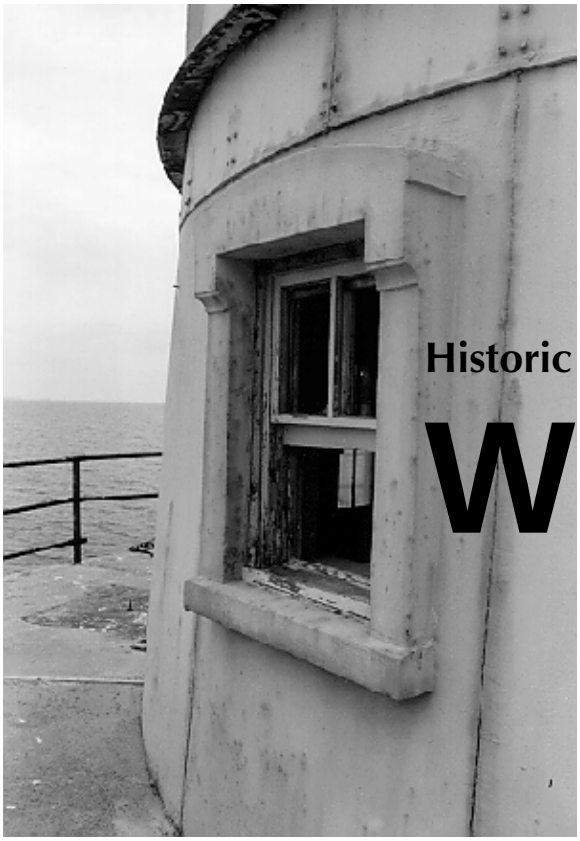
WPTC photo



Historic Lighthouse Preservation:

WINDOWS

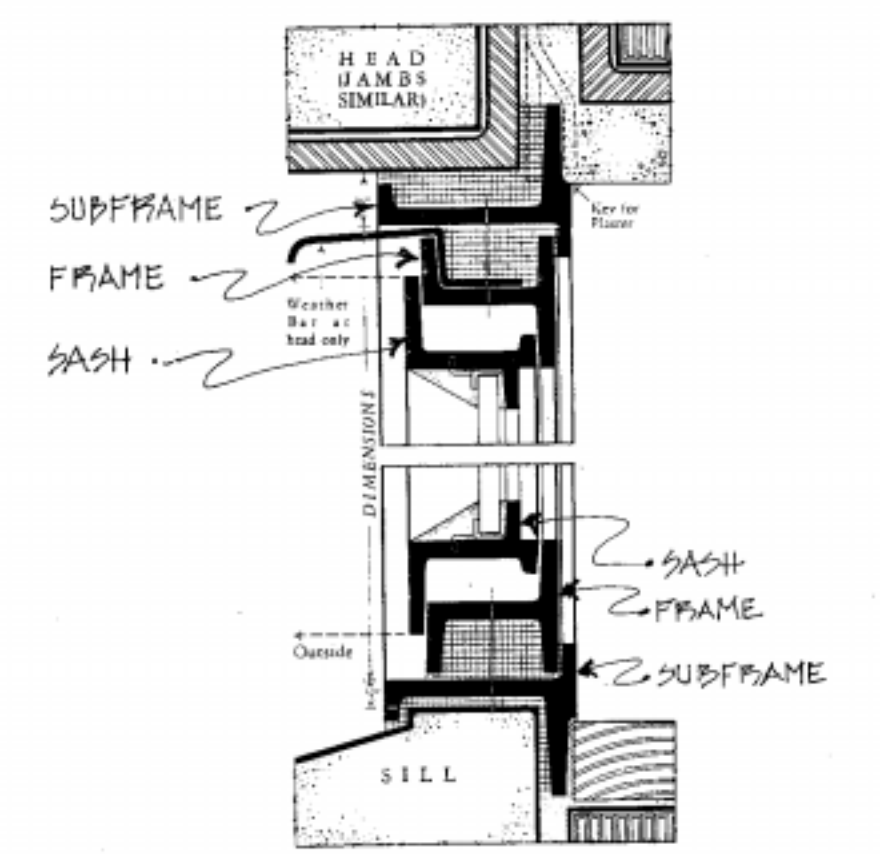
Figure 1. Close-up of a window found in a Chesapeake Bay "spark plug" lighthouse . The integral cast-iron trim is a typical character-defining feature of this lighthouse type from the late 19th century

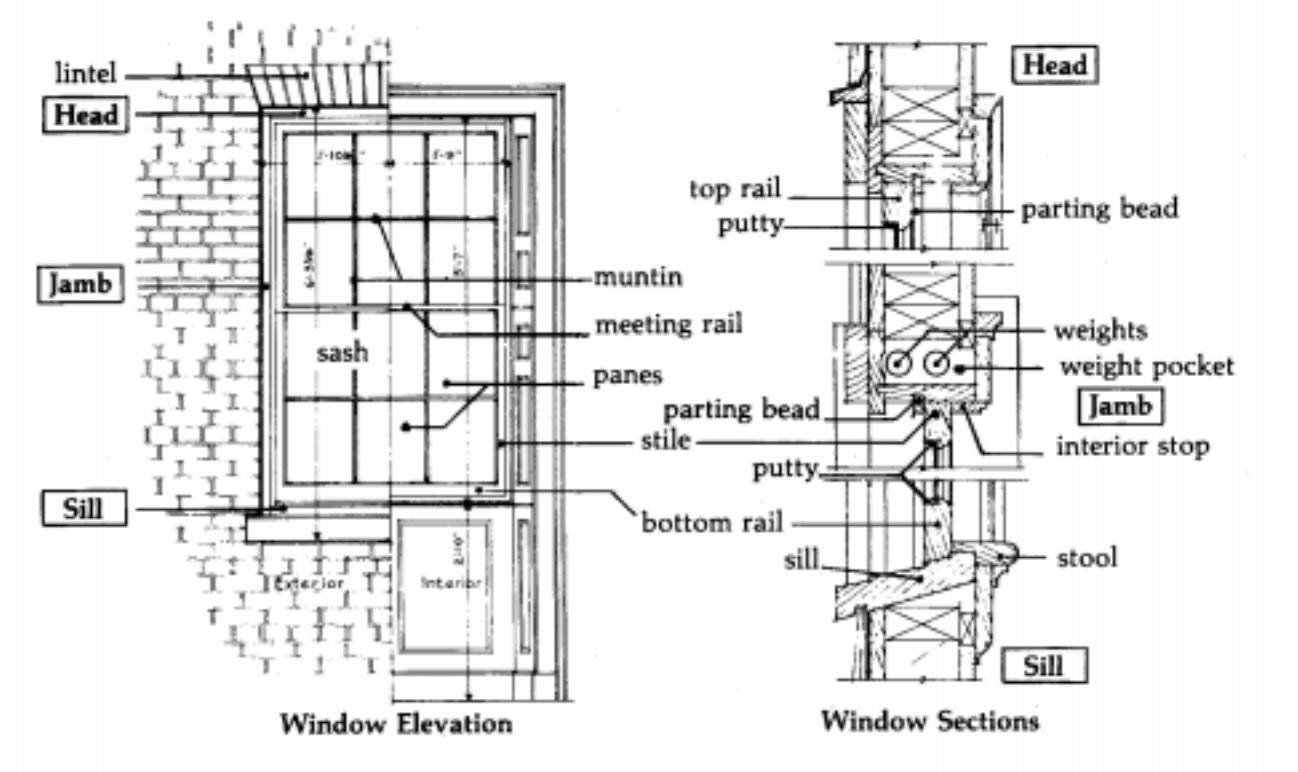
With their functional and decorative features such as keystone lintels, multi-light sashes, arched pediments, and architrave (trim or molding which surrounds the window opening), windows can be extremely important in defining the overall character of a lighthouse. Usually windows were integral components of a historic lighthouse's stylistic design and featured hallmark elements that defined the architectural style upon which the ornament of the structure was based.

The predominant window type found in historic lighthouse towers is a wood, double-hung sash variety. This window type has been used since the late 18th century. Other window types associated with lighthouses are wood and metal casement windows.

The primary cause of lighthouse window deterioration is moisture penetrating the various components through rain driven against and into windows, standing water on sills, and interior condensation. In a marine environment, deterioration caused by moisture penetration is exacerbated by extended periods of damp weather, which prevent windows from drying out, thereby encouraging expansion and rot. Other factors that contribute to window deterioration are poor design, vandalism, insect/fungal attack, settlement over time, paint buildup, broken glazing, deteriorated putty, and deferred maintenance.

Windows admit light and air into a lighthouse. Both of these functions should be maximized, but in a controlled manner. Because most lighthouses are unoccupied, mechanical methods are not always viable as a means of interior climate control. Well-maintained, operable windows will therefore be an important and preferred component in creating an efficient passive ventilating system. Replacement windows and components, when needed, should be constructed of materials of the highest





Figures 2 and 3. Wood and metal window details (source: *The Window Handbook*).

quality that can withstand a harsh marine environment. Where vandalism and security require the temporary blocking of a window to better secure the structure, sensitive measures can effectively block the opening with minimal damage to the historic window. The following is a discussion of preferred preservation methods to consider when preserving historic lighthouse windows.

Window Types

The two primary types of windows found in historic lighthouses are identified by how their moving parts operate. The wood double-hung sash is the most common. The moving parts of the window consist of two wood frames, called sashes, that capture the glass 'lights' or panes of the window. These frames are housed in a wood frame, called a jamb, that allows the sashes to slide up and down. The top of the wood frame is called the head and the bottom portion is called the sill on the exterior and the stool on the interior. The sill is responsible for shedding water away from the window opening. The second most common window type found in historic lighthouses is the metal casement. The moving parts of a metal casement window operate like a door. The terminology remains the same for the parts of the casement window.

Inspection and Evaluation

The first step to repairing historic windows is a thorough inspection of each window unit.

Inspection Chart for Lighthouse Windows	
Look For:	*Possible Problems:*
Wood Windows	
Areas of paint failure	This may indicate the wood is in poor condition and in need of repair. Wood is frequently in sound condition, however, beneath unsightly paint. After noting areas of paint failure, inspect the condition of the wood. Use an ice pick or an awl to test wood for soundness. Pry up a small section of the wood. Sound wood will separate in long fibrous splinters. Decayed wood will lift up in short irregular pieces caused by breakdown of fiber strength.
Deteriorated wood	If deterioration has begun from within the wood member and the core is badly decayed, the visible surface may appear to be sound. Pressure on a probe can force through an apparently sound outer layer to penetrate deeply into decayed wood. This technique is especially useful for checking sills where visual access to the underside is restricted.

Look For:	*Possible Problems:*
Metal Windows	
Areas of paint failure	This may indicate the paint is at the end of its effective life span or the window has been bent or deformed. Bending makes the less flexible paint fracture and 'pop' off the window frame.
Areas of corrosion on all surfaces of the sash, frame, sub-frame (if visible), and hardware	This may indicate a moisture infiltration problem. Corrosion in the form of rust will occur typically inside the frame channel and along the bottom edge of the sash.
Bowing or misalignment of window parts	Deformation could be the result of misuse/abuse or corroding components that have deformed because of rust-jacking or deterioration.
Both Window Types	
Water entering around the edges of the frame	The joints or seams should be caulked to eliminate this danger. Check the glazing for cracked, loose, or missing sections. Examine the sill for a downward slope which allows water to drain.
Condition of glass and glazing to determine the extent of required repairs	Careful probing of the glazing with an awl will aid in determining its soundness.
Gaps or cracks in the joint between the window frame and the lighthouse wall	Cracks or gaps are possible water infiltration points.
Moving parts of the windows	Bound or tight operating windows may simply be painted shut or may be stuck because of deteriorating frame members or sash frames, or bound because of corroded hardware.

PRESERVATION TREATMENTS

The following are protection/stabilization (mothballing) and repair treatments designed specifically for windows found in historic lighthouse towers. For a discussion of window treatments in ancillary structures, see NPS *Preservation Briefs 9: The Repair of Historic Wooden Windows* and *Preservation Briefs 13: The Repair and Thermal Upgrading of Historic Steel Windows*.

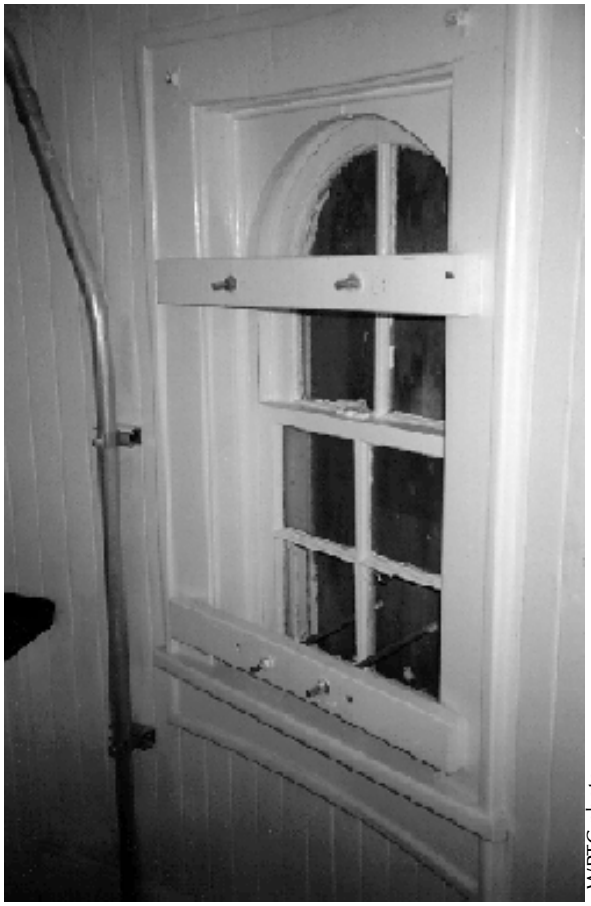
Protection and Stabilization (Mothballing)

Lighthouses which have been mothballed usually have had the openings on the lower level covered to protect fragile glass windows from breaking and to prohibit entry points. Infill materials for closing window openings include plywood, corrugated sheet-metal panels, metal grates or grills, brick, and cinder or cement blocks (in masonry lighthouses). The method of installation should not damage the opening or window jamb. During this procedure all associated sash, shutters, and frames should be protected. If removed, all window parts should be labeled to indicate which window they came from and stored for future reuse. Special care must be taken to ensure no further damage is incurred during the removal of the window parts.

- For windows, the most common security feature is the closure of the openings; this may be achieved with wooden or preformed panels or, as needed, with metal sheets or in the case of masonry towers concrete blocks or bricks may be used. Plywood panels, properly installed to protect window frames and which are properly ventilated, are the preferred treatment from a preservation standpoint. (To provide adequate ventilation the louvered opening should have an area that is approximately half of the original sash opening.)
- There are a number of ways to insert vented plywood panels into window openings to avoid damage to frame and sash. One common method is to bring the upper and lower sash of a double-hung unit to the midpoint of the opening and then to install pre-cut plywood panels on the inside face of the window using long carriage bolts anchored into horizontal wooden bracing, or strong backs (see Figures 4 and 5).
- The type of ventilation should not undermine the security of the building. The most secure installations use custom-made grills well anchored to the window frame, often set in plywood security panels. In upper-level windows vents formed using heavy millwork louvers set into existing window openings are another possibility (see Figure 6).

WPTC photo

Figure 4. A good example of a blocked window using a metal panel fitted with a hooded vent. For more adequate ventilation, the vent should be larger.



WPTC photo

Figure 5. Interior view of the blocked window. If possible, a better solution would have been to raise the lower sash and lower the upper sash and pass the bolts through the openings.

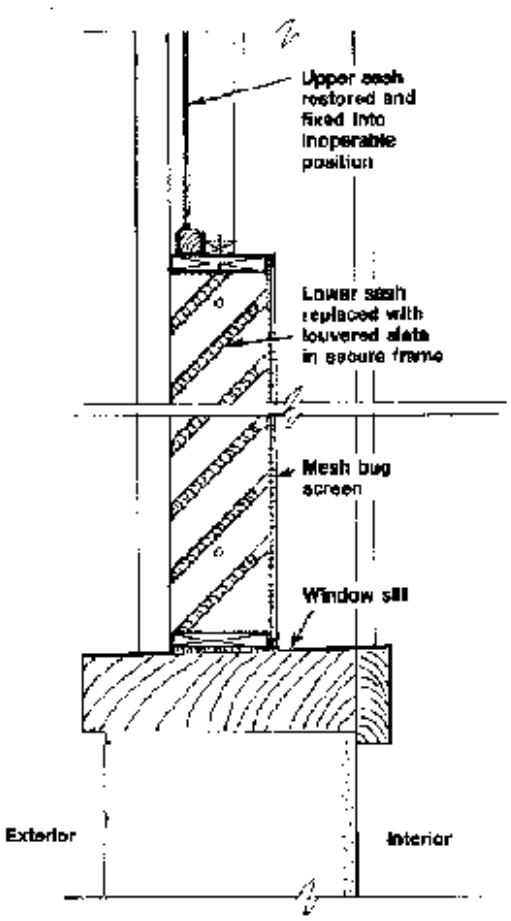


Figure 6. Detail of wood louver system designed to be inserted into lower sash opening after sash has been carefully removed. (Drawing by Thomas Vitanza, WPTC)

- Plywood panels are usually 1/2- to 3/4-inch (1.25-1.875 cm.) thick and made of exterior grade stock, such as CDX, or marine-grade plywood. They should be painted to protect them from delamination and to provide a neater appearance. These panels may be painted to resemble operable windows or treated decoratively.
- As a temporary treatment, acrylic or other high impact clear sheeting could be used to cover an entire window. The sheeting could either be attached to the actual window frame with screws, being careful not to damage any historic molding profiles or split the wood frame. A better attachment method (especially for masonry lighthouses) would be to construct a sub-frame within the window opening using 2- by 4-inch framing members and then attach the sheeting to the sub frame. If this method is used, the interior sash should be opened and the sheeting fitted with large screened louvers. (To provide adequate ventilation, the louvered opening should have an area that is approximately half of the original sash opening.) When using this treatment, the sheeting must be ventilated to ensure that condensation, which could accelerate the deterioration of the window, does not build up between the panel and the window.
- Another effective method of ventilating a lighthouse during mothballing is to lower the upper sash and install a large screened, hooded vent. These vents, together with the louvers fitted in the tower entry door, keep the interior of the tower free from condensation year round.

Repair

The following is a discussion of maintenance and repair philosophy and treatments for historic lighthouse windows. These instructions conform with the principle that the least modification to an existing window often yields the greatest return—accepted preservation practice and simple economics; the ratio of investment to return is often greater when repairing and upgrading an existing window than when replacing it.

- Identify, retain, and preserve windows (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, hood molds, paneled or decorated jambs, moldings, hardware, and interior and exterior shutters and blinds.
- When determining its historic significance, consider a window's place as a principle character-defining component of the exterior facade and its contribution to an interior space.
- Avoid changing the historic appearance of windows through the use of inappropriate designs, materials, finishes, or colors which noticeably change the sash, depth of reveal, or muntin configuration; the reflectiveness and color of the glazing; or the appearance of the frame.
- Conduct an in-depth survey of the conditions of windows early in preservation planning so that repair and upgrade methods and possible replacement options can be fully explored.
- When possible preserve all remaining original glazing. Historic glass often has distortions and imperfections that are not found in modern glass—an irreplaceable character-defining element.
- Evaluate the overall condition of materials to determine whether more than protection and maintenance are required, i.e., whether repairs to windows and window features are needed.
- Keep glazing clear to maximize the natural light source. Glass is preferred to plastics such as acrylic and polycarbonate which may scratch easily, tend to look oily, and will yellow and haze with time.
- Preserve operating systems for historic windows, (e.g., weights on double-hung windows), repairing or replacing components as needed. This should done even though the windows may not be currently used.
- Repair all broken, cracked, or missing glass immediately. If immediate replacement is not feasible, a temporary patch should be used to prohibit the entry of water, pests, and vandals. When funds are available the missing glass should be replaced.
- Where building or life-safety code requires, install safety glass into existing window sashes, carefully retaining frame and hardware components. If possible, salvage original glass for later reinstallation or use elsewhere in the structure. These codes are enforced at a local or state level and typically apply to lighthouses that are privately owned where visitors have unsupervised access to the tower.
- Remove rust and paint from metal windows by hand scraping. Low pressure (80-100 psi) sandblasting may be used to remove heavy corrosion, with careful protection of glass and surrounds. Do not use heat to remove rust or paint from metal windows; this can distort the metal members, release toxic fumes, and may cause the glazing compound to fail. If the sash is removed from the frame, the paint can be removed through a chemical dip process, but the metal surface should be neutralized before repainting.
- Do not obscure historic window trim with metal, vinyl, or other material.
- Do not strip windows of historic material such as wood, cast iron, or bronze.

Figures 7 through 9 illustrate forms of deterioration typical to lighthouse windows. All of these conditions are repairable and do not require total replacement. The following guidelines are intended to aid in the repair of such deterioration.

- Once the damage and deterioration have been identified, the affected areas must be treated. Repair window frames and sash by patching, splicing, consolidating, or otherwise reinforcing. Such repair may also include replacement of

WPTC photo

Figure 7. Deteriorated glazing putty and peeling paint on a multilite wood sash.

WPTC photo

Figure 8. Deterioration of the bottom rail and sill on a wooden double-hung window.

WPTC photo

Figure 9. Rust occurring on the inside of the steel channel that forms the sill of this metal casement window.

those parts that are extensively deteriorated or missing, using surviving prototypes such as architraves, trim, hood molds, sash, sills, and interior or exterior shutters and blinds.

- Repair defective sills to permit positive drainage away from the window sash. Poor design of the exterior window sill is a frequent problem; window deterioration usually begins on horizontal surfaces and at joints where water collects, saturating wood and corroding metal.
- Repair of historic windows is always preferred to replacement. Usually the sill must be replaced first, then lower sash parts. Splicing and dutchmen can be effective repair methods for both wood and metal window elements.
- If replacement is required, limit it to severely deteriorated components.
- Clean and oil hardware that has been painted over; in most cases, repair, rather than replacement, should be possible.
- Remove built-up paint on sashes and frames that causes sashes to be inoperable. Where possible, remove paint only to the next sound layer. In order to provide a paint chronology, a patch of sound paint should be left undisturbed for future reference.
- When possible, remove earlier repairs that have been insensitive to the historic features and materials, and repair according to accepted standards.
- Document all work through written and photographic means as a record for future reference.

Removing Paint from Wood Windows

NOTE ABOUT LEAD PAINT: In the following treatment explanations references are made to the removal of loose, flaking, and blistering paint finishes; in carrying out this treatment, all precautions should be taken to protect the workers from exposure to lead-based paint.

Historic wood windows tend to accumulate many layers of paint. This paint is likely to interfere with the proper operation of the window and is usually visually unattractive. Over time, partial peeling leaves a pitted surface that encourages moisture to collect. Excessive paint layers also obscure the shape of original molding profiles, which add definition to the window's appearance.

The extent of paint removal required depends on the condition of the paint. Treatments for common paint conditions found on historic lighthouse windows:

- ***Chalked paint:*** Clean with a mild detergent solvent, hose down, and allow to dry before repainting.
- ***Crazed paint:*** Sand by hand to the next sound layer before repainting; exposure of bare wood is not necessary.
- ***Peeling and blistering:*** Analyze between coats as to the source. If salts or impurities have caused peeling, scrape off the defective surface, hose off the underlying surface, and wipe surface dry before repainting. If the peeling or blistering was caused by incompatibility of the paints or improper application, scrape off the defective surface, and sand the underlying surface to provide a better bond with the new paint. Peeling, cracking, and alligatoring to bare wood require total removal of the defective paint followed by drying out of the wood substrate and treatment for any rotted areas before repainting. Sand or scrape only to the next sound layer of paint, exposure of bare wood is not necessary.

Paint Removal Methods

Paint is typically removed from wood surfaces by scraping after it has been softened with heat guns or plates or brushed with commercially available chemical stripping solvents. Regardless which method is chosen for paint removal, after the stripping process is complete, all affected areas will need at least light sanding.

Chemical Strippers

WARNING: When chemical paint removers are used, take care to protect your skin and eyes, provide adequate ventilation, and prevent spillage onto adjacent materials. These solvents can etch or otherwise damage the surrounding masonry, painted surfaces, and glazing. It is best not to use these chemicals on or directly adjacent to glass.

Paint on historic lighthouse window sash can be removed by softening with commercial chemical strippers such as methylene chloride, toluol, or xylol. To maximize the chemical's effect, the stripping agents have been combined with a thickener which holds them in place while the chemicals soften the paint. The softened paint is scraped with special scraping tools designed not to damage existing molding profiles. The scrapers can be formed on site by grinding the trim profile on the end of a large (2-inch-wide) scraper. Commercially available scrapers are designed with different sized curves and shapes that can be used in combination to fit the various curves and shapes of the molding profile.

Another commercially available method sandwiches the paint, softened by a solvent paste, between the wood substrate and a disposable membrane. Although materials for this method are more costly, it is less labor intensive than using traditional strippers and scraping. Even with this system some scraping is required. With either stripping method all stripped surfaces must be neutralized for the new paint to properly adhere. The neutralization method depends on the particular stripper.

Applied Heat

WARNING: Under no circumstances should a torch or other open flame be used to remove paint. When using heat to strip paint, be sure to provide adequate ventilation, properly protect skin and eyes, and wear a respirator designed for vapors. Take all precautions to protect workers from lead-paint exposure.

There are two commercially available applied-heat paint-removal systems for use on historic windows: heat guns and heat plates. Heat guns will soften paint in only a small concentrated area, making heat guns good for removing paint in trim profiles and other tight spaces. A heat gun can be used to soften and remove glazing compound only if certain precautions are taken to protect the glass. When a heat gun is used near glass, carefully cover the glass with a piece of hardboard wrapped with aluminum foil. This measure will help reflect heat away from the glass and reduce the chances of localized overheating, which can crack the glass.

To facilitate complete paint removal, remove the existing sash from the frame. To do this, pry loose the stops and parting beads as carefully as possible so that the wood does not split. All parts should be labeled and positions documented to ease reinstallation. If parts are damaged during removal they should repaired or reproduced to maintain the historic appearance of the window. Because window stop profiles have changed very little over the last 100 years, the variety of sizes available at many lumber yards will likely match the historic profile to be replaced.

Once the paint has been removed, revitalize the bare wood by rubbing it with fine-grade steel wool soaked in turpentine or mineral spirits and boiled linseed oil.

After the excess paint from the window frame and sash has been removed, it may be advisable to treat the surfaces with a wood preservative coating. Choose a commercially available preservative, taking care that it is compatible with the finish or paint system to be applied afterward. Solutions containing copper arsenate, for example, give treated wood a greenish tone and are not approved for use by most government agencies.

Removing Paint from Metal Windows

NOTE ABOUT LEAD PAINT: In the following treatment explanations, references are made to the removal of loose, flaking, and blistering paint finishes; during this process all precautions should be taken to protect workers from exposure to lead-based paint.

Historic metal windows often have accumulated many layers of paint, which is likely to interfere with the proper operation of the window and is usually visually unattractive. Over time, partial peeling leaves a pitted surface that collects moisture. Excessive paint layers also obscure the shape of original molding profiles, which add definition to the window's appearance.

The extent of paint removal required depends on the condition of the paint. Treatments for common paint conditions found on historic lighthouses:

- ***Chalked paint*** should be cleaned with a mild detergent solvent, hosed down, and allowed to dry before repainting.
- ***Crazed paint*** should be sanded by hand or with a power sander before repainting.
- ***Peeling and blistering*** between coats should first be analyzed as to the source. If salts or impurities have caused peeling, the defective surface should be scraped off and the underlying surface hosed off and wiped dry before repainting. If peeling or blistering was caused by incompatibility of the paints or improper application, scrape off the defective surface and sand the underlying surface to provide a better bond with the new paint. Peeling, cracking, and alligatoring to bare wood require total removal of the defective paint,

followed by drying out of the wood substrate and treatment for any rotted areas before repainting.

Removing paint from metal frames and sash usually includes removing some built-up corrosion and scaling. Use a wire brush, being careful not to damage the remaining glass or other surfaces. Particular attention is required to remove rust buildup at construction joints and along the crack perimeter of the sash and frame. Because older metal windows were typically primed with lead-based paint, wear a respirator rated for lead protection when using a wire brush. An alternative to abrading the surface, particularly when only light corrosion is present, is to use a liquid gel containing phosphoric, ammonium citrate, or oxalic acid. After the gel has been brushed on and has set, wipe clean and dry the steel substrate. Again, protect surrounding materials, particularly masonry and glass, during all these procedures. After removing the paint, wipe the bare metal with a solvent such as benzene or denatured alcohol to remove all chemical residue.

WARNING: Heat should not be used to remove paint from metal windows because possible distortion may result.

If corrosion is extensive, sandblasting may be necessary. Remove the sash from the frame and the glass panes from the sash. A low-pressure blast (80 to 100 psi) with small grit in the range of #10 to #45) applied with an easily controllable pencil blaster is recommended.

Because corrosion begins as soon as the bare metal is exposed to the air, apply a rust-inhibiting paint immediately after removing old paint. Two coats of zinc-rich chromate paint as a primer are recommended and the finish coat of paint should be from the same manufacturer as the primer to ensure compatibility.

Repainting

NOTE ABOUT PAINTING: The following treatments provide only general information. In preparing surfaces and applying paint, follow manufacturer's specifications and guidelines included with the product (either directly on the label or as included literature) for more specific instructions.

The most time-consuming maintenance procedure is repainting windows. Careful surface preparation is the key to a successful job. In repainting wood windows once the wood has been preserved and its moisture content reduced, select a paint that resists moisture but allows the wood to breathe. Steel windows should be primed with an anticorrosive primer and finished with a compatible paint.

A complex array of paint options have been developed by the modern coating industry. Paints containing lead, used in the past on both wood and metal windows, are no longer readily available. Solvent- and water-based paints used today are generally thicker in composition than the solvent-based paints used historically. When selecting a paint, seek assistance from manufacturers or suppliers about compatibility and methods of application.

When selecting a paint consider these factors:

- drying and recoating time
- coverage
- environmental factors, such as toxicity and flammability
- color and gloss durability
- moisture permeability (in wood windows)
- expected service life
- compatibility with window putty
- tolerance to adverse weather conditions
- adhesion between contacting surfaces

Wood Windows

The earliest water-based paints, now often referred to as latex, were developed for use on interior surfaces and performed poorly on exterior surfaces. For wood windows exterior water-based vinyl acrylic paints are generally more compatible with existing paint layers containing lead and provide better moisture permeability than water- or solvent-based alkyd paints. If the paint layer is impermeable, it may trap water that penetrates past the paint film. Alkyd paints available in flat, semigloss, and gloss finishes are fast drying, flexible, resistant to chalking, and retain color and gloss well, but are incompatible with existing paint layers containing lead.

Metal Windows

Before painting, pits that were created by corrosion should be filled by melting steel welding rod into the pits; then grind flush or use a steel-based epoxy than can be ground or sanded flush with the surrounding material. After the voids have been filled, all bare metal surfaces should be wiped with a solvent-metal-preparation solution. This will remove any chlorides (salt deposits) that may have settled on the surface from the sea air as well as microscopic rust or corrosion that may have started to form. All bare metal surfaces should be coated with a corrosion-inhibiting primer. A solvent-based alkyd paint rich in zinc or zinc chromate is generally recommended as a primer for steel windows along with two impermeable alkyd finish coats.

Caulking and Glazing Compounds

Caulking and glazing compounds are used to seal a window's nonoperable joints. Because their expected service life varies from 5 to 30 years when the window unit is properly maintained, they are considered a disposable part of the window system and therefore receive periodic maintenance. Replacing cracked or missing compounds is somewhat complicated because new materials have been developed in recent decades.

Most traditional caulks and glazing compounds had a base of linseed oil, which tended to became hard and brittle over time. Today, more than a dozen generic compounds are commercially available to fill seams and joints. Most are based on more complex plastic and silicone compounds and tend to remain pliant for a longer time, but not all are useful in window rehabilitation. Because of windows' exposure to temperature extremes and the stresses that develop at the joints where dissimilar materials meet, compounds should be durable, flexible, and resilient.

Caulking

Caulking is used to bridge the joints between the frame and the window opening. These should not be considered stationary joints, for they are constantly moving as the wall and window materials expand and contract because of changes in temperature and moisture content. Selecting an appropriate caulking also depends on the window material itself. The dimensions of a metal window within a window opening, for example, change less than a wood window does. Both, in turn, are more stable than an aluminum window, which has the highest coefficient of thermal expansion and thus requires the most sophisticated caulking.

When selecting caulking be sure to consider the following:

- the material of the window opening (some compounds do not adhere well to porous materials)
- the width of the joint to be sealed (some compounds have a limited gap range)

- the season when caulking is to be applied and the curing time (some of the better compounds require extended periods of warm temperatures above 60° Fahrenheit)
- the caulking's integral color range, often available by custom order
- its adherence to paint

Commonly used window caulks:

- ***Oil-based caulks:*** can seal joints of up to 1/2 inch and are the least expensive, but can require up to a year to cure and temperatures above 40° Fahrenheit for application. They dry hard and can deform permanently. Not paintable.
- ***Butyl rubber caulks:*** can seal joints of up to 1/2 inch, adhere well to metal and masonry, and can be painted upon cure, but require extended temperatures above 40° Fahrenheit for application. They are subject to shrinkage, and some degrade under exposure to ultraviolet light.
- ***Polysulfide caulks:*** can seal joints of up to 1 inch, are flexible and resilient, but are more expensive. They require temperatures above 60° Fahrenheit for application, as well as careful surface preparation and application of a primer over porous surfaces.
- ***Silicone caulks:*** can seal joints of up to 1 inch, are flexible and resilient even at low temperatures, and can be applied at temperatures as low as O° Fahrenheit. They are the most expensive, have limited integral color range, cannot be painted in most cases, and require careful surface preparation and application of a primer over porous surfaces. Only special silicone formulations are paintable.
- ***Polyurethane caulks:*** used in some metal windows, can seal joints of up to 3/4 inch, are flexible and resilient, and adhere well to masonry. They require application at temperatures above 40° Fahrenheit, careful surface preparation, and application of a primer over most surfaces. Not paintable.

When caulking a window, carefully scrape out the existing compound and residue before applying new caulking. If the joint is large and deep, use a filler, known as backer rod, to fill a majority of the void, leaving a gap for the caulk that is approximately as deep as the gap is wide. Then fill this gap with the caulking compound. Protect adjacent masonry surfaces before caulking, since some compounds will stain these materials. Review and strictly follow manufacturer's recommendations and instructions.

Glazing Compounds

Glazing compounds are used to seal the joints where the panes of glass meet the muntins and sash members in older, single-glazed windows. An oil-based putty is typically used on wood sash, while specially formulated glazing compounds are used in steel sash. Most compounds should be protected by paint, but harden with age and rapidly deteriorate when exposed to the elements. Sections of deteriorated glazing compound can often be replaced without removing the sash from the frame. Complete replacement of the compound, however, is best accomplished with the sash on a horizontal surface and the glass removed.

Preparing the Sash

When completely replacing the glazing compound, remove all deteriorated material manually by scraping, taking care not to damage the rabbet, where the glass is positioned. During all operations take every precaution to protect the historic glass.

Wood Windows

If the putty or other compound has hardened in the rabbets, it can be softened by applying heat. A heat gun may be used if the glass is protected by a heat shield (hardboard wrapped with aluminum foil). A better heat source is a heat plate with only a perimeter element and a built-in heat shield that is designed for the purpose of softening putty in wood windows. Before the glass panes are replaced, the surfaces of sash members should be prepared. Clean and finish bare surfaces of wood sash by

rubbing the surface with a fine-grade steel wool or a fine grade of high-quality sandpaper, and then apply a solution of equal parts of boiled linseed oil and turpentine. Finally, prime and repaint.

Metal Windows

First, carefully remove all damaged glazing compound and the mounting clips that retain the glass pane. This must be done mechanically. Do not use applied heat, which may cause the window frame to distort. Use a wire brush or, for more severe conditions, a pencil sand blaster at low pressure (80-100 psi) to remove any corrosion. Paint all surfaces with a solvent-based alkyd paint rich in zinc or zinc chromate as an anticorrosive primer. Then apply two coats of a compatible, impermeable alkyd-finish top coat.

Setting the Glass

With wood sash and most steel sash, apply a thin bed of putty along the inside face of the rabbet. This process, known as back-puttying, provides a tight seal and protective cushion for the glass. Insert the glass, replace glazing points (in wood windows) or retaining clips (in metal windows), and putty the exterior face in a neat triangular bead. For metal windows, use only a glazing compound designed for metal windows. For wood windows, use either a linseed-oil putty that is thickened with commercial whiting or a pre-mixed glazing compound. Paint the glazing compound only after it has completely cured. When painting, allow the brush to overlap and drag slightly over the glass to form a durable seal.

Repairing Damaged or Deteriorated Windows

Window repairs, such as splicing new wood, fitting dutchmen, consolidating wood sections, welding steel sections, bending steel sections, replacing glass (see previous section on glazing compounds), and adjusting hardware are generally performed as needed during the course of maintaining a building. Such repairs greatly improve the performance of older windows by returning them to an operable condition.

Splicing and Dutchmen

Deteriorated portions of wood windows can be effectively repaired using like-kind splices or dutchmen. Splicing of a wood member is required when a portion of the window, i.e., a frame rail, has been damaged or has deteriorated and only that portion needs removal and a new section attached in its place. All deteriorated material should be removed, and the end where the replacement member will be attached should be cut on a diagonal to increase the gluing surface area. The replacement member should match the existing members in grain orientation and in any existing shape or profile. The new member can even be made from matching salvaged stock. To attach the new member,

WPTC photo

Figure 10. Close-up of a recently restored replacement metal window at Cape Hatteras Lighthouse. Now that the repair work is done, all that this window needs is the hardware lubricated and periodic maintenance to remain in operable condition for the next 50 years. At the time of this lighthouse restoration, it was discovered that the original windows were not repairable and funds were not available to replicate the original cast-iron frame design. The original windows were more like a shutter, constructed in two parts, hinged at both sides and meeting in the middle. The new landing windows were installed as a temporary measure until additional funds are available.

WPTC photo

Figure 11. Example of a metal casement window in a lighthouse dating from the 1870s

WPTC photo

Figure 12. Close-up of severely deteriorated bottom rail of the same window in Figure 11. This condition can be repaired by splicing a new piece of sash

cut the end diagonally to match the existing member; then drill aligned holes in both members for reinforcing dowels.

A 'dutchman' is a fitted patch in a wood member that has only localized deterioration. To fit a dutchman, first probe the deteriorated area to determine the approximate depth of the deterioration. Second, cut a wood patch or dutchman with its grain aligned with the existing member's. The dutchman can be rectangular or diamond shaped. Both shapes will work; however, a diamond shape is a little more difficult to fit but will provide more gluing surface and blend with the grain better if the window is finished with varnish instead of paint. Be sure the dutchman is large enough to cover the affected area and thicker than the deterioration is deep. Slightly bevel all of the edges of the dutchman so that the widest face is the top. This will ensure a tight cork-like fit. Next, trace the outline of the dutchman's narrowest face on the existing member over the deterioration. Using the outline as a guide, carefully remove all of the deteriorated wood with a chisel. Test-fit the dutchman, and trim the hole until the dutchman bottoms out and fills the affected area entirely; the dutchman should be slightly higher than the existing material. Glue and clamp the dutchman in place. Once the glue has cured, use a chisel or hand plane to make the dutchman flush with the surrounding material. Hand sanding can be used for the final leveling of the two surfaces.

WPTC photo

Figure 13. Close-up of a dutchman repair (light-colored wood used to mend a window muntin).

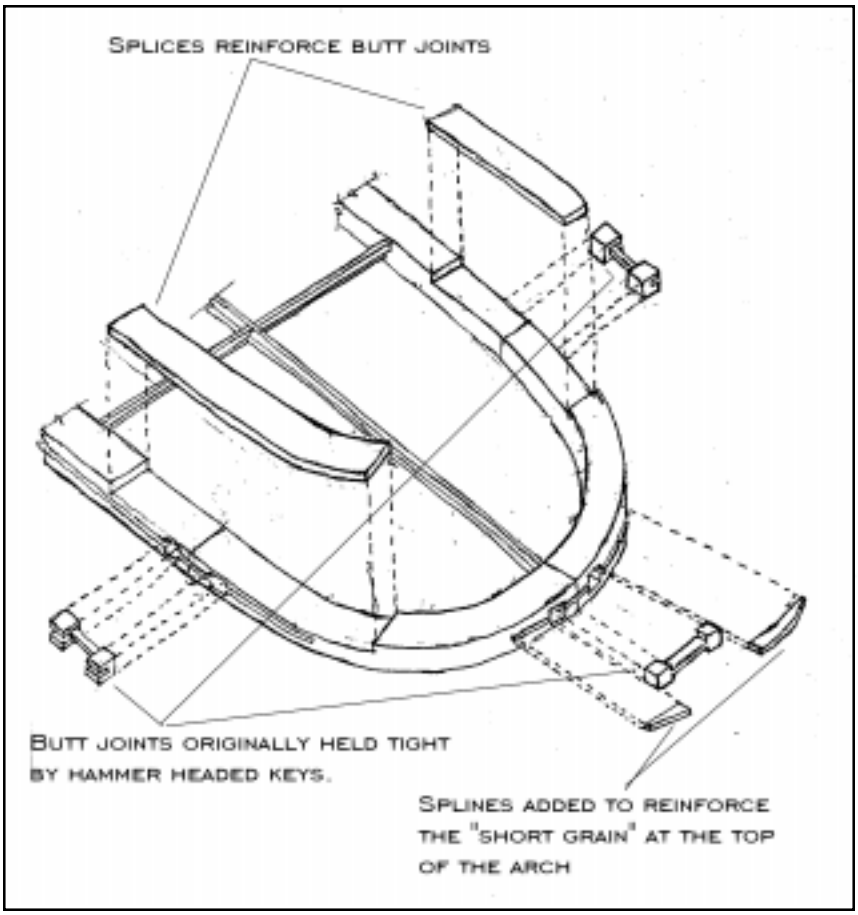


Figure 14. A wood window splice repair. (Illustration by Eric Ford, WPTC)

Epoxy, Fillers, and Consolidants

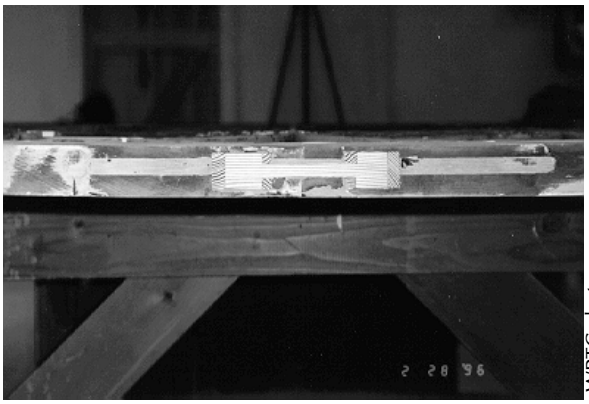
NOTE ABOUT EPOXY, FILLERS, AND CONSOLIDANTS: Epoxy treatments are irreversible, may not be approved for National Historic Landmark structures, and should be used only after a careful study has been made of more traditional repair technologies such as splicing and dutchmen. Some epoxy, filler, and consolidant treatments require training in the application of the system. Individuals not familiar with the use, effectiveness, and results of this technology should be trained in its use before field application.

Wood Windows

Repair of deteriorated wood sash and frame members is possible where there has been loss of material. It should be considered a primary option when joints have not twisted or warped, as when the surfaces of sills, lower portions of the frame, and bottom rails of sash have become eroded but have not cracked or split. Filling and consolidation of most frame members is performed in place, while sash consolidation is usually done in a shop.

When only wood surfaces are eroded, voids can be eliminated by applying a paste or putty filler. Apply fillers after the wood has dried and has been treated with a fungicide and a solution of boiled linseed oil.

In cases where a limited amount of rot has progressed well into the substrate, interior voids are filled in by saturating the wood with a penetrating epoxy consolidant formulated for wood. Surface voids, as well as decayed or missing ends near joints, are then filled or built up with an epoxy compound. When sash are in such poor



WPTC photo

Figure 15. This window sash frame was repaired with traditional (replacement wood hammerhead key) and modern epoxy filler (material to left and right of the hammer head key) techniques.

condition that they require consolidation, puttying and painting are typically also needed. Moreover, the joints connecting stiles and rails are likely to have become loose. After the glass and paint in affected areas have been removed, the sash is placed in a jig on a horizontal surface. Separated corners should first be repaired by pulling the joints together with a pipe clamp, drilling holes through adjacent stiles and rails, and securing each joint with a blind dowel. Rotted, missing, or eroded sections are then treated with the saturating epoxy, allowed to cure, and resurfaced with the epoxy paste. Surfaces are then sanded and painted as required.

Splicing and Bending Metal Window Parts

Damaged or severely corroded metal window sections can be removed and matching sections welded into place. Some rolled steel window stock is still manufactured or can be located in architectural salvage yards. Depending on the extent of deterioration, this repair can be done *in situ* or the sash may be removed and repaired in a shop. Because special skills are required for this type of repair, a certified window repair contractor should be consulted.

Deformed windows can be reshaped by gently applying pressure in the right location. This process may take a few days to complete. Depending on the extent of deformation, this repair can be done *in situ* or the sash may be removed and repaired in a shop. Because special skills are required for this type of repair, a certified window repair contractor should be consulted.

Adjusting Hardware

Properly cleaned and adjusted hardware will greatly extend the operable life of wood or metal windows. For routine cleaning use fine steel wool or a fine brass-wire brush and a cleaning solvent. All moving parts should be lubricated with a noncorrosive lubricant.

Limited Replacement In Kind

Windows are character-defining features of the historic lighthouse. Replacement of existing historic sash, no matter its condition, is a last-resort treatment. Replacement is usually the most expensive alternative and results in total loss of historic fabric. Replacement may be considered only if the historic sash are missing or too deteriorated for repair techniques. This decision should be made by a preservation professional such as a historical architect, engineer, or facility manager trained in preservation.

If replacement windows are put in a historic lighthouse, they should match the characteristics of the historic sash: number and size of lights, muntin width and profile, stile and rail dimensions and profiles, setback in window opening, and window-frame size and profile. For more information refer to NPS *Preservation Briefs: 9, 13, 16, 17, and 18*.

Use the following as a guide when considering window replacement:

- Always keep replacement to a minimum. Where sash replacement is called for, attempt to retain the window frame, hardware, and trim.

- Replacement may be the only feasible option when substantial structural damage to a window has occurred. Choose a replacement window with particular care. Ideally the new window should be an exact match of the old one. If this is not possible, carefully consider all of the window's characteristics, both interior and exterior, and its importance in the facade, when selecting a replacement.
- When a window is deteriorated to the point where it is no longer weathertight, the opening may be temporarily blocked in a manner which does not damage the historic window features. Reference the previous mothballing section for sensitive window blocking methods designed for historic windows.

For more information on the replacement of lighthouse windows refer to Part V., **Beyond Basic Preservation**.