,200, or 13.5 percent in annual energy costs.

The second scenario for reducing the annual heating costs would be to improve the thermal efficiency of the building envelope, addressing infiltration and the insulating properties of the walls, windows, and attic/roof. For this building insulating the walls was not considered an option given the solid masonry construction.[7] The energy-model simulation did, however, include several scenarios for the windows, which comprise roughly 15 percent of the surface area of the building envelope, typical for a building of this era. As in many historic buildings the windows are a weak point in the thermal envelope. Single-pane windows provide little resistance to heat transfer, and the gaps around older windows allow significant leakage of outside air into the building.

The first scenario to be modeled would be refurbishing the existing single-glazed wood windows to assure a tight fit when locked, installing weather-stripping, and providing storm windows.[8] This approach improves the effective U-value of the window assembly from roughly 1.1 to 0.5 and greatly decreases air infiltration around the units, which should reduce anticipated energy costs by $900, or 5.5 percent, annually. New energy-efficient windows, either wood or vinyl, with double-glazing and low-e glass, reduce the assembly U-value further to approximately 0.35.

However, since so much of the existing heat loss is due to leakage and the low-e glass is actually a detriment in winter because it reduces solar heat gain, this option provides similar overall modeled energy savings of $900, or 5.5 percent, annually. In contrast to the windows, large energy savings and comfort gains can be realized by providing insulation in the attic and venting the attic in the summer.[9] Swift Hall has a small attic over the central portion of the building; insulating and adding active summer venting just at this location was calculated to reduce annual energy costs by $2,850, or 17.5 percent.[10] If the insulation were also installed in between the roof rafters where there is no attic, the anticipated savings would increase to $3,550, or 22 percent.

The ideal energy-savings solution, of course, would be to combine these approaches and possibly others. It is not possible, however, to simply add up the percentage savings for each of the chosen improvements, as the total savings available decreases with each additional measure. For example, improving the thermal efficiency of the building envelope would reduce the savings to be found by replacing the boiler. Creating an energy model that combines all of the chosen elements together, however, will provide an accurate picture of the overall savings. For example, a scenario that includes replacing the lighting fixtures and controls, upgrading the existing steam-boiler control system, adding attic insulation and venting, and installing weatherstripping and storm windows would produce a calculated savings of $7,100, or 44 percent, of the annual energy cost of the building. This approach would result in an annual energy bill of approximately $9,000, which averages out to a value of $1.50 per square foot, which is 16 percent below the Northeast average. In comparison, a more intensive effort that would include replacing the lighting fixtures and controls, installing a new high-efficiency boiler and hot-water heating system, adding insulation and venting to the attic and insulation between the roof rafters where there is no attic, and installing new energy-efficient windows would produce an anticipated savings that is only 10 percent higher ($8,350, or 52 percent, of the annual energy cost). While a 10 percent savings is a definite, measurable benefit, it is important to determine whether this additional savings is worth the added expense necessary to achieve it. The answer to that question lies in the life-cycle costing for the proposed project.

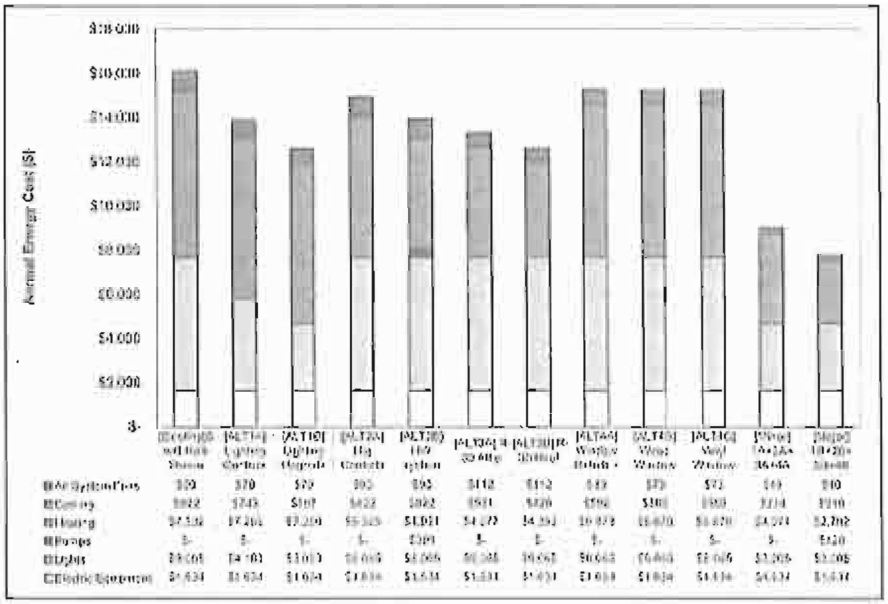

Fig. 5. Simulation results for each scenario tested using the energy model, showing not only total annual energy costs but also how each energy component of the building would be affected by the proposed change.

Life-Cycle Costing

As outlined above, there are four major components that contribute to the life-cycle cost of a material or system — first cost, operation, maintenance, and replacement. The selection of one alternative over another will have an economic impact on the institution not only at the time of construction but also over the lifetime of the building. A life-cycle cost analysis will consider and compare the first-year investment; the annual operating costs, including energy, repairs, and maintenance; and any necessary replacement at the end of the system's life.

However, the value of a dollar spent on a building improvement today is greater than the value of that same dollar in the future, due to its potential to earn interest if it were invested rather than spent. This concept is often referred to as the "time value of money," and future investments and expenses should be discounted to the equivalent present value for comparison.

The life-cycle cost analysis, therefore, takes into account anticipated values for inflation, energy-cost changes, and interest rates. By applying these factors to the life-cycle components over a set period of time, it is possible to determine a net present value (NPV) for the material or system. To understand whether or not a particular set of initiatives makes sense financially, one can compare the NPV of the proposed undertaking against the NPV of doing nothing; the option with the lowest NPV represents the best approach strictly from a cost basis. Other metrics can also be used to compare the options. The annual equivalent payment (AEP) would represent the annual amortization cost for the difference in net present value. It is important to recognize that these are the financial indicators only and that typically a project will have other benefits as well, such as improved appearance or comfort, ease of use, occupant satisfaction, and reduced demands on maintenance staff or service contractors.

The life-cycle cost analysis includes several financial variables, which can be adjusted to observe how sensitive the analysis is to any particular factor. As applied to the case study the values were as follows. The annual rate of inflation

Table 1. Life-Cycle Analysis Overall Comparisons

	First-Year Costs				25-Year Values			Annual Equivalent Payment Savings		Annual Equivalent Energy Savings	
	Project	Energy	Maintenance	Payback	NPV	AEP	AEE				
Lighting Upgrades											
Full Lighting Upgrade	$70,000	$12,600	$16,000	11	$594,787	$46,528	$20,600	$2,573	5.2%	$7,376	26.4%
Lighting-Controls Upgrade	$10,000	$13,904	$17,000	4	$582,025	$45,530	$22,731	$3,571	7.3%	$5,244	18.7%
Existing Lighting Maintained	$0	$16,143	$17,500		$627,679	$49,101	$27,976				
Heating System Upgrades											
New High-Efficiency System	$250,000	$13,961	$9,500	18	$685,217	$53,602	$22,825	-$4,501	-9.2%	$5,151	18.4%
Upgrade Existing Controls	$95,000	$14,936	$14,500	17	$642,310	$50,246	$24,419	-$1,145	-2.3%	$3,557	12.7%
Existing Central Steam Maintained	$0	$16,143	$17,500		$627,679	$49,101	$27,976				
Attic Insulation and Summer Venting											
Full-Roof Insulation/Venting	$22,000	$12,590	$18,000	6	$582,472	$45,565	$20,583	$3,536	7.2%	$7,392	26.4%
Attic-Only Insulation/Venting	$10,000	$13,319	$18,000	4	$586,387	$45,871	$21,775	$3,230	6.6%	$6,200	22.2%
Existing - No Insulation/ Venting	$0	$16,143	$17,500		$627,679	$49,101	$27,976				
Window Upgrades											
New Vinyl Windows – 20-Year Cycle	$90,000	$15,236	$12,500	none	$658,501	$51,512	$24,909	-$2,411	-4.9%	$3,066	11.0%
New Vinyl-Clad Windows	$150,000	$15,236	$12,500	19	$667,289	$52,200	$24,909	-$3,099	-6.3%	$3,066	11.0%
New Wood Windows – 40-Year Cycle	$150,000	$15,236	$15,500	none	$717,055	$56,093	$24,909	-$6,992	-14.2%	$3,066	11.0%
Refurbish and Add Interior Storms	$51,000	$15,252	$15,500	14	$623,993	$48,813	$24,935	$288	0.6%	$3,040	10.9%
Existing Wood Windows Maintained	$0	$16,143	$17,500		$627,679	$49,101	$27,976				
Combination Projects											
Major Intervention Scope*	$492,000	$7,800	$6,500	none	$734,992	$57,496	$12,752	-$8,395	-17.1%	$15,223	54.4%
Minor Intervention Scope*	$166,000	$9,000	$11,500	11	$535,467	$41,888	$14,714	$7,213	14.7%	$13,262	47.4%
Existing Conditions Maintained	$0	$16,143	$17,500		$627,679	$49,101	$27,976				

* Major scope includes upgrades to lighting and controls, installing insulation and venting at the attic and rafters, a new high-efficiency boiler, and new wood windows.

* Minor scope includes upgrades to lighting and controls, installing insulation and venting at the attic, upgrading the controls of the existing heating system, and refurbishing the existing windows and installing storm windows.

was set at the commonly accepted value of 3 percent. Decreasing the rate typically will lower the NPV and reduce the relative savings. The cost of energy was assumed to rise at 5 percent per year, recognizing that energy prices will continue to increase but at a rate somewhere between the high percentages of the past few years and the relatively stable values that preceded them. A higher rate will increase the NPV and increase the resultant annual savings. The interest rate, also known as the discount rate, was set at a relatively conservative value of 6 percent. Increasing the rate typically will lower the NPV values and decrease the impact of the large initial investments.

The various scenarios analyzed for the case study are presented in Table 1, including both existing conditions and a series of potential improvements in the building's energy consumption. The first columns allow a simple comparison of the initial investment, the annual energy costs, and the annual maintenance costs of the proposed improvement versus the cost of doing nothing. The payback column indicates the year in which the initial investment in the project is "paid for" out of the annual energy and maintenance savings. The next set of columns show 25-year values that include the time value of money impacts over the 25-year study period, including the anticipated annual savings in all expenses, as well as just the energy portion of those costs. What is striking is that while all of the suggested improvements offer definite projected energy savings (none is less than 10 percent), only some of them are able to translate the energy savings into overall life-cycle cost savings, due mostly to the difficulty of overcoming high initial-investment costs of some of the improvements.

Reviewing the table and each area of potential improvement studied, it becomes clear that two of the most effective projects that can be undertaken at a historic building such as Swift Hall are upgrading the light fixtures and controls to improve efficiency and insulating and ventilating the attic. These results are not surprising, since both are relatively inexpensive undertakings that also result in high energy savings. In contrast, two projects that are often touted for their energy-saving benefits, upgrading the heating system and replacing windows, are unable to fully recapture their steep initial investment costs with energy and maintenance savings.

In the case of the heating system, upgrading the controls of the existing central steam system carries only a slight projected annual cost increase ($1,145), which can be justified easily by the improved comfort for the occupants and the reduced workload for maintenance personnel. Installing a new high-efficiency boiler, in contrast, has a much steeper anticipated annual cost increase ($4,500) to accompany the higher energy savings. It could be argued, however, that the benefits of this heating-system upgrade would last longer than the 25-year-life cycle period of the study, decreasing the cost impact of the new system.

In contrast to the other systems described above, the benefits of window replacement are, at best, questionable.[11] Given the relatively low overall energy savings offered by the various forms of window improvements, the only option that makes clear economic sense is to refurbish the historic wood windows and install storm windows, and even this course of action is barely a break-even undertaking according to the financial analysis. Replacement with painted wood windows is a very costly approach, due not only to the cost of purchasing and installing the new units but also due to need for periodic painting. New wooden windows also lack the durability of historic windows made with old-growth lumber. Vinyl-clad windows can eliminate the need for painting but still are not able to achieve cost savings compared to keeping the originals. Replacement with solid vinyl windows is not any better. They are cheaper than wood windows and do not require painting, but they have a relatively short lifespan; the cheapest versions will last less than 10 years before the vinyl becomes brittle and the joints open up, but even the more expensive models will be hard pressed to last much beyond 20 or 25 years before failure becomes problematic. The short replacement cycle for these windows overwhelms their initial lower cost and reduced maintenance costs, and the unwitting property owners typically will find themselves replacing them before the windows have finished paying for themselves.

Finally, comparing the combination projects, one can now see that the anticipated additional 10 percent in energy savings offered by the major intervention scope over the minor intervention scope is not a particularly good investment from a financial perspective. The high cost of the new boiler and new windows create such a high project cost that the savings in energy and maintenance costs offered by these options cannot overcome them. In contrast, the minor scope lighting upgrades, attic insulation and venting, upgraded heating controls, window refurbishing, and storm windows — offers not only substantial energy savings but also significant savings in annual expenses compared to the option of doing nothing. These interventions also carry the additional benefit of being more respectful of the character of the historic building, creating the ideal scenario of saving energy while saving history.

Conclusion

As can be seen from the case study, it is entirely possible to meet the goals of improved energy efficiency in a manner that is both cost-effective and sensitive to the historic character of the building. By using energy modeling, it is possible to better understand the inherent properties of a particular historic resource that cause it to perform differently from new construction and thereby to design improvements that use those features to their best advantage. It also allows the designer to use life-cycle costing to better understand the cost implications of a particular intervention over the long term, which will help in decision-making if the loss of historic material or character cannot be justified by improvements in energy performance. Combined with other considerations not discussed in this article, such as the aesthetic, historical, environmental, and functional impacts of any chosen course of action, these tools can help the conscientious building owner, architect, engineer, or preservationist make the argument that sometimes using the newest materials or technology is not the most appropriate course of action in a rehabilitation project and that maintaining and restoring historic buildings is often the most sustainable step to take.

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Acknowledgements

Special thanks to Richard Voith of Econsult Corporation for his help in reviewing the cost data and organizing the life-cycle assessment chart.

Notes

1. Energy Efficiency and Renewable Energy (EERE) Division of the U.S. Department of Energy (DOE) Building Energy Software Tools Directory, http://apps1.eere.energy.gov/buildings/tools_directory.

2. Marc Rosenbaum, "Understanding the Energy Modeling Process: Simulation Literacy 101," in *The Pittsburgh Papers: Best of Green-Build 2003* (Pittsburgh: BuildingGreen, Inc., in assoc. with the U.S. Green Building Council, 2003), 99–108.

3. Checking the energy model for the existing building against actual billings is an important step, as the assumptions made in the model can impact the results; particularly for larger buildings, the variations could have a measurable impact. This ability to verify usage is also an advantage that existing buildings have over new buildings. It is also worth noting that the computer model is limited in accuracy when simulating unusual system types or building properties. For example, one of the benefits of older masonry buildings is their inherent thermal mass, but this feature is not accommodated well in the current software. Reviewing the actual energy use against the energy model can help identify and address such issues.

4. Scientific Applications International Corporation (SAIC), *Life Cycle Assessment: Principles and Practice*, EPA/600/R-06/060 (Springfield, Va.: U.S. Dept. of Commerce, Technology Administration, National Technical Information Service, 2006), 4.

5. Average $1.51 per square foot for all commercial buildings, $1.71 for office buildings, $1.22 for education buildings, based on 2003 data, which is the most recent available. Energy Information Administration of the United States, Department of Energy, Commercial Building Energy Consumption Survey (CBECS), 2003 CBECS Detailed Tables, Table C2A "Total Energy Expenditures by Major Fuel for All Building Types, 2003." See http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set14/2003pdf/c2a.pdf.

6. All of the percentage savings from this energy model are derived by comparing the energy savings from a particular intervention to the overall building energy consumption. Therefore, since lighting accounts for 38 percent of the building's energy costs and since electricity has a less efficient energy-per-unit cost ratio than other fuel sources, a reduction of 50 percent of energy costs in the lighting calculates to an overall energy savings of 22 percent.

7. It is possible to insulate solid masonry walls by installing interior studs and insulation. However, this is a very expensive and invasive approach, which consumes square footage, alters the historic appearance of the interiors, and may have the potential to cause long-term damage to the masonry wall by reducing the ability of the wall to dry out. For a more in-depth review of this topic, see William B. Rose, "Should the Walls of Historic Buildings Be Insulated," *APT Bulletin* 36, no. 4 (2005): 13–18.

8. While not performed in this case study, there are additional window-improvement variables that could be modeled where appropriate. For example, the effects of adding a reflective solar film or storm windows with low-e glass could be considered. The benefits of using glass with different solar heat-gain coefficients at different building exposures could also be determined using the model.

9. When considering additional insulation in a historic building, a full understanding of moisture migration through the building envelope is important. For a review of the principles involved refer to the *ASHRAE Fundamentals Handbook 2009*, Mark S. Owen, ed., chapters 25, 26, and 27, "Heat, Air, and Moisture Control in Building Assemblies – Fundamentals," "Heat, Air, and Moisture Control in Building Assemblies – Materials," and "Heat, Air, and Moisture Control in Building Assemblies – Examples" (Atlanta: American Society of Heating Refrigeration and Air-Conditioning Engineers, 2009), 25.1–27.13.

10. In this case study, the active ventilation was modeled for summertime ventilation to reduce temperature build-up in the attic. While it would increase electricity usage in the summer, it would be inoperable and closed in the winter. It is distinct from the passive ventilation system for condensation control that is already present and would remain unchanged.

11. For a more comprehensive discussion of aesthetic, performance, maintenance, and environmental issues with replacement windows, see Walter Sedovic and Jill H. Gotthelf, "What Replacement Windows Can't Replace," *APT Bulletin* 36, no. 4 (2005): 25–29.

What Replacement Windows Can't Replace: The Real Cost of Removing Historic Windows

WALTER SEDOVIC and JILL H. GOTTHELF

Sustainability looks even better through a restored window.

MATERIALS	EMBODIED ENERGY MJ/kg	EMBODIED ENERGY MJ/m3
Aggregate	0.10	150
Straw bale	0.24	31
Soil-cement	0.42	819
Stone (local)	0.79	2030
Concrete block	0.94	2350
Concrete (30 Mpa)	1.3	3180
Concrete precast	2.0	2700
Lumber	2.5	1380
Brick	2.5	5170
Cellulose insulation	3.3	112
Gypsum wallboard	6.1	5890
Particle board	8.0	4400
Aluminum (recycled)	8.1	21870
Steel (recycled)	8.9	37210
Shingles (asphalt)	9.0	4930
Plywood	10.4	5720
Mineral wool insulation	14.6	139
Glass	15.9	37550
Fiberglass insulation	30.3	970
Steel	32.0	251200
Zinc	51.0	371280
Brass	62.0	519560
PVC	70.0	93620
Copper	70.6	631164
Paint	93.3	117500
Linoleum	116.0	150930
Polystyrene insulation	117.0	3770
Carpet (synthetic)	148.0	84900
Aluminum (recycled)	227.0	515700

NOTE: Embodied energy values based on several international sources - local values may vary.

Fig. 1. Comparative values of the embodied energy levels of common building materials. Note that glass and aluminum (i.e., principal components of many replacement windows) are ranked among the highest levels of embodied energy, while most historic materials tend to possess much lower levels. Courtesy of Ted Kesik, Canadian Architect's Architectural Science Forum, Perspectives on Sustainability.

For all the brilliance reflected in efforts to preserve historic buildings in the U.S., the issue of replacing windows rather than restoring them remains singularly unresolved. Proponents on both sides of the issue may easily become frustrated by a dearth of useful data, as well as conflicting information, or misinformation, promulgated by manufacturers. Indeed, it often seems that many preservation practitioners and building owners remain in the sway of advertising claiming that the first order of business is to replace old windows. In the context of preservation and sustainability, however, it is well worth reconsidering this approach.

Sustainability and Authenticity

In considering alternatives to replacing historic windows, one needs to keep in mind two important elements: sustainability and authenticity. Sustainability (building green) and historic preservation are a natural marriage, so long as one remains mindful that sustainability is not just about energy conservation.[1] Preservation and sustainability involve myriad elements that can work in symbiotic and synchronized ways toward a favorable outcome. For example, preservation work is more labor- than material-intensive, which benefits local economies; natural ventilation afforded via operable windows can reduce the size of mechanical equipment, especially of air-conditioning; and salvaging historic materials, such as wood sash, obviates the need to harvest live trees and other natural resources for the manufacture of replacement units.

Similarly, retaining and celebrating authenticity is one key element of an exemplary preservation program. No one should take lightly the option of discarding authentic historic materials — in this case, windows — without fully evaluating the consequences. Once authentic material is lost, it is lost forever. It does not matter how accurate the replacement window, it never reflects the nuances of the original.

Taking the Long View

Historic windows possess aesthetic and material attributes that simply cannot be replaced by modern replacement windows. Like preserving whole buildings, restoring historic windows is a solid step forward into the realm of sustainability. The present approach to sustainability, however, still too often focuses on new construction and issues such as "intelligent" windows and energy efficiency, while overlooking other important, holistic benefits of preserving historic windows, such as the following:

- Conservation of embodied energy (i.e., the sum total of the energy required to extract raw materials, manufacture, transport, and install building products). Preserving historic windows not only conserves their embodied energy, it also eliminates the need to spend energy on replacement windows. Aluminum and vinyl — the materials used in many replacement windows — and new glass itself possess levels of embodied energy that are among the highest of most building materials (Fig. 1).[2]
- Reduction of environmental costs. Reusing historic windows reduces environmental costs by eliminating the need for removal and disposal of existing units, as well as manufacture and transportation of new units. Also, many replacement units are manufactured with such materials as

MISSOURI DEPARTMENT OF NATURAL RESOURCES
ENERGY CENTER - ENERGY LOAN PROGRAM
WINDOW REPLACEMENT WORKSHEET

BUILDING	LOCATION	DATE

To estimate the savings of replacing existing windows with efficiency upgrades, the following information must be known:

The U-Factor of the existing window (See U-Value table below).
The U-Factor of the replacement window (See U-Value table below).
The total area of the windows being replaced (square feet).
The heating energy cost ($/million Btu).
The heating plant efficiency (in percent).

SAVINGS CALCULATIONS

1. Enter the U-Factor of the existing windows .... ______
2. Enter the U-Factor of the replacement windows .... ______
3. Subtract line 2 from line 1 .... ______
4. Add 0.86 to line 3 .... ______
5. Enter the total area of the windows to be replaced .... ______
6. Multiply line 4 by line 5 .... ______
7. Multiply 0.1 by line 6 .... ______
8. Enter the heating plant efficiency (percent divided by 100) .... ______
9. Divide line 7 by line 8 .... ______
10. Enter the energy cost ($/million Btu) .... ______

YEARLY SAVINGS

11. Multiply line 9 by line 10 .... $ ______ /year

PROJECT COST

12. Enter the total cost of the window replacement including material, labor and design........ $ ______

SIMPLE PAYBACK

13. Divide line 12 by line 11 .... ______ years

WINDOW U-VALUE TABLE

Window System Type	U-Factor*
Single Glass	1.10
Single Glass with storm window	0.50
Single Glass, low E coating	0.91
Single Glass, low E coating with storm window	0.44
Insulating Glass (double glass)	0.55
Insulating Glass (double glass) with storm window	0.35
Insulating Glass (double glass), low E coating	0.38
Insulating Glass (double glass), low E coating with storm window	0.32
Insulating Glass (triple glass)	0.35
Insulating glass (triple glass) with storm window	0.25

* U-Factor values adapted from the 1985 ASHRAE Fundamentals Handbook.

MO 780-1383 (5-98) DNR/TAREOV 3.5 (5-98)

Fig. 2. Many excellent worksheets are available for calculating payback of replacement windows; this one is produced by the Missouri Department of Natural Resources. Results of payback calculations often reveal grossly overstated claims. Courtesy of the Missouri Department of Natural Resources.

vinyl and PVC, whose production is known to produce toxic by-products. So, while energy savings is green, the vehicle toward its achievement — in this case, replacement windows — is likely to be the antithesis of green.[3]

- Economic benefits. Restoration projects are nearly twice as labor-intensive as new construction, meaning more dollars spent go to people, not materials. This type of spending, in turn, has the beneficial effect of producing stronger, more dynamic local economies.[4]
- Ease of maintenance. "Maintenance-free" is a convenient marketing slogan; many replacement windows, in reality, cannot be maintained well or conserved. Vinyl, fiberglass, sealants, desiccants, and coating systems all degrade, and they are materials that remain difficult or impossible to recycle or conserve.[5]
- Long-term performance. While manufacturers' warranties have been lengthened in the past few years (they are now generally from 2 to 10 years), they still pale in comparison to the actual performance life exhibited in historic windows, which can reach 60 to 100 years and more, often with just minimal maintenance.

Clearly, sustainability takes into account more than just the cost of energy savings. It also promotes salient social, economic, and environmental benefits, along with craftsmanship, aesthetics, and the cultural significance of historic fabric. Still, the issue of energy savings is often used to justify replacement over restoration, but just how valid is this argument?

Energy Savings

If the foremost goal for replacing historic windows is energy savings, beware of "facts" presented: they very likely will be — intentionally or not — skewed, misinformed, or outright fallacious. Window manufacturers universally boast about low U-values (the measure of the rate of heat loss through a material or assembly; a U-value is the reciprocal of an R-value, which is the measure of resistance to heat gain or loss). For example, U-values are often misleadingly quoted as the value for the entire window unit, when in fact it is the value through the center of the glass (the location of the best U-value), not that of the sash nor the average of the entire unit.[6] To be sure that data are being presented appropriately, request the U-values published by the National Fenestration Rating Council (NFRC), which rate whole-window performance.[7]

When U-values are offered for the entire window assembly, they often are significantly worse (i.e., higher) due to infiltration around the frame and rough opening.[8] In cases where replacements tend to warp and bow over time (and they do), this factor becomes ever more crucial.[9] It is also important to watch for comparative analyses: some replacement-window manufacturers compare their window units to an "equivalent" single-pane aluminum window. Clearly, this is an inappropriate analogy since these types of windows are not likely to be found in a preservation context.

Infiltration of Outside Air

Infiltration of outside air — rather than heat lost through the glass — is the principal culprit affecting energy; it can account for as much as 50 percent of the total heat loss of a building.[10] When retrofit windows are installed over or within the existing window frame, the argument for preservation already exists: restoring the integrity of the fit between the frame and building wall should be the first component of a preservation approach.

Sash pockets, pulleys, and meeting rails are areas prone to air infiltration in double-hung units. Yet, several weatherproofing systems for existing windows can overcome these heat-sapping short circuits.[11] Replacement-window manufacturers themselves admit that even among replacements, double-hung units present the greatest challenges for controlling heat loss because infiltration occurs most frequently at sash-to-sash and sash-to-frame interfaces, which are highly dependent on the quality of the installation.[12] The energy efficiency of restored windows incorporating retrofit components (weatherstripping and weatherseals combining pile, brush, bulb, or "Z" spring seals) can meet and even exceed the efficiency of replacement units.[13] This approach is suggested as the first alternative among green-building advocates.[14]

Payback

Focusing on windows as the principal source of heat transfer may lead to the conclusion that windows are more important than, say, insulating the attic, foundation, or walls. While data vary somewhat, up to 25 percent of heat may be lost through doors and windows.[15] But when the aforementioned potential 50 percent loss through infiltration is taken into account, the total effective percentage of heat loss attributed to the window units themselves would be only 12.5 percent. That is a relatively small percentage for a potentially large investment, especially when other options are available.

In actuality, typical window-replacement systems offer payback periods that are often nowhere near manufacturers' claims: the payback of a typical unit could take as long as 100 years (Fig. 2).[16]

Heat Loss/Heat Gain

Heat loss is often discussed, but what about heat gain? In summer, heat gain can add significantly to the energy costs associated with cooling a building.[17] Long waveforms within the daylight spectrum that enter through the glass must be able to exit, or else they degrade to heat that then must be overcome by the building's cooling system.[18] Low-emittance ("low-e" or "soft low-e") glass handles this task best, improving thermal performance by virtually eliminating infrared (long-wave) radiation through the window.[19] It accomplishes this task by allowing short-wave radiation through and reflecting long-wave heat back to its source, while at the same time providing an appearance that is virtually clear.[20]

Low-e glazing can be substituted into existing units that are only single-glazed and still achieve important energy savings. Single-pane low-e glass can provide a virtually equivalent level of combined energy savings as a standard new double-glazed unit when used in concert with an existing single-paned sash (e.g., as a storm or interior sash).[21] Replacing panes of glass, then tightening up the sash and frame, is a very simple and cost-effective way to achieve the desired whole-assembly U-value without having to modify visible light, mullions, or sash weights.[22]

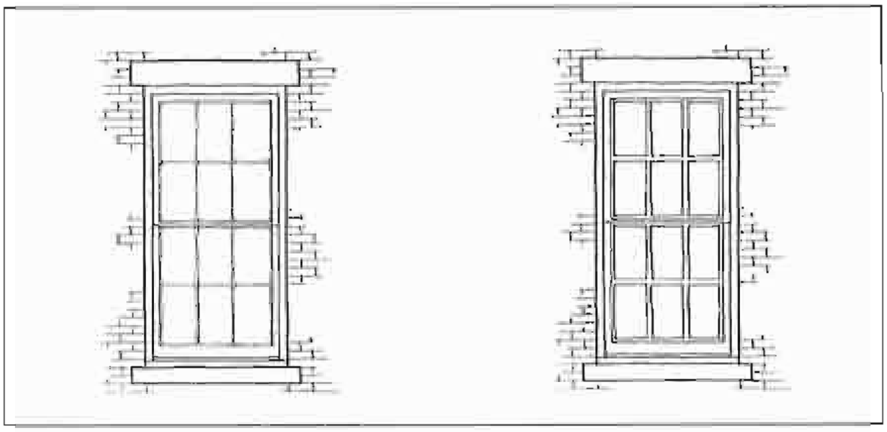

Fig. 3. At left is a drawing of a typical late-nineteenth- to early-twentieth-century six-over-six, double-hung window. At right is a modern "equivalent" replacement. The considerably thicker mullions and frame of the replacement unit (necessitated by the use of insulated glass) result in a nearly 15 percent reduction of visible light and views. Drawing by Walter Sedovic Architects.

Insulated Glass

Replacement windows nearly always incorporate insulated glass (IG) units. The effectiveness of an IG unit is greatly dependent on the depth of the airspace between inner and outer panes, as well as on the nature, type, and amount of desiccant and seals employed around the unit perimeter.[23] While manufacturing techniques for IG units have continued to improve, when IG units fail, they are difficult and time-consuming to replace.[24]

The additional weight and thickness of IG units preclude their use as retrofits in historic sashes of either wood or metal. Indeed, to compensate for their heft, virtually all IG replacement window mullions, sash, and frames are bulkier than their historic counterparts. The result is that visible daylight levels are reduced by 15 percent or more and views are interrupted.[25] Reducing daylight and negatively affecting views are explicitly not consistent with a sustainable approach (Fig. 3).

Laminated Glass as an Alternative

Laminated glass remains an often-overlooked alternative to IG units, perhaps because of the industry's focus on marketing it as "safety" glass. While laminated glass cannot compete with technologically advanced, complex IG units, it does offer enhanced U-values for monolithic glass without having to materially alter the mullions of the historic sash into which it is being fitted.[26] It is important to recognize, though, that a U-value is not the only criterion that determines the relative thermal efficiency of a window. Solar and light transmittance also affect performance, and they may be benefit when low-e laminated glass is selected.[27] The benefits of laminated glass, though, go much further when considered part of a comprehensive program to restore and thermally upgrade historic sash:

- Laminated glass offers significantly higher levels of noise abatement than IG.
- Historic glass may be laminated, offering energy and noise benefits while maintaining an authentic finish.
- Laminated glass is far easier and less expensive to procure and install and allows for field cutting.
- It offers superior safety and security features.
- Laminated glass may be equipped with low-e glazing to help offset heat gain.
- Historic sash, both metal and wood, can be outfitted with laminated glass without modifying or replacing mullions and frame elements (something that would be required by the installation of significantly thicker IG units).
- Condensation is reduced as a result of the internal thermal break of laminated glass.
- A variety of features (UV protection, polarization, translucency, etc.) can be incorporated as layers within laminated glass. Efforts to achieve the same results in IG units through the use of applied films (as opposed to an integral layer within the glass) has been shown to greatly reduce the life of double-glazed units by inhibiting the movement of their seals.[28]

Performance and Material Quality

A hallmark of sustainability is long-term performance. Intrinsic within that premise are issues about material quality, assembly, and conservability. As noted above, some material choices (e.g., PVC) incorporated into replacement-window units are inherently not able to be conserved.[29] When the material degrades, it then becomes necessary to replace the replacement.[30]

One of the great virtues of historic windows is the quality of the wood with which they were constructed. Historic windows incorporate both hardwoods and softwoods that were often harvested from unfertilized early-growth stock. Such wood has a denser, more naturally occurring grain structure than what is generally available today from second-growth stock or fertilized tree farms. Also, historically, greater concern was given to milling methods, such as quarter- or radial sawing. The resulting window performs with greater stability than its modern counterpart. This alone has far-reaching benefits, from minimizing dimensional change, to holding a paint coating, to securing mechanical fasteners.

No amount of today's staples, glue, finger-splices, and heat welds can match the performance of traditional joinery.[31] Similar comparisons could be made of the quality of hardware employed in replacement windows, such as spring-loaded balances and plastic locking hardware; they cannot compete with the lasting performance and durability of such historic elements as pulley systems and cast-metal hardware.

Ease of Maintenance

For cleaning windows, traditional single- and double-hung windows are often outfitted with interior sash stops that may be removed readily, allowing for full access to the interior and exterior, as well as to the pulley system. Both casement and pivot windows are inherently very easy to clean inside and out.

Replacement windows incorporating tilt-in sash — a feature that on its surface appears enticing — require that there is no interior stop, increasing the potential for air infiltration around the sash. Compressible jamb liners that allow for the tilt-in feature are often constructed of open-cell foams that, once they begin to degrade, lose both their compressibility and sash-to-frame infiltration buffer.

The ability to readily disassemble historic wood windows also allows for selectively restoring, upgrading, and adapting individual components of a window throughout its life. Most replacement-window systems cannot make that claim.

Aesthetics and Authenticity

Nuances in molding profiles, shadow, line, and color of windows, along with quality and appearance of the glass, contribute greatly to the overall building aesthetic and generally emulate the stylistic details of the building as a whole. Even what might seem like small changes in these elements can and does have a noticeable and usually detrimental effect on many historic facades. Outfitting historic buildings with modern replacement windows can and often does result in a mechanical, contrived, or uniformly sterile appearance. Worse, when historic windows are replaced, authenticity is lost forever.

Value and Cost

Repairs of historic windows should add to the value of the property, as an authentically restored automobile would command greater value than one "restored" with plastic replacement parts.

While there is a dearth of cost-comparative analyses between a replacement window and its restored, authentic counterpart, empirical knowledge based on field experience covering a wide variety of window types suggests that restoration is on a par, cost-wise, with a middle-of-the-road replacement. Corollary conclusions are that:

- cheap replacement windows will always exist to superficially counter the cost-basis argument for restoration; and
- high-quality equivalent replacement units have been shown in practice to cost as much as three times that of restoration.

Windows are a critical element of sustainability, but sustainability is not just about energy. It is about making environmentally responsible choices regarding historic windows that take into account the spectrum of associated costs and effects. The choice of whether to replace or restore requires embracing a more encompassing definition of sustainability. The answer is not as simplistic as some would have us believe.

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Traditional Building
Special Product Report

APRIL 9, 2009

The Right Thing

Do you replace or restore historic windows? What are the facts and myths in this most contentious of debates?

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By Walter Sedovic and Jill H. Gotthelf

In just the past few years, both sides in the debate over replacement vs. restoration of historic windows have been called upon to clarify their stance. For those advocates of restoration, there has been a virtual watershed of support, mostly in the form of states, historical commissions and preservation organizations across North America identifying historic wood windows as "endangered" elements.

The damage wrought by replacement windows is self-evident and increasingly pervasive. ***All photos: © Walter Sedovic Associates***

On the other side of the fence, and in response to this newfound "endangered" status, replacement window manufacturers have sought to develop standards that would demonstrate their products' effectiveness in a format that would – much like the FDA's nutrition labeling system – allow consumers to more readily compare apples to apples. At least one major manufacturer, Marvin Windows & Doors of Warroad, MN, has been reaching across the aisle to develop products that respond to the concerns of preservationists when replacement is appropriate. To their immense credit, it has even joined in arguing for retention and restoration of historic wood windows as a first option.

What has been gained by all of this activity? Despite this surge toward restoration, a generation (it has been 28 years since the first fully assembled replacement window system was introduced by Andersen Windows in 1980) of listening to the marketing mantra of "replace those old drafty windows" continues to run deep in our national psyche. The preservation community, armed with increasingly useful information, is now in the position of responding: "Go ahead. Replace those old drafty windows--with new drafty windows."

Indeed, much of the current outcry against wholesale choices toward replacement has to do with how poorly many replacement windows perform. Payback periods are not promoted, and, unlike historic windows that have been in service for 50, 75, 100 or more years, replacement windows are creating a costly cycle of replacing, over and over again.

Still working against preservation, however, is the dearth of useful facts that counter the assertion that old windows are inherently detrimental to the energy performance of a building. That notion is beginning to change; at present, people are considering the alternatives, and that alone is a huge leap in the right direction. In time, we will be armed with the facts and talking points that will facilitate a full-fledged movement toward restoration. And that is important on many levels: economic, environmental, educational and aesthetic.

This window replacement resulted in reduced visibility and daylight.

To help this movement along, we have assembled a list of talking points, backed by data currently available (and growing at an accelerating pace), that will help arm those in search of truth, balance and a desire simply to do the right thing.

1. Replacement window manufacturers have now all but abandoned the claims of "U" factors that were given for the glass, not the assembly. They now favor a standardized rating system offered through the independent National Fenestration Rating Council (NFRC), which measures whole window performance.

Misleading. While it is true that in response to the misuse of "U" values, the NFRC has been engaged in the testing and evaluation of whole window assemblies, what is not said is that every manufacturer has the option of discounting – and not revealing – two important markers: infiltration and condensation.

U-factor is the universal measure of heat gain or loss due to differences between inside and outside temperature, or the measure of how much heat may be conducted through a building element. It is the inverse of R-value, which measures a material's resistance to heat transfer. For U-values, lower numbers are better. A U-factor may refer to just the glass or glazing alone, but the NFRC's U-factor ratings are intended to represent the entire window performance, including frame and spacer material. Data requirements for the ratings have been relaxed, to permit the exclusion of condensation, air infiltration, visible transmittance (VT) and light-to-solar gain, the ratio between solar heat gain coefficient (SHGC) and VT.

Simply put, that means that a consumer may very well be purchasing a replacement window system that allows as much or more infiltration as their existing windows. While in the past, the argument favoring historic windows was largely based on anecdotal information, preservationists have tools already at their disposal to discount replacement window arguments: namely, standardized tests defined by the American Society for Testing & Materials (ASTM) that allow for both field and laboratory testing of infiltration. Employing these testing methods will clearly reveal the

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performance of existing windows and help put to rest claims that new windows perform better.

Also missing from the equation is visual transmittance (VT) and light-to-solar gain (LSG). LSG is important as a component of sustainable performance since glass and films used to receive low (i.e., positive) SHGC ratings often reduce the amount of visible light and therefore require a correspondingly increased use of artificial lighting. Clearly, consumers will benefit as more information is provided on labels, and despite efforts, we are not too much further along in understanding the performance of one window over another, and certainly not over the performance of an existing historic window assembly.

Windows are not the only elements maligned by inappropriate replacements.

2. Replacement window manufacturers offer the option of reusing existing frames and replacing just the sash, at a more economical cost.
Misleading. As stated above, it is the whole window assembly that determines the performance benefits. Infiltration through a window occurs in many locations, not just the sash. Reusing an existing frame that is not tight, within a wall system that leaks will produce the same effects that existed before the replacement window was installed. Any window system – new or old – must be part of a weather-tight system from the sash to the walls.

Further, several independent studies have shown that windows contribute only 10-12% of overall infiltration to the building envelope. Much more infiltration occurs at roof eaves, foundations and even through wall receptacles, dryer and plumbing vents and fireplaces. Concentrating funds to these elements has a much greater potential of providing a quick payoff than replacing windows. Replacing sash alone is not holistic, and very likely not economical. It is far better in the long run to replace or restore the entire window assembly.

3. Replacement windows are maintenance free.
No. As Michael Jackson, FAIA, chief architect of the Illinois Historic Preservation Agency pointed out in a recent presentation, "Embodied and Operating Energy: Balancing the Eco-Equation," "maintenance free" means it can't be repaired. This truism is critically important when deciding whether to replace or restore. Vinyl, fiberglass and aluminum windows – and insulated glass – are formed using materials and techniques that by and large are not conservable. Once they deform, fade, warp or fail in other ways, there is virtually nothing that can be done but turn to replacements--again.

4. Replacing historic wood windows with new wood windows is a fair trade-off.
Not likely. The quality of new wood from managed forests, tree farms and fertilized

stock is no match for that of early, natural-growth wood that comprises historic window frames and sash. "Wood density is a good predictor of economic value and strength of wood products, determined by the simultaneous increase in late-wood percentage and tree ring density. The short rotation and intensive treatments associated with industrial forestry prolong the growth of low quality juvenile wood, while postponing the growth of the stronger and more stable mature wood." This is according to a report published in May, 2007, by Robert A. Andrus for Willamette University, "How Tree Rings Reflect Wood Quality: Evidence from Industrial and Sustainably-Managed Stands."

Current wood-grading standards for density were developed during the period of old-growth forestry and may not be applicable to woods harvested from today's industrial forests.

Traditional storm window systems offer not only superior performance and energy efficiency, but can also be a graceful complement to the historic sash.

The bottom line is, new wood is not comparable to early wood. Beyond that, other factors that lead to windows of less desirable qualities include methods of milling, drying and joining woodwork; all of these affect durability and performance. Aesthetically, modern mullions – even when attempting to emulate historic profiles – can be exceedingly large, obscuring sight lines and reducing visible light. It remains an unfortunate reality that after much discussion regarding this topic throughout the preservation and sustainability communities, noted landmark commissions still cling to the idea that replacement windows are acceptable as long as they somewhat copy the superficial elements of their historic counterparts.

5. Installing storm windows will lead to condensation.
Quite possibly. In discussing storm window applications, the choice is often based on aesthetics, or ease of installation and maintenance, rather than on specific regional and environmental conditions. Properly fitted storm windows outfitted with laminated or low-e glass may help to offset the emergence or amount of condensation present, which forms when warmer, moisture-laden air comes into contact with colder glass surfaces. This effect may be mitigated by thoughtful design and selection, and even improved upon over time with alternate choices of weather-stripping systems and glass types.

6. Replacement windows are more energy efficient and are therefore sustainable.
Not true. If you're not already reconsidering replacement based on energy considerations alone, consider these other non-sustainable features of many replacement windows. A poorly performing window that requires replacement after just a few years means additional debris in our landfills, resources extracted for production and energy for manufacturing and transport, none of which is sustainable. Also, the materials that comprise many replacement windows – aluminum, vinyl and glass – are among the greediest in terms of energy consumption, resource depletion and inability to recycle. All leave a heavy environmental footprint.

Replacing sash while ignoring the primary sources of infiltration can have detrimental and costly results.

7. In order to be energy efficient, windows need to have argon-filled, low-e, insulated glass.
Not true. It's a fallacy to believe that there is a one-size-fits-all solution to proper window assembly. Environmental conditions, including orientation, play heavily into the choices offered for glazing. Laminated glass is an appropriate substitute for insulated glass and has many ancillary benefits. It can incorporate historic blown (wavy) glass, it can be field cut, it is safety glass, it is less expensive initially, it won't fail and fog when the desiccant seal fails, it may be outfitted with low-e glass, and it has excellent noise abatement characteristics. Plus, it can be installed in existing or new true-divided-light sash and won't require enormous mullions to support it.

8. Storm windows are cumbersome and high maintenance, requiring removal, storage and reinstallation each year.
Not true. Multiple manufacturers offer elegant wood storm windows that can be outfitted and custom designed for virtually all historic window configurations. They are available in a variety of styles – hinged; multi-paned with laminated, low-e and blown glass; and interchangeable screens – that work in concert visually and functionally with operable historic windows. They can be installed (and removed) from the interior or left in place if desired, without affecting the ability to open windows, and allow for natural ventilation throughout the year. Of course, they may also be removed and stored seasonally, if desired. They are a relatively inexpensive solution, with demonstrated superior energy-saving benefits that translate into short payback periods. Plus, storm window systems are reversible and easily upgraded.

A 2007 report by Keith Haberern, licensed architect and engineer and chairman of Collingswood (NJ) Historic District Commission, supports this statement. It shows that the payback time for adding a single-pane storm window to an existing single-pane window is 4¼ years. On the other hand, the payback time for replacing a single-pane window with insulated glass window is 41½ years, and for replacing a single-pane window and storm with a low-e insulated glass window, it's 222 years!

9. Replacement windows increase property value.
Highly dubious. Interestingly, this claim has surfaced with increasing regularity as the argument for payback has become universally disproved. Credible data regarding elevated or declining property values relative to window replacement installations have yet to appear. Arguably, as more becomes known about the shortcomings of many types of replacement systems, data will prove that retaining historic windows actually provides for more stable (or increased) property values; in fact, historic commissions already are advocating just that.

10. Replacement windows pay for themselves.
Nonsense. Replacement window manufacturers generally have backed off this once ubiquitous claim, simply because it's patently untrue. As discussed herein, varied studies have shown that far better payback periods are realized through restoration, careful glazing choices, the incorporation of well-designed storm window systems and

a healthy cynicism about unproven, off-handed claims. Facts and research are quickly putting this – the most blatant of them – to rest.

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Preservation How-To

Technical Preservation Services for Historic Buildings

National Park Service

Inside this Brief

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Technical Preservation Services (TPS), Heritage Preservation Services Division, National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments to a broad public.

The Repair of Historic Wooden Windows

John H. Myers

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 proceed 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 runoff, particularly 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 endgrain 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 section 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 reinstallation 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 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 weather-tight seal. After the proper curing times have elapsed for paint and putty, the sash will be ready for reinstallation.

While the sash are out of the frame, the condition of the wood in the jamb and sill can be evaluated. Repair and refinishing of the frame may proceed concurrently with repairs to the sash, taking advantage of the curing times for the paints and putty used on the sash. One of the most 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 process 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 semirigid epoxies which saturate the porous decayed wood and then harden. The surface of the consolidated wood can then be filled with a semirigid epoxy patching compound, sanded and painted (see figure 5). Epoxy patching compounds can be used to build up 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 other 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, TimeLife 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 wherever 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 contemporary weatherstripping should be considered an integral 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 accurate, they will usually be viewed as an acceptable contemporary 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 condensation problems must be addressed. Moisture which becomes trapped between the layers of glazing can condense 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 window may clearly indicate replacement. The decision process 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 appearance 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 profiles; 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 understanding of how the window reflects the period, style, or regional characteristics of the building, or represents technological development.

Armed with an awareness of the significance of the existing 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 windows. Continue looking until an acceptable replacement can be found. Check building supply firms, local woodworking mills, carpenters, preservation oriented magazines, 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 successfully 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 window added should thermally outperform a new double-glazed metal window which does not have thermal breaks (insulation between the inner and outer frames intended 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. According 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 replaced 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 element of a building's significance will have been preserved for the future.

Additional Reading

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Sash Window Clinic

Maintaining the Mechanics of Double-Hung Windows

By William T. Cox Jr.

Most old houses have scores of double-hung windows, and most windows are built to outlast the carpenters who installed themÑif they are properly maintained. Unfortunately, past generations sometimes cared little about the moving parts of a wood window. In fact, it's tough after, say, 75 years of painting to recognize the removable parts, especially those that are badly neglected. Yet, when a window gets painted shut or the sashes loosen up, when weights fall or cords fray, knowing how to dismantle the parts of a wood sash window is half the repair battle. Here's a refresher course in maintaining the mechanical parts of a typical double-hung window, one of the easiest and most satisfying operations in old-house upkeep.

The Perils of Paint
poor painting skills destroy windows. It takes little more than one sloppy coat of paint to bind a sash in place as strong as any glue. Windows should always be painted in an open position and moved often to keep the sashes free while the paint dries.

To unstick a window that is paint bound, start with a sharp utility knife and gently score the joints between the sashes and stops. Do the same between the bottom rail and stool (the indoor equivalent of the sill). Don't attempt to cut through the paint on the first try. If you dare, most likely the tip of the blade will skate across the face of the stop, leaving you with a gash to repair. Instead, make light passes at first (a cautious approach that has saved many pieces of trim). As you cut, try pushing against the bottom sash stiles several times with your hand to help break the bond. Avoid using a pry bar at this stage as pry marks are nearly impossible to remove.

You may have to go outdoors and cut between the bottom sash and parting stops. Or try this trick. Run a long, thin, flat piece of metal like a saw blade or metal strapping between the bottom sash stile and parting stop at the top and bottom sash meeting rails. Still unsuccessful? Then remove the inside stops by carefully prying these mouldings from their jambs (see next section). If the sash still stays put, soften the paint with stripper and try again.

Removing Stops and Sash
stops are built to be movable so you can pull the sash for service, as well as clean off overpaint. To remove stops without damaging the finish, first cut the paint at the joint with a utility knife. Then, get behind the stop on the channel side using nothing bigger than a 6 ÒtrimÓ pry bar to avoid pry marks. Starting at the middle, pry the stop away from the jamb a little at a time along its full length, prying at or near the nails that typically hold them in place. These mouldings become quite brittle over time and will splinter if moved out too far in one spot. Also, nails rust here more than anywhere else in a house

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and hold very tightly. If you're unable to move the stop, look for screws. Some stops are fastened to the jamb with flat-head slotted brass screws and cup washers.

As you work the stop free, gently bow it in the middle to release the ends. Note how they are built. Many stops are mitered at the top, but they may also slip into pockets that will split the wood if you muscle the stop out. I've also found stops reinstalled upside down. When you remove the first stop completely, mark an ÒRÓ or ÒLÓ on the back near the top. Remove the finish nails by pulling them through the wood with nippers.

There are so many sash-and-stop designs you may consider becoming a detective instead of a carpenter. Some sashes have a slot cut the full length of the stile, which holds a crimped piece of galvanized tin nailed to the channel. Pulling the top two nails should loosen the sash. (You may have to cut the rest of the nails to remove the metal strip in one piece.) Try using a 5 taping knife to get behind the metal weatherstripping. Or, if you resort to tearing the metal out, replace it with 11Ü4 spring bronze weatherstripping.

Parting Strips
with one stop removed, you should be able to cock the bottom sash out of the window frame so it dangles from two cords. Have your helper hold one side of the sash while you investigate how the cord is attached to the stile. The knotted end of the sash cord should sit in a pocket, perhaps secured with a nail. Before removing the cord, tie a slip knot near the pulley (or clamp the cord) to keep the weight from falling into the weight chamber, cord and all. If your windows are big enough to have chains, slip a nail through one of the links.

To remove a double-hung top sash, cut the paint between the top sash and the parting strip. The parting strip (or parting bead) is a standard millwork item; if it breaks, you can replace it at your local lumber yard. Pick a side, then start prying the parting strip out near the sill using a pair of locking pliers to gently loosen the wood. It may be secured with two or three 6d box nails. Remove the nails as you pry, working the strip free up to the top sash, but, don't try to remove it completely at this time.

Now, slide the top sash down as far as it will go. Don't worry if it binds. Work the parting strip loose from the header down. The parting strip should twist out of its gain (recess), freeing the top sash. For now you can leave the other strip in the jamb. Remove the sash cords the same way as described before, then scrape, glaze, and paint the two sashes as needed.

Weights and Cords
with stops and sashes removed, look for a small door sitting flush in the bottom of the sash channel. This door, usually secured with a single wood screw, will give you access to the weight pockets without having to remove the inside window trim. As you reach for the cords, note which weight goes with each sash. If you have, say, a six-over-two window pattern, the bottom sash may be the lighter of the two and will never stay down with the wrong weights tied to it.

Anytime the sash cord shows signs of wear or sloppy painting (which makes the fibers brittle), replace it with the best product you can find. True sash cord is braided cotton surrounding a cotton inner core. I've seen people use clothesline but it doesn't last. (Sunlight and heat destroy the plastic coating, making quite a mess.) Check the oldest hardware store in your town; they should sell sash cord by the foot or fifty foot coils and in sizes for the weights of residential windowsÑusually No. 7 (5 lbs. to 12 lbs.) or No .8 (12 lbs. to 20 lbs.). Cut the new cord to the length of the old cord. If the cord is gone, measure from the knot pocket on the sash stile to the top rail, and from the window header to the sill. Adding these two measurements will approximate the length for the sash cord.

Feed the cord back over the pulleys, then tie an appropriate knot to hold the weightÑusually either an overhand knot (for recessed holes) or a bowline or Òsash knotÓ (for standard holes). If need be, you can use a snake (a string tied to a small weight) to get to the bottom of the weight chamber. Don't tie the weights so they bottom out on the sill or bind at the pulleys when the sash is moved from header to sill. After you've scraped the sashes and stops free of paint build-up, reinstall the parts in reverse order. Some folks lightly wax the sash channels at this point with paraffin or bee's wax, but never use soap (it tends to stain). With sash in place, nail or screw the inside stops snug to the bottom sash, then slide the sash up to the header and secure the stops snug there, too. Check the stops again in a few months; seasonal humidity swings will affect stop-to-sash clearance. Last, slide your sashes up and down a few times to satisfy yourself that everything is in effortless working order.

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Landmark Preservation Documentation

Design Review Submittal Checklist: Window Replacement

12.17.10

Applications submitted for design review must be accompanied with a variety of materials which adequately describe the proposal. Filing deadline for the LPC is Tuesday, three weeks prior to scheduled meeting, a full documentation set are due in the Landmarks office by 9:00 A.M. If staff clears the submitted documentation, then it is the applicant's responsibility to produce 15 full packets of the documentation for distribution to the commission. Occasionally commission review is not necessary for projects that comply with the *Revised Municipal Code of the City and County of Denver, Colorado; Chapter 30 Landmark Preservation, Secretary of the Interior's Standards for Rehabilitation, Design Guidelines for Landmark Structures and Districts* (1995). Staff will contact applicants as to their review evaluation.

The commission requires that there is demonstrated need to replace original windows. Demonstrated need is shown in the form of a window assessment as outlined in National Park Service Preservation Briefs #9, *The Repair of Historic Wooden Windows*. The assessment needs to correspond to photos of the windows to be replaced and a floor plan showing the location of those particular windows. Staff also needs documentation on the proposed replacement windows. It is **highly** recommended that an owner discuss window replacement with a staff member prior to submitting documentation.

The following Is REQUIRED:

- ❑ **1.** Complete Application for Design Review
- ❑ **2.** Complete window assessment
  Each assessment must include:
  1. Description of each existing window including type, material, and size
  2. Detailed assessment of frame and sash condition and ability to function
  3. Recommended treatment for each window
     a. If replacement: written explanation of why repair and/or weatherizing will not work
  4. Assessed window should be numbered to correspond to the floor plan and photos
- ❑ **3.** Documentation on the proposed replacement windows
  1. Window type and material
  2. Graphic comparison of size of existing window and size of replacement window
  3. Product literature or cut-sheet on window brand
- ❑ **4.** Floor Plan drawn to scale. The floor plan must include the following:
  - Address, Scale, North Arrow, floor
  - Notation of windows to be replaced corresponding to the assessment
- ❑ **5.** Color photos of existing windows to be replaced
  All Photographs must be:
  1. Labeled to correspond with the floor plan and the assessment
  2. In color, no smaller than 4"x6"
  3. Each photo should contain only one window
  4. Submitted via hard copy, digital format (e-mailed to staff) and/or on a CD

*Please note: Work In Country Club Historic District must first be reviewed by the Country Club design review subcommittee.

The drawings should all be on the same size sheets of paper (none larger than 11"x 17"). Each sheet should be labeled with the title, page number, address, date, and name of preparer (person or firm). Examples of drawing standards are available from LPC staff. Documentation must be scaled so that the dimension on any part of the plan can be ascertained. The title and scale of each drawing must be clearly identified. Clear notation of materials should also be shown. Submitted drawings become part of the permanent record of the City and County of Denver for the subject property.

201 W. Colfax Ave., Dept. 205
Denver, CO 80202
720.865.2709 or landmark@denvergov.org

							Frame						Sash					Functions				
Room Number	Window Number	Description and/or notes	Orientation (Face of bldg)	Operation (DH,SH,C,H,F,O,D)	Material (S,W,A,O)	Operation Impaired (Y,N)	Sill	Jambs	Exterior trim & stops	Stool	Interior trim & stops	Interior wall surfaces	Lowest rail	Other rails & stiles	Muntins and mullions	Meeting Rails (DH,SH only)	Glazing putty & gaskets	Operators & handles	Movement Mechanics	Locks	"Square"	Weatherstripping

Name: ______________________ Address: ______________________________________

							Frame						Sash					Functions				
Room Number	Window Number	Description and/or notes	Orientation (Face of bldg)	Operation (DH,SH,C,H,F,O,D)	Material (S,W,A,O)	Operation Impaired (Y,N)	Sill	Jambs	Exterior trim & stops	Stool	Interior trim & stops	Interior wall surfaces	Lowest rail	Other rails & stiles	Muntins and mullions	Meeting Rails (DH,SH only)	Glazing putty & gaskets	Operators & handles	Movement Mechanics	Locks	"Square"	Weatherstripping

KEY

CONDITION

0	Excellent
1	Maintenance required
2	Unstable
3	Advanced deterioration
NA	Not Applicable

MATERIAL

S	Steel
W	Wood
A	Aluminum
O	Other

OPERATION

DH	Double Hung
SH	Single Hung
C	Casement
H	Hopper
F	Fixed
D	Decorative
O	Other

City of Boulder Panning and Development Services

WINDOW AND DOOR REPLACEMENT APPLICATION

Windows and doors are very often character-defining features of a historic building, therefore applicants are encouraged to repair rather than replace historic windows and doors. However, if the condition of the feature is determined to be deteriorated beyond repair, it is important that the replacement feature is compatible with the style and character of the building.

A Landmark Alteration Certificate is required for the replacement of historic windows and doors on buildings located in a historic district and for individual landmarks. Review by the Landmarks Design Review Committee is required for window and door replacement and the project may be referred to the full Landmarks Board for review if the committee considers the replacement is inconsistent with the guidelines and may be to the detriment of the property and/or the historic district. The condition and location of the windows or doors proposed for replacement must first be identified before submitting the replacement product information. Part I will be reviewed by staff and may be reviewed by the LDRC; if window(s) and/or door(s) are appropriate candidates for replacement, a second application must then be submitted identifying the proposed replacement windows or doors. The complete application will then be reviewed by the LDRC and may be referred to the full Landmarks Board for review. For more information about windows and doors on landmarked buildings and in historic districts and the process for assessing their historic significance, please consult sections 3.7 and 3.8 of the *General Design Guidelines for Boulder's Historic Districts and Individual Landmarks* available on line at: http://www.bouldercolorado.gov/files/PDS/historicpres/pdfs/draftgenguidelines.pdf or by calling 303.441.1880.

Part I: Identify existing location and condition of window(s) or door(s) proposed for replacement. The following materials are required as Part I of this application; see below for more information.

☐ Completed Landmark Alteration Certificate Application.
Available through the Planning Department, 1739 Broadway or online at boulderhistoricpreservation.net

☐ Context photograph of the subject building, with labeled location of each windows or doors proposed for replacement.
Photograph(s) of the building as viewed from public right-of-ways; if the building is located on a corner or is visible from an alley, multiple photographs should be taken. Windows or doors proposed for replacement should be labeled as "A1, A2, B1, B2…" depending on the location and number of the windows. A= primary elevation (if the building is located on a corner, two elevations may be considered primary), B= secondary (side) elevation, C= tertiary (typically the rear) elevation. If only one window or door is proposed for replacement, the photograph may simply be labeled 'door' or 'window'.

☐ Photographs of each window or door proposed for replacement, showing the condition of the window or door.
A minimum of three photographs of each window or door proposed for replacement is required as follows:

1. A photograph of the window or door from the exterior, showing the molding or other decorative features surrounding the window or door.
2. Close-up photograph of the window or door from the exterior,

showing the condition of the frame, sash, pane(s), and muntins (if applicable).
3. Close-up photograph of the window or door from the interior, showing the condition of the frame, sash, pane(s), and muntins (if applicable).

☐ A short description of the condition of each window or door proposed for replacement.
A written description for each window or door proposed for replacement should include the following:
1. Description of the location of the window (e.g. "Window A1 is located on the second story on the north side of the house, which faces Dewey Avenue")
2. The type of window or door (i.e. screen door, multi-paneled door, French door, or double-hung, leaded glass, divided-light, casement, hopper, or transom window) as well as the materiality (i.e. wood, aluminum, glass) and operation of the window, if applicable (i.e. double-hung vs. casement window).
Description of the condition of the window or door, including the operability and condition of the frame, sash, sill, pane(s), muntins (if applicable) and casing condition (i.e. "Window A1 is a wooden, 4-over-1 double-hung window. The sash and sill are in a deteriorated state; the wood has rotted and there is an 1/8" gap when the window is fully closed. The muntins and pane are intact. Overall, the window is difficult to operate.")

Please submit a completed Landmark Alteration Certificate application and required information to a historic preservation planner for review. The project will be reviewed within 14 days, and if the proposed replacement of windows or doors is determined to be appropriate, Part II of the application shall be submitted and reviewed within 14 days by the design review committee and may be referred to the full Landmarks Board.

Part II: Comparison of Existing Window(s) or Door(s) and Proposed Window(s) or Door(s). The following materials are required for Part II of this application:

☐ Completed Landmark Alteration Certificate Application

☐ Completed Part I of this application

☐ Information regarding the proposed window(s) or door(s)
Windows and doors are character-defining features of a historic building, therefore applicants are encouraged to repair rather than replace historic windows and doors. However, if the condition of the feature is determined to be deteriorated beyond repair, it is important that the replacement feature is compatible with the historic windows and the historic character of the building. Detailed photographs or drawings, including dimensions, or a spec sheet is required for review of the proposed replacement window or door.

☐ Completed 'Window or Door Replacement Application-Existing and Proposed Comparison' form.
The attached form allows a side-by-side comparison of the existing and proposed window or door. It is important that following characteristics are maintained:
1) the pattern and size of the openings
2) proportions of the frame and sash;

3) configuration of window panes;
4) muntin profiles;
5) type of wood;
6) paint color;
7) characteristics of the glass
8) associated details such as arched tops, hoods, or other decorative elements.

The National Park Service Preservation Brief 9: The Repair of Historic Wooden Windows offers further guidance on repairing or choosing replacement windows. This brief is available at www.nps.gov.

For more information on the appropriateness of window and door replacement, please refer to the General Design Guidelines, available online at: http://www.bouldercolorado.gov/files/PDS/historicpres/pdfs/draftgenguidelines.pdf or through the Long Range Planning office 303.441.1881.

SAN FRANCISCO
PLANNING
DEPARTMENT

Standards for **Window Replacement**

A GUIDE TO APPLYING FOR
A WINDOW REPLACEMENT PERMIT

SAN FRANCISCO PLANNING DEPARTMENT | APRIL 2019

ORGANIZATION

This document is divided into two sections:

Frequently Asked Questions Regarding Window Replacement

How to Apply for a Window Replacement Permit

Windows are an integral part of the design and character of most buildings, and choosing appropriate replacement windows is frequently a critical aspect of any rehabilitation project. Along with the need for energy conservation, the various window systems available today can overwhelm an owner in selecting the appropriate treatment for window re-placement. Windows located on primary – the front or visible elevations – traditionally feature a higher degree of detail and ornamentation than windows located on secondary – the side or rear elevations. With such a variety of different window shapes, muntin profiles, methods of operation and configu-rations, seemingly minor changes can seriously damage or alter the appearance of a building, or overall neighborhood character. The Planning Department recognizes this challenge and has developed A Guide to Apply for a *Window Replacement Permit*, which also includes a list of frequently asked questions.

The San Francisco General Plan, the Planning Code's Priority Planning Policies and the Residential Design Guidelines each call for protecting and enhancing neighborhood architectural character citywide. Since their revision in 2003, the Residential Design Guidelines set window requirements for all buildings within a Residential Zoning District (Page 46). To clarify the Department's policy and serve as an additional guide to answer frequently asked questions in regard to window replacement and neighborhood character, the Department developed this *Window Replacement Standards* handout. This document also answers questions regarding what materials are required to be submitted to review a permit application for the repair, rehabilitation, restoration, or replacement of windows in San Francisco. Please note that rehabilitation and alteration standards for the preservation of designated City Landmark properties, including contributing buildings in historic or conservation districts, are contained in Articles 10 and 11 of the Planning Code.

This document hereinafter represents the San Francisco Planning Department's policy in regards to this type of work and is based on the following principles:

1. Windows that are seen from the street or other public right-of-ways are an important part of neighborhood character as well as the individual architectural character of a building.

2. If replacement windows are proposed for any type of structure, the new windows visible from the public rights-of-way should be compatible with both the character of the neighborhood and the subject building in terms of size, glazing, operation, finish, exterior profiles and arrange-ment.

3. Historic windows and character-defining window features on architecturally significant structures should be retained and repaired wherever possible.

REMINDER:
Do not purchase replacement windows before confirming with the Planning Department that the windows can be approved. The Planning Department will not approve inappropriate replacement windows, even if they have already been purchased or installed.

Frequently Asked Questions Regarding Window Replacement

The information listed below can assist an owner in determining what replacement windows are appropriate for their property. If replacement is necessary, thoroughly document and investigate the structural and architectural detailing of the window and seek appropriate professional consultation. At any time, a Planner located at the Planning Information Center (PIC) can answer questions regarding window replacement. The PIC may also be reached by phone at 415-558-6377. For more information, please also review the How to Apply for a Window Replacement Permit Handout & Checklist.

? DO I NEED A BUILDING PERMIT TO REPLACE WINDOWS?

ALL replacement windows that are visible from a street or other public right-of-way require Planning Department review. This includes:

- Windows on the primary elevation (commonly the street façade of the building). Please note that corner buildings are considered to have two primary elevations.
- Windows on the side of a building or in a visible recessed area near or next to the street.
- Windows on a back wall that can be seen from the street or another public right-of-way.

? CAN I REPLACE HISTORIC WINDOWS WITH VINYL, FIBERGLASS, OR ALUMINUM WINDOWS? CAN'T I GET VINYL OR ALUMINUM WINDOWS THAT LOOK VIRTUALLY THE SAME FROM THE STREET AS WOOD PAINTED WINDOWS?

Wood windows were originally installed on the majority of residential buildings constructed up until World War II. In San Francisco, where most buildings are viewed at close range from the street, the differences between wood windows and substitute materials are almost always easily detectable. Particularly with older buildings, these alternate materials usually stand out visually, and rarely match the character of the neighborhood. They always look like what they are: plastic or aluminum – materials that are not architecturally compatible with the building.

Vinyl, fiberglass, and aluminum windows almost never look similar to painted wood windows for a number of reasons. The primary reason is that these windows have a flat appearance and their exterior profiles, depth, and dimensions are not designed to match the dimensions of most common wood window sashes and moldings. In addition, windows of substitute materials have very little or no reveal between the face of the sash and the glass, have visible seams, have multi-faceted tracks, and in some windows the upper sash is often larger than the lower sash. Furthermore, most aluminum or vinyl windows cannot be painted, come in limited colors, and have an overall finish that is inappropriate to the overall character of the building and the neighborhood.

Another significant difference is that vinyl, fiberglass, and aluminum windows often do not have an important detail that is common on most older wood windows: the Ogee (*pronounced Oh-jee*) lugs at the bottom of the top sash (also called the meeting rail) of a double-hung window. These details are considered an important character-defining feature of older wood windows. (Please refer to the parts of a window diagram on page 8 for more information on the location and design of ogee lugs).

However, some manufacturers have recently begun producing better quality aluminum windows that come in a variety of colors and profiles. From a distance these windows can appear similar to wood painted windows. If proposed, these windows will be evaluated on a case-by-case basis.

Need another reason? Authentic wood windows (or, in the case of some early 20th century buildings, steel casement windows) add the appearance of warmth and beauty to the interior and exterior of a residential or commercial building, where the appearance of alternative materials commonly appears foreign to the interior architectural design. Using architecturally appropriate windows will enhance the property value of your building by improving its appearance inside and out.

Take a look around

If you have any doubts about the difference in appearance between vinyl, fiberglass, or aluminum, and painted wood windows, take a walk around your neighborhood and notice the buildings that have wood windows and compare them to the ones that have used substitute materials (many of them installed without benefit of a permit or before the current window replacement standards). You will easily notice differences in the profile and depth of the window. The older and more elaborate the architectural style of the building, the more likely new vinyl, fiberglass, or aluminum windows will look out of place.

REMINDER:
If you are required to use wood windows on the visible elevations you are often able to use replacement windows of a substitute material in light wells or rear facades that are not visible from the street or other public rights-of-way.

DON'T WOOD WINDOWS COST MORE AND REQUIRE MORE MAINTENANCE, AS OPPOSED TO VINYL AND ALUMINUM WINDOWS?

It depends. The highest quality custom-made wood windows by major manufacturers may be more expensive than windows of other materials. But there are a number of manufacturers and local craftsmen that produce quality, double-paned, architectural grade, painted wood replacement windows that are competitive in price and also provide the beauty and authenticity that only comes with real painted wood sashes and assemblies.

Also, while it is often desirable to have all wood replacement windows in your building or house, in many cases, you may choose to use replacement windows of a substitute material in light wells or rear facades that are not visible from the street or other public right-of-ways. The only instance when a property owner may be required to use historically appropriate windows on all elevations is when the subject property has been determined to have historic significance. Examples of these properties are those identified as part of Article 10 or 11 of the Planning Code or as an eligible historic resource for the purposes of the California Environmental Quality Act (CEQA).

In terms of maintenance, wood windows do require painting every five to ten years, depending on their location, sun exposure, water exposure, paint quality, priming, wood quality, etc. Although vinyl and aluminum windows do not require painting, they are rarely maintenance free, and economy grade vinyl and aluminum windows can fail within a few years. Finishes on vinyl and aluminum can deteriorate through UV exposure, oxidation, and denting. Quality wood windows can last *indefinitely*, depending on maintenance and the quality of wood used. Double-hung painted wood windows can also be installed with metal or vinyl tracks, making them easier to open and close as they age.

WHAT ABOUT WOOD WINDOWS THAT HAVE VINYL, FIBERGLASS, OR ALUMINUM CLAD EXTERIORS?

For clarification, a clad window is part of a window system that is primarily constructed of wood but has an additional material, such as aluminum, applied to the exterior face for maintenance purposes. Generally, clad windows are not appropriate, especially on older residential and commercial properties. However, in some instances they may be acceptable, and if proposed, shall be reviewed on a case-by-case basis. Most clad window products do not have Ogee lugs, which are an important feature of older double-hung wood windows. In addition, a true divided light option is not offered for clad windows by any manufacturer. Another issue with vinyl-clad window systems is that they often show seams, as some of these windows are clad with vinyl strips on the outer surface. Aluminum and fiberglass finishes can come in a variety of colors and often have a finish that more closely resembles a painted surface.

There are a number of windows constructed of substitute materials on the market today that strive to match the styles and profiles of historic windows. The Planning Department is always open to reviewing any new products for compatibility with older properties. A quick way to get a initial feedback on a new product is to bring the manufacturer's specification sheet to the PIC for a planner to review. In some cases, the Planning Department may consider approving clad replacement windows that are visible from the street or other public rights-of-way if their architectural compatibility can be adequately demonstrated in terms of overall, size, glazing, operation, finish, exterior profiles, and arrangement.

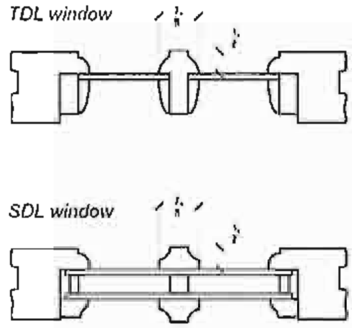
SOME INFORMATION REGARDING SIMULATED DIVIDED LITE (SDL) WINDOWS.

Older windows are often made up of two sashes that include smaller panes of glass. These windows are referred to as "divided-lite windows." The panes of glass are separated by thin wood members, or moldings referred to as a "muntin." A true divided-lite (TDL) window is defined when the muntin separates individual panes of glass. Most TDL windows are single-paned; however, a simulated divided-lite (SDL) window often contains an insulated unit of glass with an applied exterior grid that mimics the appearance of a divided-lite window. The majority of simulated divided-lite windows do not accurately reflect the depth and the profile of a true divided-lite window.

If a property owner chooses to use an SDL window to replace a window that has true divided lites, then the replacement window must meet all of the following criteria to be considered for Planning Department approval. Please note that the Planning Department has the discretion to prohibit the use of SDL windows when the existing windows to be replaced are determined to be architecturally unique or considered to be an example of outstanding craftsmanship. In these cases, the Planning Department may ask for the existing windows to be repaired rather than replaced.

Criteria for using SDL windows in place of TDL windows:

- The SDL must match the existing window muntin in profile and depth to the greatest extent possible. This width may vary; however, the most common width for a TDL window muntin is 7/8" including glazing putty on either side of the division. The SDL muntin must have a depth of at least ½".
- There should be an interior space bar, preferably of a dark color, within the insulated unit that visually divides the interior and exterior grilles.
- The SDL should be integral to the window sash – snap on grilles or grilles placed between an insulated glass unit are not permitted.



The differences between a true divided-lite (TDL) window and a simulated divided-light (SDL) window can be seen in the illustrations at left. The muntin on the TDL window (top image) separates two individual panes of glass while the muntin on the SDL window (bottom image) is applied to the interior and exterior of the window without piercing the insulated glass unit.

REMINDER:

Simulated divided lite windows will not be approved for individually listed City Landmarks in Article 10 of the Planning Code on ANY elevation visible from a public right-of-way. Simulated divided lite windows will be reviewed on a case-by-case basis for *contributors* within Article 10 Districts or within and Article 11 Conservative District.

WHY SHOULD I LOOK INTO REPAIRING MY WINDOWS BEFORE REPLACING THEM?

Deterioration of poorly maintained windows usually begins on horizontal surfaces and at joints, where water can collect and saturate the wood. Wood windows, when repaired and properly maintained, will have an extended life while contributing to the architectural character of the building and the neighborhood. Property owners should conduct regular maintenance of window frames and sashes to achieve the longest life possible.

It's important to note that many wood windows constructed during the late 19th- and early 20th-centuries still perform very well and may not require replacement. This is largely due to the fact that these windows were constructed out of Heartwood or the center of tree. This durable old-growth wood is denser and more resistant to fungi, insects, and rot than wood farmed to manufacture windows today. For this reason always explore the possibility of repairing the historic windows on a building before replacing them. There are a number of professional window replacement companies who can help you determine if your windows can be repaired, or if some or all need to be replaced.

Be sure to evaluate ALL of the existing windows or hire a professional to conduct a conditions assessment to avoid spending money on windows that don't need replacement. It may be that only certain windows on your building need replacement, while some may only need repairs or other minor refurbishments, thus significantly reducing costs. One solution for replacing deteriorated windows on visible elevations is to consolidate other windows from the rear and sides of the building that are still in good condition and relocate them to the primary façade.

ENERGY CONSERVATION & SUSTAINABLILTY.

Windows don't always require replacement in order to see and feel big results in reducing energy usage; however, energy conservation and sustainability is one of the primary reasons for replacing windows that are considered to be obsolete, particularly replacing single-glazed sashes with double-glazed sashes. Currently, most manufacturers' warranties for replacement windows are from 2 to 10 years; however, historic wood windows with minimal maintenance have a performance life of 60 to 100 years. Retaining and repairing existing windows also conserves embodied energy (i.e. the sum of the energy required to extract raw materials, manufacture, transport, and install building products). Replacement window materials – primarily aluminum, vinyl, and glass possess some of the highest levels of embodied energy of all building materials.[1]

Older windows are renewable and repairable; however, newer thermal windows are not repairable and once the dual glazing seals are broken, they must be totally replaced. While the advantages of double-paned windows are well known, a prop-erly weather-stripped, single-glazed sash window can greatly reduce or eliminate air, noise and air infiltration (where most energy is lost). The cost of weather stripping is nominal when compared to the price of replacement windows.

The California Office of Historic Preservation (OHP) administers the 20% Federal Rehabilitation Tax Credit for California in partnership with the National Park Service pursuant to federal regulations (36 CFR Part 67). This federal program provides a dollar-for-dollar income tax reduction credit equal to 20% of qualified rehabilitation expenditures on income producing properties that are certified historic structures. For more information regarding this program, please contact the OHP at 916-653-6624.

The Mills Act is designed to provide owners of both owner-occupied and income-producing property the opportunity to rehabilitate, restore, preserve and maintain "qualified historical properties" while receiving property tax relief. The Mills Act provides for a potential 50 percent reduction in property taxes on "qualified historical properties" in exchange for the owner's agreement to maintain and preserve the resource in accordance with standards established by the Secretary of the Interior's Standards for the Treatment of Historic Properties. For more information on the Mills Act in San Francisco, please refer to San Francisco Planning Department Preservation Bulletin No. 8.

MY WINDOWS ARE BEYOND REPAIR AND NEED TO BE REPLACED. WHAT TYPE OF WINDOW IS ACCEPTABLE FOR MY PROPERTY?

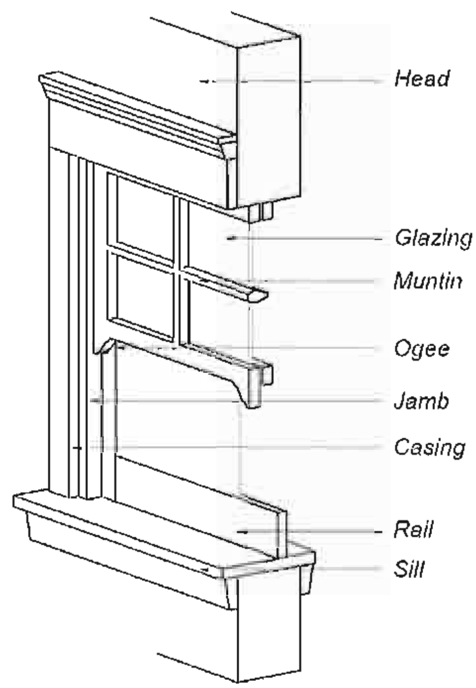
If replacement windows are required due to deterioration, those that are visible from the street or other public rights-of-way should be replaced with windows that are appropriate to the time period your building was originally constructed. For example, if the building was originally constructed in 1908 with wood double-hung windows, then they should be replaced with wood double-hung windows with similar exterior dimensions. If the appropriate window type cannot be determined, then a window that is otherwise architecturally appropriate to the building and surrounding neighborhood character, in terms of style, material, visual quality, and detailing can be considered. For example, if the building was originally constructed in 1925 and currently has vinyl sliding windows but similar neighboring buildings from the same time period have their original steel casement windows, then the appropriate replacement window would be a metal casement window.

WHAT IS THE IMPORTANCE OF BRICK MOLDS AND OTHER EXTERIOR MILLWORK?

A brick mold is the exterior molding often used to trim the edge of windows in a masonry opening. On a wood frame building this window detail is referred to as millwork. A common practice when installing replacement windows is to replace only the sashes and cover the trim and framework around the exterior of the window with capping or panning to give the window a cleaner, "updated" look. This panning, whether vinyl, fiberglass, or aluminum, is used to cover over brick molds and other exterior millwork that frame the opening and makes up part of the exterior profile of the windows. The Planning Department will not approve replacement windows where those elements are covered or obscured from view. Wherever possible, all surrounding millwork or brick molds should be retained and left exposed. When replacement is required due to deterioration or missing elements, these elements should be replaced in the original material, and a profile of the existing and proposed millwork should be included as part of the permit application drawings for review by Planning Department staff.

Mixing Window Types

Mixing window types and materials creates an inconsistent appearance to a building's facades. This issue becomes particularly important in dealing with condominium and apartment buildings. In general, the Planning Department will not approve partial window replacement for a building unless the replacement windows are meant to restore the windows to their historic configuration.



The axonometric drawing of a wood window above identifies the parts of a window system that most owners should be familiar with when applying for a window replacement permit.

WHO ARE SOME WINDOW MANUFACTURERS THAT SPECIALIZE IN HISTORIC OR OTHER ARCHITECTURAL GRADE REPLACEMENT WINDOWS?

As a city agency, the Planning Department cannot recommend the use of one manufacturer over another; however, a list of some commonly used window manufacturers or representatives can be obtained from the Planning Information Center (PIC) on the first-floor of 1660 Mission Street. The PIC may also be reached by phone at 415-558-6377.

If your building is protected under Article 10 or 11 of the Planning Code or is deemed an eligible historic resource, please contact the PIC for a list of the organizations that may help you find a product or manufacturer that best suits your needs.

WHAT SHOULD I DO FIRST IF I NEED TO REPLACE MY WINDOWS?

If replacement is necessary, thoroughly document and investigate the structural and architectural detailing of the window and seek appropriate professional consultation. Please refer to the following questions every applicant should review before applying for a permit to replace windows. At any time, a Planner located at the Planning Information Center (PIC) can answer additional questions regarding these standards and window replacement. The PIC may also be reached by phone at 415-558-6377.

APPLYING FOR A WINDOW REPLACEMENT PERMIT.

When applying for a window replacement permit, please bring as many of the applicable items on the How to Apply for a Window Replacement Permit as possible in order to ensure the most efficient review possible. There are a number of basic questions that a property-owner can answer when examining the windows proposed for window replacement.

MANY OF THE BUILDINGS IN MY NEIGHBORHOOD ALREADY HAVE VINYL, ALUMINUM, OR FIBERGLASS WINDOWS. WHY CAN'T I HAVE SIMILAR WINDOWS APPROVED FOR MY BUILDING?

There may be a number of reasons why a Planner may not approve vinyl, aluminum, or fiberglass windows for your building. The most common reason is that the windows in your own building and in adjacent buildings may have been installed before the revision of the Residential Design Guidelines in 2003 and the preparation of this document, Window Replacement Standards, August 2008. As the Planning Department strives to promote and enhance neighborhood character citywide, the Department acknowledges that windows may be inconsistent with the architectural features and the original design intent of older structures. In addition, it is possible that the

- **What is the pattern of window openings and their size?**
  (Irregular, Regular)
- **What are the proportions of the frame and the type of sash operation?**
  (Double-Hung, Casement, Pivot, Slide, Hopper)
- **What is the configuration of the windowpanes?**
  (2-over-2, 4-over-1, 6-over-6)
- **What (if any) are the muntin profiles?**
  (Shallow, Deep, Simple, Ornate)
- **What is the material?**
  (Wood, Steel, Vinyl, Aluminum, Fiberglass)
- **What are the characteristics of the glass?**
  (Decorative, Wavy, Clear, Opaque, Translucent, Leaded)
- **Are there any associated details?**
  (Decorative millwork, Brick Molds, Arched Tops, Window Surrounds or Hoods)

windows installed on adjacent buildings were done without the benefit of a permit or contrary to the scope of work outlined in the building permit.

THE PLANNER SAID THAT I HAVE TO REPLACE MY WINDOWS "IN-KIND." WHAT DOES THAT MEAN?

If a Planner has stated that you should replace your windows "in-kind" this means that a wood double-hung window should be replaced with a wood double-hung window or a metal casement window should be replaced with a metal casement window. All details must match, including muntin profiles and exterior millwork. Please note that replacing a double-hung wood window with a double-hung vinyl window is not "in-kind" replacement.

HOW LONG WILL IT TAKE THE PLANNING DEPARTMENT TO REVIEW MY PERMIT?

- If windows are being replaced in-kind or on non-visible elevations and all the required materials for review are submitted, an over-the-counter approval can be issued at the Planning Information Center.
- If the windows are visible from the street and the new windows are consistent with the building's historic window type or compatible with the building and neighborhood character, planning approval will be over-the-counter at the Planning Information Center. Please note that in some instances window replacement on an Article 10 or Article 11 property must be approved by the Historic Preservation Commission or the Zoning Administrator.
- If installing a new window on a portion of the building that is visible from the street is desired, and the plans and photos are adequate, a planner will determine right away if the permit can be approved, or if it will require further design review.

In some situations such as window replacement on a historic building, further review may be required. The window replacement permit application will be reviewed at the Planning Information Center and may be referred upstairs to a Preservation Technical Specialist for review.

How to Apply for a Window Replacement Permit

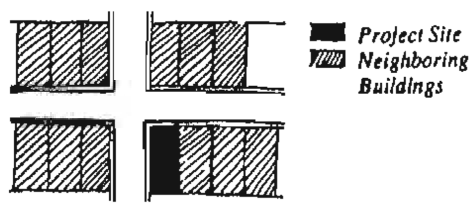
The Planning Department reviews each window permit application on a case-by-case basis. The following is a list of information that may be required to process an application to replace windows. Please note that buildings listed as City Landmarks or as contributors to a historic district as part of Article 10 of the Planning Code require a Certificate of Appropriateness for any exterior work. In addition, buildings listed under Article 11 of the Planning Code must also be reviewed for historic architectural compatibility by the Zoning Administrator. Either approval must be obtained before the building permit is issued. Please note that in some instances Planning Department staff may request additional information.

Where original or historic windows exist and replacement is proposed, please submit the information on the following checklist for review:

- ☐ Photographs of the overall building taken from the curb and streetscape photos of the immediate block. Also, include close-up photos of the different types of windows to be replaced, including any millwork or brick molds between windows and surrounding the window openings.
- ☐ A site plan or a clear aerial photograph showing your building and the walls of your neighbor's building on each side of you as well as overall photos of each elevation where the proposed window replacement is to occur.
- ☐ Please provide window details for the proposed windows (head, jamb, meeting rail, sill, etc.) with dimensions and showing exterior profiles including brick molds and surrounding exterior millwork. The Planning Department needs to know the materials, size, and appearance of both the existing and the replacement windows. The manufacturer's product sheet may have this information for the new windows. Please note that if historic windows are to be replaced then the replacement windows should match the existing windows in overall, size, glazing, operation, material, finish, exterior profiles and arrangement.
- ☐ If the existing windows have divisions (muntins) they may be replaced with either true divided light or simulated divided light (SDL) windows provided that the replacement windows match the historic size, glazing, operation, finish, exterior profiles and arrangement and the SDL windows meet the additional requirements listed in this document.
- ☐ If proposing to replace or change the profile of exterior millwork or brick mold, please submit details of the existing and proposed new millwork or brick molds with dimensions.

When the original or historic windows no longer exist, the owner has the option of retaining the existing window or replacing it with a compatible sash. For window replacement, please submit the information above for review, the following:

- ☐ Photographs of the neighboring buildings and their windows on each side of your building
- ☐ Photographs of the neighboring buildings and their windows immediately across the street
- ☐ For corner lots, bring photos of the subject building and the building's other three intersections, showing their windows closest to each corner.



A QUICK SUMMARY:

1. A building permit is required for ALL window replacements.

- A permit is needed to replace windows regardless of their location on the building.
- Failure to obtain a building permit may result in enforcement, fines and removal of windows installed without the benefit of permit.

2. DO NOT purchase windows until you have obtained a building permit for their replacement.

- The Planning Department must review all permits for windows proposed for replacement that are visible from the street for architectural compatibility.
- The Planning Department review applies to all buildings in San Francisco, not just historic buildings.
- The Planning Department will not approve windows if it is determined that they are not architecturally appropriate, even if they have already been purchased and/or installed without benefit of a permit.

3. Evaluate what windows may only need repairing rather than replacing.

- Survey all of the windows on your buildings to determine which ones actually need replacement.
- Windows on eastern and northern facades often last longer and need less frequent replacement than windows with southern or western exposure.

4. Replacement windows should match the HISTORIC windows in size, glazing, operation, material, finish, exterior profiles and arrangement.

- The Residential Design Guidelines, since their revision in 2003, have set requirements for windows for all buildings within residential zoning districts (P. 46).
- If the historic window type cannot be determined, a window type appropriate to the building's architectural period and style should be used. A Preservation Technical Specialist can help in determining an appropriate window type.
- Please refer to pages 44-46 of the Residential Design Guidelines for more information on determining what types of windows are compatible with the architectural character of the building.
- Where visible from the street, aluminum and vinyl windows cannot be approved as replacements for windows that were originally wood.
- The proposed use of Simulated Divided Lites (SDLs) will be reviewed on a case-by-case basis and must meet the criteria identified in this document.
- Replacement wood windows that have vinyl, fiberglass, or aluminum clad exteriors will also be reviewed on a case-by-case basis.

5. All exterior trim and millwork must be left exposed.

- The underlying trim and millwork must be left exposed and be repaired in place. If beyond repair, the trim and millwork must be replaced in kind.

NOTES

1 Walter Sedovic and Jill H. Gotthelf, "*What Replacement Windows Can't Replace: The Real Cost of Removing Historic Windows*", APT Bulletin: Journal of Preservation Technology, 36:4, (2005) 25.

SAN FRANCISCO
PLANNING
DEPARTMENT

FOR MORE INFORMATION:
Call or visit the San Francisco Planning Department

Central Reception
1650 Mission Street, Suite 400
San Francisco CA 94103-2479

TEL: **415.558.6378**
FAX: **415 558-6409**
WEB: **http://www.sfplanning.org**

Planning Information Center (PIC)
1660 Mission Street, First Floor
San Francisco CA 94103-2479

TEL: **415.558.6377**

Planning staff are available by phone and at the PIC counter. No appointment is necessary.

Cambridge Historical Commission

Guidelines for Preservation and Replacement of Historic Wood Windows in Cambridge

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May, 2009

Cambridge Historical Commission

Guidelines for Preservation and Replacement of Historic Wood Windows in Cambridge[1]

Introduction

A primary objective of the Cambridge Historical Commission is to ensure the preservation and protection of the distinct characteristics of historic buildings and places throughout the city. Historic wood windows are considered to be one of these distinct characteristics. The Historical Commission believes that the protection of historic wood windows not only preserves an irreplaceable resource, but is also cost-effective to the homeowner and environmentally responsible. The following guidelines are intended to inform Cambridge property owners on the benefits of wood window restoration, and to guide property owners of locally-designated buildings and commission members in evaluating the appropriateness of window replacement.

The Cambridge Historical Commission and the city's neighborhood conservation district commissions have varying degrees of jurisdiction over window replacement within the boundaries of their designated districts (see http://www.cambridgema.gov/ Historic/ meetingsprocess.html for a description of the districts). In general, commissions have jurisdiction over all "exterior architectural features" of buildings, and no building permit may be issued for work in an historic or neighborhood conservation district until a commission has issued a Certificate of Appropriateness, Nonapplicability, or Hardship.[2] A Certificate of Appropriateness will be issued when the commission determines that the work is not incongruous to the character of the building or district; a Certificate of Hardship will be issued if the applicant demonstrates hardship, financial or otherwise, and the proposed work will not have an adverse effect on the district; and a Certificate of Nonapplicability will be issued if the work is judged to be not within the jurisdiction of the commission, or not visible from a public way.[3]

Why Preserve Historic Wood Windows?

Windows are an essential component of buildings, both as a means for light, ventilation, and visibility, and as an architectural feature. By providing scale, profile, and composition to a façade, windows are often one of the most important character-defining features of a structure. Federal preservation guidelines advise that "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."[4] Today's busy homeowner is often led to believe that old

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[1] These guidelines primarily pertain to the one-, two- and three-family homes that characterize the city's residential districts. Different standards may apply for apartment houses and commercial and industrial buildings.

[2] The Massachusetts historic district statute defines "exterior architectural features" as "such portion of the exterior of a building or structure as is open to view from a public street, public way, public park or public body of water, including but not limited to the architectural style and general arrangement and setting thereof, the kind, color and texture of exterior building materials, the color of paint or other materials applied to exterior surfaces and the type and style of windows, doors, lights, signs and other appurtenant exterior fixtures; (M.G.L. Ch. 40c, Sec. 5).

[3] The statute defines the scope of the a commission's review: "In passing upon matters before it the commission shall consider, among other things, the historic and architectural value and significance of the site, building or structure, the general design, arrangement, texture, material and color of the features involved, and the relation of such features to similar features of buildings and structures in the surrounding area" (M.G.L. Ch. 40C, Sec. 7).

[4] Myers, John. "Preservation Brief 9: The Repair of Historic Wooden Windows." Technical Preservation Services, U.S. Department of the Interior (1981) (http://www.nps.gov/history/hps/tps/briefs/brief09.htm)

windows cannot be repaired, and that they are inconvenient, high maintenance, inefficient, and ultimately replaceable. Historic wood windows were built to last, however, and some are still in service after two centuries or more.

A Brief History

Moveable wood sash windows date back to the early 1700s. Early sash construction techniques evolved into an intricate combination of molded wooden members ("muntins") to hold panes of glass. Early wood sash windows were marked by thick muntins and small panes, or lights, due to the high price of glass. As glass technology improved and prices decreased, lights became larger and muntins became thinner.

By the late eighteenth century, dimensions of windows were standardized according to the sizes of glass imported from Britain.[5] The principal window type of this era was the double-hung sash, which is commonly found today in Cambridge's older buildings. Sash construction remained a complex process, and windows were milled from old-growth lumber that is denser than the wood available today – one reason for the longevity of these windows.

Historically, the character and configuration of window sash have been essential to the style of a building. Nineteenth century muntin profiles and sash designs changed with evolving architectural styles, demonstrating deliberate design choices and skilled craftsmanship. Window glass manufactured before the mid-1920s exhibits wavy patterns and defects that are an important characteristic of older buildings. Historic windows are detailed differently than modern windows, and their old glass provides a markedly different pattern of reflection from modern glass. Preserving the sometimes subtle distinctions between modern and historic sash is critical to maintaining the historic character of a building.

Consider Restoration before Replacement

The staff of the Cambridge Historical Commission receives proposals for and inquiries about window replacement on a regular basis, a reflection of the rapid growth of the window replacement industry. Property owners are sometimes reluctant to hear the case for restoring historic wood windows opposed to their replacement. The benefits of window restoration can be summed up under three categories: Sustainability, Energy-Efficiency, and Historic Character.

Sustainability

An important facet of preserving historic buildings is the retention of original components. Like most structural elements of older, wood-framed buildings, historic wood windows were milled from old-growth lumber that can last centuries, even when not properly maintained. Their sustainability is complemented by the fact they were carefully constructed with mortise and tenon joinery to fit tight into the window openings of a house with extreme care and craftsmanship. Mass-produced wood replacement windows are typically constructed of new-growth lumber, often with glued-together finger

[5] There are local window companies that manufacture a "Boston Pattern" sash based on these eighteenth-century standards, which will fit nearly any window opening in Cambridge. "New York" pattern windows sold in western and southern New England are slightly different.

joints and are highly susceptible to rot. The preservation of an old window maintains an irreplaceable, sustainable resource.

In addition to craftsmanship and the durability of the wood, historic wood windows are also sustainable in that they are easily repairable. With the abundance of allegedly "maintenance-free" replacement window options on the market today, it's not surprising that property owners are often inclined to do away with old wood windows. "Maintenance-free," however, is a misleading claim. Any product that is in constant operation and is susceptible to seasonal fluctuations and weathering will need maintenance. Replacement windows typically have plastic and metal parts that become outmoded over time, making them difficult (if not impossible) to repair. Vinyl windows are prone to denting, warping and fading in high temperatures.[6] In most cases, wood replacement sash have aluminum or vinyl exterior cladding meant to protect the wood as an alternative to storm windows. However, if moisture finds its way in, through weep holes or other infiltration sources, the new-growth lumber shielded beneath the cladding can quickly rot.[7]

Another major claim of the window replacement industry is insulating glass. Insulating glass involves two panes of glass with an inert gas sealed in the space between them; these windows are called "double-glazed." Their design, however, does not lend to sustainability. Windows with insulating glass come with only a 15 to 20 year warranty; when the sealant fails, the window will lose its insulating quality, the glass will fog, and the entire window may have to be replaced.[8] Historic wood windows with a single pane of glass can be repaired with tools found at a local hardware store and will last up to 10 times longer than a replacement model. Homeowners should be aware that the payback period for restoring wood windows and installing quality storm windows is significantly less than installing replacement windows. In sum, the term "replacement window" means just what it says – it will have to be replaced again and again.

As global warming and related "green" issues are in the headlines, recycling and sustainability are important terms. Window restoration incorporates both of these concepts. Restoration of existing wood windows reduces both landfill waste and the production of the energy-consuming, synthetic materials found in many replacement windows. Hiring a local window restoration specialist to work on your windows also helps sustain local economies as *labor* intensive, opposed to *materials* intensive, concept.

Energy-Efficiency

Much like sustainability, energy efficiency is an important factor in the "green" discussion, and is often the primary reason homeowners look to replace their windows. The generally erroneous notion is that older wood windows are not as energy efficient as today's double-glazed replacement models. However, window replacement companies will often compare their product to an unrestored wood window with little or no weatherstripping and a poor (or no) storm window. With proper repair and

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[6] Paul Fisette, "Understanding Energy-Efficient Windows," *Fine Homebuilding* 114 (1998): 68-73

[7] See for example, class action suit brought against Pella Windows in February 2008 from homeowners who alleged that their Proline aluminum-clad wood replacement windows had design flaws that allowed water penetration beneath the exterior cladding, causing premature rotting in the sash.
http://www.freedweiss.com/investigations_pella.htm

[8] Walter Sedovic and Jill H. Gotthelf, "What Replacement Windows Can't Replace: The Real Cost of Removing Historic Windows," *APT Bulletin: Journal of Preservation Technology* 36:4 (2005): 25-29

maintenance, coupled with weather stripping and a quality storm window, *a single-glazed historic wood window will have a comparable level of energy efficiency to that of a double-glazed replacement window.* Industry guidelines indicate that the addition of a storm window to an existing single-glazed window will reduce the energy loss through the window area by approximately 50%.[9] As replacement window manufacturers will attest, the best insulation on a small scale is dead air space. The extra dead air space created with a sealed storm window (typically 2") means more insulation and increased energy efficiency. Replacement window dead air space between the double-glazing is only 1/16 to 1/32 of an inch.

It is important to note that infiltration of air, rather than heat loss through the glass, is the principal culprit affecting energy efficiency; it can account for as much as 50% of the total heat loss of a building.[10] Moreover, most of the heat loss in an old house occurs in areas other than windows. Insulation in walls, attics, and between floors, and weather stripping around doors will help prevent loss of heat.[11] Replacement window manufacturers also often misquote U-values as the value through the center of the glass (the location of the best U-value) and not for the entire unit.[12] A U-value is a rating of energy efficiency for all the *combined* components of a window or door – the lower the U-value, the greater the efficiency. An optional feature of replacement windows is "low-e" (low emissivity) glass, a microscopically thin, virtually invisible, metal or metallic oxide layer deposited directly on the surface of one or more of the panes of glass. The low-e coating reduces the infrared radiation from a warm pane of glass to a cooler pane, thereby lowering the U-factor of the window. The same effect can be achieved with low-e storm windows and/or energy-saving window film that can be applied directly to single-glazed windows.

Historic Character

A third reason to restore existing wood windows is the retention of character-defining features of historic wood windows that are nearly impossible to duplicate with double-glazed replacement windows. As mentioned earlier, the muntin profiles and old glass in wood windows are distinct characteristics of a historic façade. Replacement windows or sash rarely have the same details. The traditional ½" or 5/8" exterior muntin with a putty bead is difficult to reproduce in an insulated glass, true divided light window, and is extremely costly. Many wood replacement windows have a muntin at least 7/8" wide with an inappropriate moulded profile affixed to the glass and not actually holding individual panes of glass (referred to as a "simulated divided light" to simulate a true divided light profile). Cheaper models, typically vinyl or aluminum windows, feature removable grilles or grilles between the glass, providing no profile, depth, or shadow lines. Some replacement windows will decrease the glazed opening by as much as 3" in width, with a significant loss of light and alteration of the appearance.

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[9] Several studies reveal comparable energy savings between a restored single-glazed wood window/storm combination and a double-glazed replacement window. See Bill Mattinson, et. al., "What Should I Do About My Windows?" *Home Energy* 19/4 (2002); Noelle Lord, "Embracing Energy Efficiency," *Old House Journal* (September/October 2007); Andrew Shapiro and Brad James, "Creating Windows of Energy-Saving Opportunity," *Home Energy Magazine Online* (September/October 1997), http://homeenergy.org/archive/hem.dis.anl.gov/eehem/97/970908.html.

[10] Sedovic and Gotthelf, 27.

[11] The U.S. Department of Energy has detailed information on air infiltration and other energy-loss related issues at http://www1.eere.energy.gov/consumer/tips/air_leaks.html

[12] Sedovic and Gotthelf, 27.

Replacement windows will also often require a change in a window's rough opening because these products are based on national standards and do not match "Boston Pattern" dimensions –window sash sizes that have been standard in the Boston area since the 18th century. This will involve an increase in vinyl or aluminum framing members to hold the replacement window properly, detracting from the historic character of a building. Custom sizing will add to the expense of replacement windows.

It is often argued that storm windows have a negative impact on the historic character of wood windows. An important point to consider is that storm windows have been used for over 100 years. Although aluminum storm windows do not replicate the appearance of wood storms, they are allowed without review in historic districts and neighborhood conservation districts and are always preferred to window replacement unless the windows themselves are judged not significant. Storm windows are a fully-reversible alteration that protect the original fabric of the building and can make the window assembly as energy-efficient as replacement windows. For optimal results, the storm windows meeting rails should correspond to the position of the existing meeting rails of the sash and match in color.[13] Contact the Historical Commission for appropriate models.

When is Replacement Acceptable?

In some cases, an old wood sash may be beyond repair and need to be replaced. In such a situation, replacing the historic, single-glazed wood sash with a single-glazed reproduction wood sash is the preferred option. It is important that the new sash have the same number of lights (unless the existing sash are themselves inappropriate replacements – contact the Historical Commission for advice). Coupled with a quality storm window, this solution satisfies much of the rationale for restoration listed above. The staff of the Historical Commission has compiled a list of window manufacturers that produce single-glazed, true divided light windows. Local manufacturers such as Brosco and Boston Sash & Millwork feature a line of Boston Pattern wood sash. Several other manufacturers produce custom wood sash that are authentic reproductions of historic sash.

If a double-glazed replacement window is the only option, Commissions will generally consider how the proposal will impact the historic character of a building; namely how closely the replacements match the originals in pattern, details, materials and finishes as closely as practicable. Dimensions and profiles of casings, sills, jambs, meeting rails and muntins are all subject to review. Some manufacturers have been able to produce double-glazed wood windows with muntin profiles that are a closer match to those found on single-glazed sash; contact the Historical Commission for recommended models. Although there have been advances in recreating the details of historic windows, the sustainability and energy efficiency issues are still highly debatable. However, there are replacement models of higher quality than others. Replacing a pre-existing replacement window with an in-kind replacement window is typically reviewed and approved at the staff level, as well as windows that are not visible from a public way.

It is essential to distinguish between "windows" and "sash," especially when discussing their potential replacement. "Replacing a window" means removing the entire window, including the sash, the jambs, the interior and exterior casings, and the sill, and installing an entirely new unit. This is often problematical because the casings will almost inevitably have different dimensions from the original,

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[13] Interior storm windows or energy panels are a secondary option, but can damage casings and sills and cause condensation on the interior face of the sash. Moreover, the exterior face of the sash is not protected from the elements.

leaving gaps against both exterior and interior finishes. Unless specially ordered, modern windows will have a different configuration of casings, stops, and screens, dimensionally-thinner sills and casings, and will sometimes occupy a different plane in the wall.

"Replacing a sash" means replacing the moveable parts of a window, leaving the casings, jambs and sill intact. There are two approaches to replacing sash:

- Replacing the sash and balances only. Locally-made Boston Pattern sash fit window openings from all periods. Sash can be replaced with new spring balances that eliminate sash weights and allow weight pockets to be filled with insulation. This operation may have little or no effect on the exterior architectural character of the house.
- Replacing the sash with a new window, within the existing jambs. Some manufacturers offer replacement windows containing both sash and jambs that are made to fit within the existing jambs. This may seem like an attractive alternative, but the additional width of the extra jambs and balances introduces new visual elements and can significantly reduce the size of the glazing.

What about Lead Paint?

Lead paint was banned by the federal government in 1978 to reduce the risk of lead poisoning in children. In older homes, windows, in particular, may contain lead paint. The repeated use and operation of the window sash may increase the likelihood of paint chipping and the creation of lead dust. Property owners are often concerned that the presence of lead paint on windows may require immediate replacement of the windows. Although it is not uncommon to find lead paint on historic wood windows, lead abatement can be achieved without posing serious health hazards. A licensed risk assessor can confirm the presence and location of lead paint and a licensed lead abatement contractor should be able to stabilize and treat it appropriately. Homeowners need to be aware that certain methods of lead paint removal, including electric sanding without proper filter vacuums and the use of heat guns, are illegal. This is especially critical when hiring a paint contractor or window restoration specialist to work on site, as these methods can produce dust and are considered a potential health hazard for the worker(s), but more importantly, for children under the age of six. With proper precautions and safety measures, however, historic wood windows with lead paint can be remedied.

In legal terms, the Code of Massachusetts Regulations directs a property owner to fully comply with State lead abatement procedures when a child under six years old resides in a house or building where lead paint is identified by a certified lead inspector.[14] The regulations do not require the immediate removal of windows or window sash containing lead paint, but rather careful and thorough abatement. Special consideration is given to buildings on the State Register of Historic Places, recommending offsite stripping and reinstallation of any components containing lead paint and advising against permanent removal of "historic architectural features" such as wood sash.[15] The abatement method, either through stripping of the lead paint or replacing the sash, is ultimately at the discretion of the homeowner.

For more information on lead abatement in Cambridge, contact Lead Safe Cambridge at (617) 349-5323.

Contact the Historical Commission

[14] See CMR 460.000, "Lead Poisoning Prevention and Control" from the Department of Public Health.
[15] Ibid.

Cambridge Historical Commission

If you are a Cambridge resident and live in a historic or neighborhood conservation district or own an otherwise designated property and are thinking about replacing your windows, contact the staff of Historical Commission at 617.349.4683 or histncds@cambridgema.gov. The staff keeps a running list of local window restoration contractors that is available to the public, as well as window companies that manufacture single-glazed replacement models. For residents outside of the districts, the staff is happy to provide technical assistance regarding window restoration or replacement.

Cambridge Historical Commission

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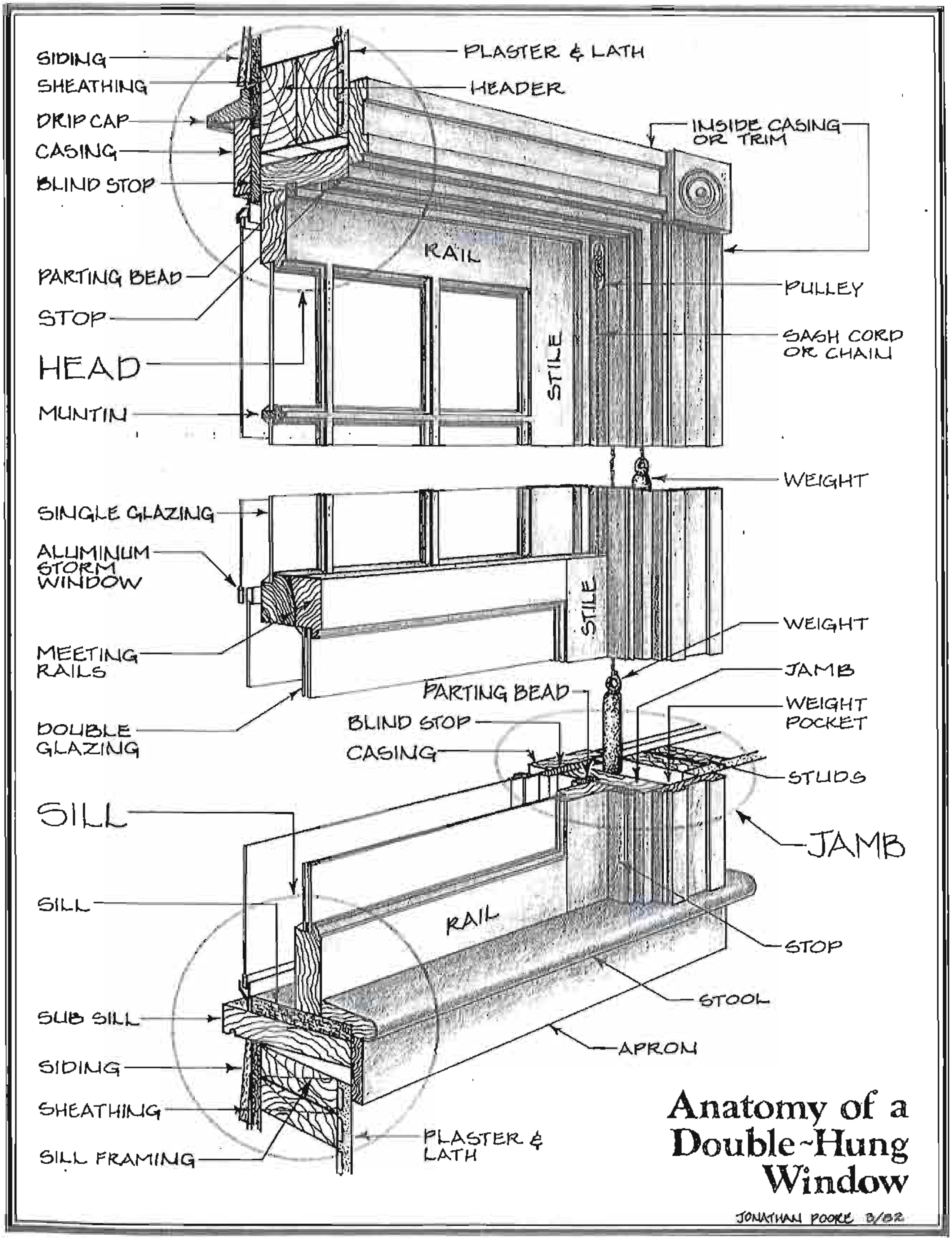
SIDING
SHEATHING
DRIP CAP
CASING
BLIND STOP
PLASTER & LATH
HEADER
INSIDE CASING OR TRIM
RAIL
PARTING BEAD
STOP
HEAD
MUNTIN
STILE
PULLEY
SASH CORD OR CHAIN
WEIGHT
SINGLE GLAZING
ALUMINUM STORM WINDOW
MEETING RAILS
DOUBLE GLAZING
STILE
WEIGHT
JAMB
PARTING BEAD
BLIND STOP
CASING
WEIGHT POCKET
STUDS
SILL
JAMB
SILL
RAIL
STOP
STOOL
SUB SILL
APRON
SIDING
SHEATHING
SILL FRAMING
PLASTER & LATH
Anatomy of a Double-Hung Window
JONATHAN POORE 8/82

HISTORIC WINDOWS – RESOURCES AND LINKS

Federal Sites

National Park Service
http://www.nps.gov/index.htm (search windows)

National Park Service, National Center for Preservation
http://ncptt.nps.gov (search windows)

Secretary of the Interior's Standards
http://www.nps.gov/history/hps/tps/tax/guidance.htm
http://www.nps.gov/history/hps/tps/tax/incentives/avoiding_1.htm
http://www.nps.gov/history/hps/tps/

National Park Service Preservation Briefs
http://www.nps.gov/history/hps/tps/briefs/presbhom.htm

U.S Department of Energy
http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/historic_homes_guide.pdf

National Sites

National Trust for Historic Preservation
http://www.preservationnation.org/resources/homeowners/
http://www.preservationnation.org/issues/sustainability/

Alliance of Preservation Commissions
http://www.uga.edu/napc/programs/napc/publications.htm

Association of Preservation Technology International
http://www.apti.org/publications/bulletin-index.cfm (search windows)

State Sites

Missouri SHPO
http://www.dnr.mo.gov/shpo/links.htm

Kansas SHPO
http://www.kshs.org/portal_shpo (search windows)

California State Parks
http://www.ohp.parks.ca.gov (sustainability)

Preservation North Carolina
http://www.presnc.org/Preservation-Answers/Historic-Windows-Resource-Page

International Sites

Northern Ireland
http://www.ni-environment.gov.uk (search windows)

Heritage Canada Foundation
http://www.heritagecanada.org/eng/news/archived/spring2006/windows.html
http://www.heritagecanada.org/eng/news/archived/summer2006/windows.html
http://www.heritagecanada.org/eng/news/archived/spring2007/thermal.html

Scotland
http://www.historic-scotland.gov.uk/gcu-technical- thermal-efficiency-traditional-windows.pdf
http://www.historic-scotland.gov.uk/caring-for-your-sash-case.pdf

City Sites

Denver, CO
http://denvergov.org/Preservation/DesignReviewCertificateofAppropriateness/Applicationmaterials/tabid/438031/Default.aspx

Albany, OR
http://www.cityofalbany.net/comdev/historic/

San Francisco, CA
http://www.sf-planning.org/index.aspx?page=1825

Cambridge, MA
http://www2.cambridgema.gov/Historic/windowglines_final.pdf

Phoenix, AZ
http://phoenix.gov/HISTORIC/hprehab.html#technical

Boulder, CO
http://www.bouldercolorado.gov/index.php?option=com_content&task=view&id=2033&Itemid=1862

Technical Papers

Saving Energy in Historic Buildings: Balancing Efficiency and Value
http://www.apti.org/publications/Cluver-Randall-41-1.pdf

What Replacement Windows Can't Replace: The Real Cost of Removing Historic Windows
http://ohp.parks.ca.gov/pages/1054/files/replacement_windows%20sedovic%20gotthelf.pdf

The Effects of Energy Efficiency Treatments on Historic Windows
http://www.conservationcenter.org/assets/EffectsEnergyonHistoricWindows.pdf

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Research into the Thermal Performance of Traditional Windows: Timber Sash Windows
http://www.english-heritage.org.uk/professional/research/buildings/energy-efficiency/thermal-performance-of-traditional-windows/

Media and Video Links

http://www.kshs.org/p/window-repair-videos/14680
http://www.presnc.org/Preservation-Answers/Historic-Windows-Resource-Page

Old House Journal
http://www.oldhousejournal.com/npsbriefs2/brief09.shtml
http://oldhousejournal.com/Sash_Window_Clinic/magazine/1078

Traditional Building
http://www.period-homes.com/Newsletter/SPR_APRIL_9_09_NEWSLETTER.html