PRESERVATION

Tech Notes

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WINDOWS

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Aluminum Replacement Windows With True Divided Lights, Interior Piggyback Storm Panels, and Exposed Historic Wooden Frames

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BOOTT COTTON MILLS (The Boott Mills) Lowell, Massachusetts

The complex of buildings which make up the Boott Mills is considered one of the best examples of a large 19th-century New England textile factory. The 3,000 double-hung windows, most of which are 3½′ x 7′ in size, are a distinguishing characteristic of this interconnected red-brick grouping of nine mills, a counting house, and a cotton storehouse. The point-grid patterning of these windows, rhythmically punched into the multi-story plain brick walls, and the nearly uniform 12-over-12 configuration of lights tightly stretched over the facades, creates an austere yet powerful composition evident not just in the first four mills of the mid-1830s but in the additions that continued until 1899. Rather than being subservient to more richly detailed wall treatment, the windows became the dominant element of detail and decoration for the Boott Cotton Mills. Many other textile mills of the 19th century could be characterized in this way.

The rehabilitation of the Boott Mills complex, located in a National Historic Landmark district, presented the opportunity to arrest decades of neglect and deterioration and to re-establish the important historical and architectural contribution of the windows. This Tech Note will explain the work that led to an innovative solution, combining alu-

Deteriorated historic windows should be repaired rather than replaced wherever possible. When replacement is necessary, the new windows should match the historic ones in design, color, size, configuration, reflective qualities, shadow lines, detail and material. Only where it is not feasible to match the historic material should a substitute be considered and only when it is shown through such means as field mock-ups that it is possible to match closely both the detail and the overall appearance of the historic windows.

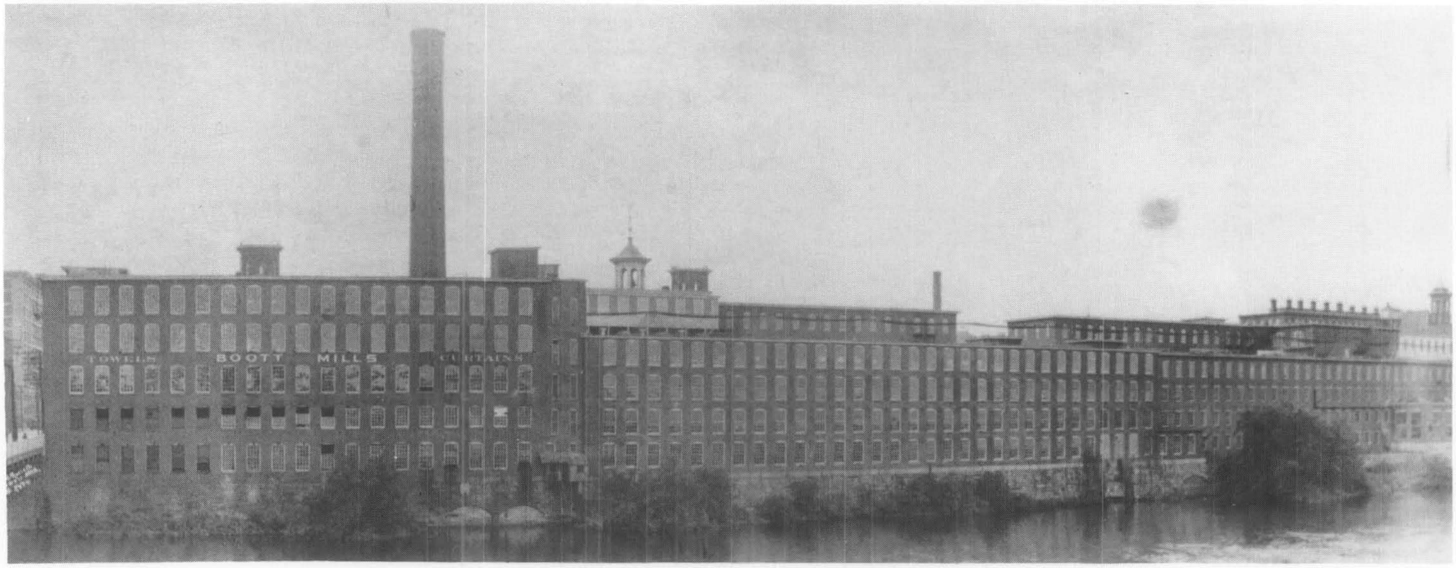

Figure 1. The windows are the dominant element of detail and decoration in the Boott Cotton Mills. Photo: Courtesy of the Center for Lowell History

minum window technology with an older double-glazing technique. The new windows that were developed virtually duplicated many of the important historic attributes of the original wooden windows on the large mill facades *(see figure 1)*.

Problem

The projected three-phase, $63 million rehabilitation of the Boott Mills involves 700,000 square feet of space. An appropriate window treatment was foremost among several important preservation design problems. The developer and the historic review commission agreed that one-over-one aluminum replacement windows with exterior muntin grids were not desirable. Because of the significance of the complex, it was established that the windows needed to have true divided lights and that the dimensions and profiles of all visible elements would be near copies of the originals *(see figure 2)*.

Restoration of the existing windows was one solution that was considered. This approach was undertaken on one late 19th century facade where the windows retained structural integrity due to oversize muntins and a mild weather exposure. However, the results of the architect's survey of the windows concluded that the vast majority of the surviving wooden sash were deteriorated well beyond repair. The historic windows had indeed fared badly in the decades following the collapse of the New England textile industry after World War I. The lack of proper building maintenance beginning at that time has been documented by historians studying the business and labor history of the Boott Mills. The only significant window work during the waning textile operation at the mill resulted in the spot replacement of many of the 12 light sash with 6 light sash. Virtually no work, including painting, had been done on the windows following the cessation of textile production in 1954. The one exception was the replacement of several hundred windows on the exposed river elevations that had been destroyed by an off-site explosion in 1976 and replaced with inexpensive aluminum double-hung, single light sash.

The developer and architect next investigated the replacement with wooden reproduction windows. Several wooden window manufacturers were approached for design and price quotations for a custom window with true divided light sash that maintained the historic sight lines of the visible members of the window. At the same time, the project team investigated the possibility of developing an aluminum true-divided-light sash that would satisfactorily duplicate the historic wooden window while providing for double glazing. A new aluminum window system would result from their efforts.

Window Design

In the fall of 1988 the developer and architect turned to a manufacturer with whom they had previously worked and proposed the development of a vertical sliding aluminum sash window which would contain true divided lights with thin muntins and members with dimensions and finish profiles that match those of the historic wooden window.

Over the next few months, the following basic requirements were established for the new window:

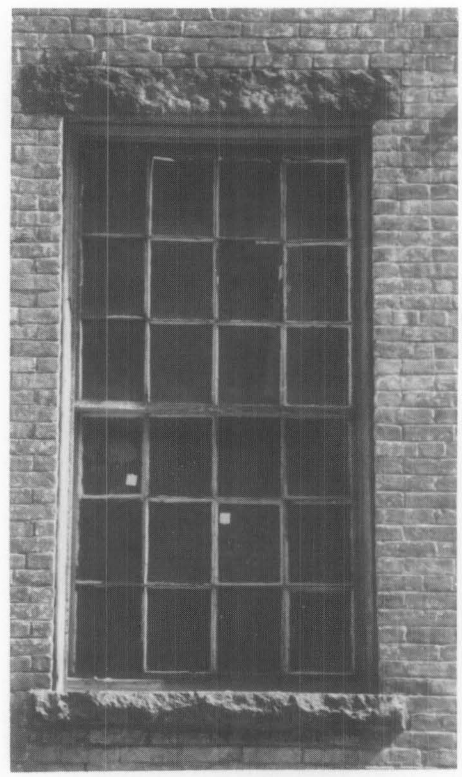

Figure 2. Because of the historic character and significance of the complex, replacement sash needed to have true divided lights and the dimensions and profiles of visible elements needed to be close copies of the originals. Photo: Courtesy of Huygens DiMella Shaffer

1. True-divided lights/integral muntins
2. Dimensions and profiles of all visible members that virtually duplicate the historic window
3. "Wet" glazing for small divided lights.
4. Double glazing
5. Thermally broken unit
6. Aluminum construction with factory-applied paint

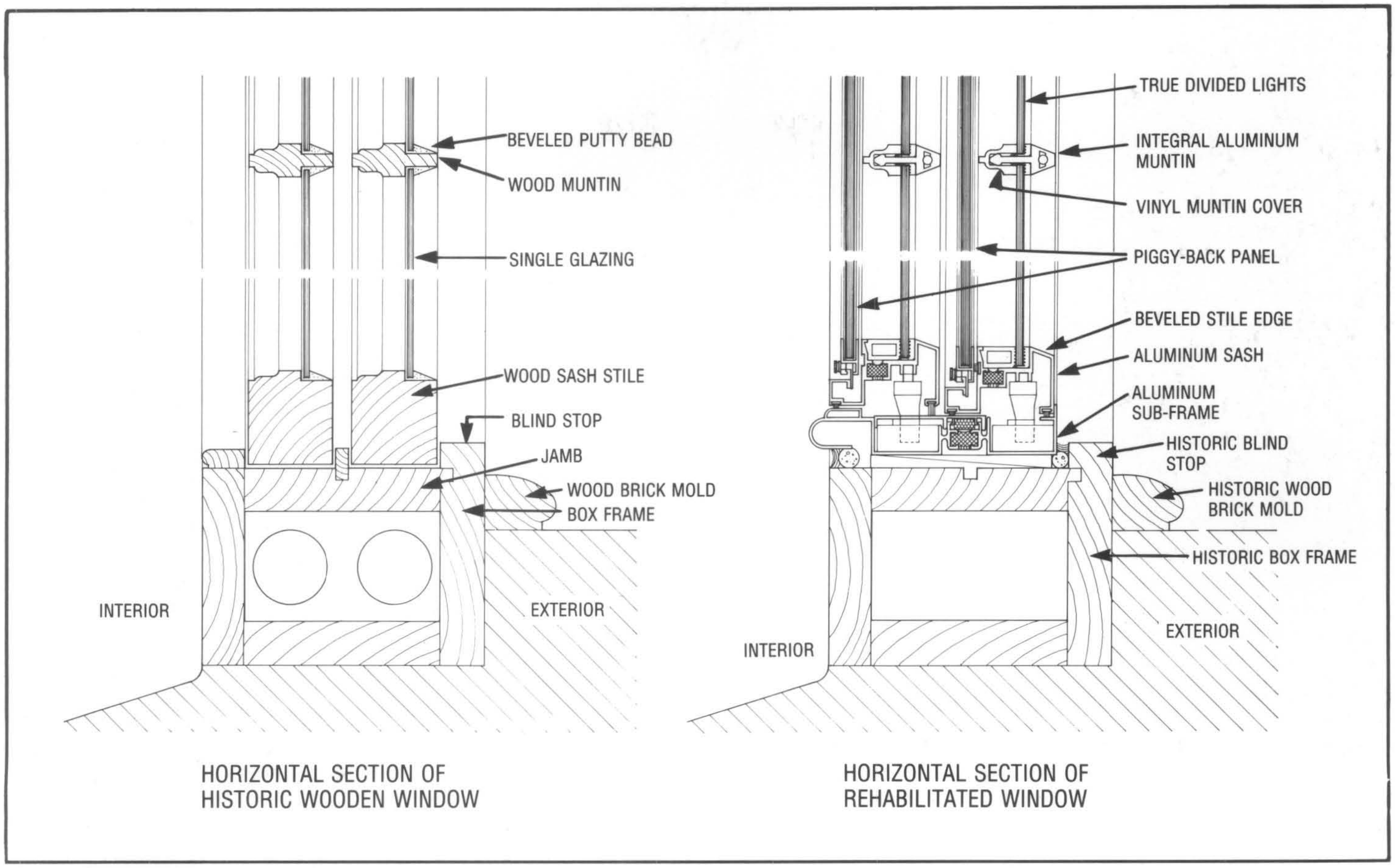

Figure 3. Horizontal section of the window shown with old and new sash. Drawing: Timothy Buehner

7. Conventionally weatherstripped and counterbalanced vertical sliding sash
8. Retention of the historic wooden frame as the receptor for the new window system

Although the latter five requirements are typical of most recent historic building rehabilitations, achieving the first two demanded that a new window system be developed. Recent aluminum replacement windows on historic rehabilitation projects were nearly all based on available window systems, limiting the flexibility to closely match specific windows on a project-by-project basis. In addition, the thin muntins typical of 19th century multiple-light sash could only be achieved through use of an exterior aluminum trapezoidal grid against the exterior sheet of glass. The near-universal industry use of sealed insulating glass necessitated true-divided aluminum muntins that were excessively wide. In the case of the Boott Mills, use of a standard true divided light aluminum window with insulating glass would require muntins over twice the width of the historic ⅝″-wide wood muntins.

In order to permit the use of true muntins of sufficient narrowness at the Boott Mills, it was necessary to limit the muntin-supported glass panes to single glazing, as in a historic window, and to achieve double glazing with a secondary window system *(see figure 3)*. This secondary window consisted of a "piggy-back" interior glazing panel, which left exposed on the exterior the multiple facets of the true divided lights so characteristic of historic multiple-pane windows. The interior glazing panel was attached to the room side of the sash. It was also decided that the existing wooden frames would be retained and used to receive the aluminum sub-frame for the new window. Finally, new aluminum extrusions were to be made for all members to ensure a very close match to the historic units.

The design work evolved into a back-and-forth exchange of full-scale details between the architect, developer, contractor, and manufacturer. First, the architect produced section details of the late 19th-century window at Boott Mills to serve as a basis for sight-line matching. (The early 19th-century windows were similar, but had thinner sash members, a flat-headed masonry opening instead of an arched opening, and generally a smaller overall height.) From these drawings, the manufacturer began to design the new window.

Window Detailing

The manufacturer's initial design roughed out the first technical details for the new system, including:

- duplication of the face dimensions of the meeting and lower sash rails;
- duplication of the face dimensions of the stiles and head rail, taking into account the addition of the new aluminum sub-frame;
- vinyl snap-on interior grid to snuggly fit the glass against the sealant, provide a thermal break and approximate the appearance of the interior profile of the muntin; and
- extruded reveals in the sash to receive the piggy-back panels so as to conceal the panel frames from the exterior;
- thin sill extension of the sub-frame beyond the exterior face of the lower sash to minimize the introduction of a non-historic double sill; and
- shaft extension of the sash-lock arm to extend below the intruding piggy-back panel of the upper sash.

The first muntin design was an adaptation of the true-divided-light muntin developed by the manufacturer in 1985 for another historic rehabilitation project (see Tech Note Windows No. 12). It was narrowed and profiled to approximate the beveled glazing bead and sticking of the historic wooden muntins. However, it was found that the technology of the 1985 three-piece muntin system could be reduced only to about $\frac{7}{8}$″ in thickness. A new two-piece true muntin was then developed by the manufacturer that met the general dimensions and profile of the putty-glazed historic muntin; it provided the needed strength and proved to be simpler in design and less expensive to fabricate. This muntin consisted of an aluminum tee extrusion with a trapezoidal flange and a web terminating in a triangle-shaped point over which a profiled cover of extruded rigid PVC was snapped to hold the glass panes in place. Plastic was used for this cover to provide the flexibility needed to remove the cover in case of glass breakage and to provide the thermal break to insulate the aluminum tee member. The snap cover extrusion was to be made in the pre-selected custom color chosen for the window *(see figure 4)*.

The framing and new muntin designs were supplied to the architect who prepared full-scale sections to show how the new window would be installed in a repaired window frame. To conform more precisely to the visible features of the late 19th-century window, the architect modified the inside edge of the rail and stile extrusions to include the beveled shape of the historic glazing putty. Revisions were incorporated by the manufacturer as the design evolved and further refinements were added.

On the sub-frame, a drip edge that broke the sight line at the head was eliminated as unnecessary. The detailing of the sub-frame was also revised to facilitate installation into the existing frame from the building interior. This resulted in a cleaner interior finish; however, it also increased the height of the sub-sill, making it somewhat more visible on the exterior. The overall depth of the early design was also reduced, resulting in a final depth only about $\frac{1}{2}$″ larger than the historic window. Because the muntin had to clear the piggy-back panel behind it, the overall muntin depth was to be $1\frac{9}{16}$″, just $\frac{3}{16}$″ less than the historic ones (see figure 5).

Refinements were also made to the piggy-back panel. In the original version, they were clipped into a frame reveal on the inner face of each aluminum sash. As revised, the panel frame was fastened more substantially using receptor channels along the rails of both sash and tamper-proof turn buttons fixed into a slot along the stiles. This modification greatly eased panel removal and reinstallation for cleaning and maintenance. It also produced a cleaner, more finished interior appearance.

Figure 4. The decision to use an integral muntin for the outer glazing and a piggy-back interior glazing panel was an important component of the successful window solution. Sash shown before and after rehabilitation. Photos: Charles Parrott

Before die production was initiated by the manufacturer, a full-scale mock-up of one typical window was custom-built from aluminum stock, duplicating the exterior sight lines of the new extrusions. The window was then compared visually to a repaired and painted existing wooden window, to determine whether the new window sufficiently matched the historic appearance.

After evaluating the mock-up, two additional extrusions were developed at the recommendation of local preservation officials to create a narrower meeting rail for use in certain windows. This was determined necessary since the early 19th-century sash had sight lines much narrower than the later ones—all face widths of sash members were $\frac{3}{4}$″ narrower. Since this was especially noticeable at the extremely narrow $\frac{3}{4}$″ meeting rail of these early windows, an alternate extrusion pair was developed that narrowed the meeting rail to $1\frac{1}{8}$″, for use where the early 19th-century sash were to be replaced. The $1\frac{1}{8}$″ was as narrow as technically possible.

Existing Technology

Various features of the new window involved relatively standard aluminum window industry auxiliary materials and design techniques. These carefully selected components permitted most of the development costs to address visual requirements. These components included:

- block-and-tackle sash balances for the lower sash—the upper sash is fixed but removable for maintenance;
- an insulating, plastic thermal break between the interior and exterior halves of the sash frame;
- plastic "wool" pile with fin seal (at head, meeting rail and jambs) and vinyl bulb (at sill) weatherstripping held in shallow slots in each extrusion to control air and water infiltration between both moving and fixed extrusions;
- silicone rubber-edge blocks to cushion the glass panes against their rabbets in the aluminum extrusions;
- "wet" sealent (silicone) to glaze the small individual lights; and
- custom-colored, rigid PVC snap covers at the jambs to cover the sash balances and provide a weather seal.

The muntin joinery also applied existing techniques to the problem of creating a structural grid capable of adequately supporting independent glass panes (just as in a wooden multiple-light sash.) As in a wooden window, the vertical muntins are continuous from rail to rail, with horizontal muntins individually pieced in between. The continuous vertical member minimizes the introduction of water into the joint, just as it does in a wooden window. The ends of the horizontal bars are coped to the profile of the extrusion, and the vertical

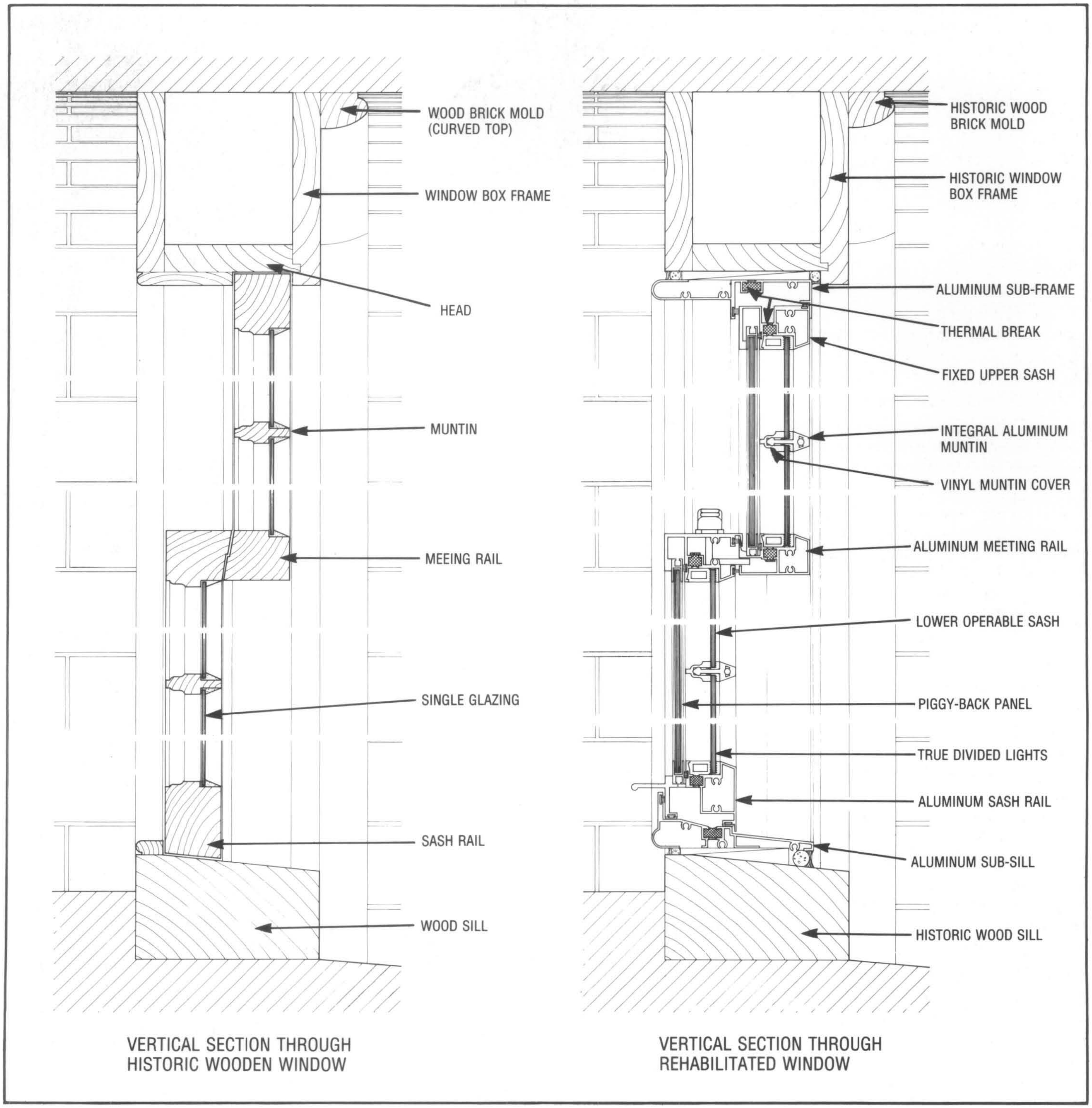

Figure 5. Vertical section of the window shown with old and new sash. Drawing: Timothy Buehner

muntin is drilled to accept a stainless steel pin which is force fit through the connection. An extruded longitudinal hole through the muntin accepts the pin into the horizontal members. Where the muntins intersect the stile and rail extrusions, a welded connection is used to minimize the penetration of water into those members. The interior snap cover is cut and fit in like manner—continuous vertical members with pieced-in horizontal sections coped around the ogee profile.

Window Fabrication and Installation

After approval of the mock-up for its ability to reproduce the appearance of the historic wooden windows, cutting of dies and production of extrusions proceeded during the summer and fall of 1989. A full scale window was constructed for performance testing to the standards of the American Architectural Manufacturers Association (AAMA), the industry's standard-setting body for aluminum windows. The performance evaluation was done by an independent testing laboratory and was certified to meet the specified standards. By spring 1990, the new windows were being installed at the site.

Windows were fabricated in several different sizes according to the dimensions of the sash opening of the existing wooden frames. All new sash had 12 lights or more, replicating the configuration of the original sash.

The aluminum components of the

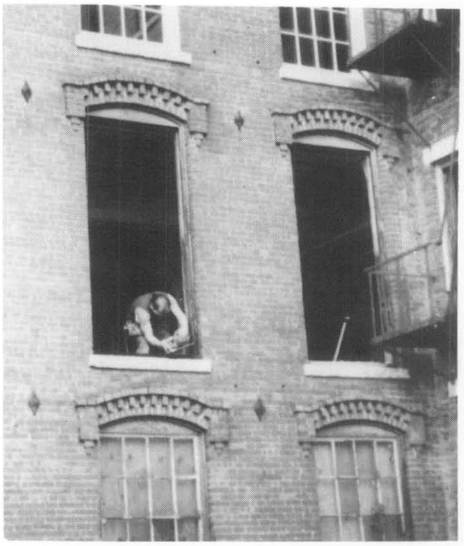

Figure 6. Work on the frames consisted largely of making dutchman repairs to the pulley stiles where required; renailing or replacing brick moldings; replacing some sills; and surface preparation. Photo: Charles Fisher

sub-frames and sash, including piggy-back panels, were first cut and assembled, then painted a light grey color. The assembled windows were shipped to the job site complete with weather-stripping, balances, and glazing.

Site Preparation and Installation

While the new aluminum sash were being fabricated, the work at the site involved the removal of the remaining wooden sash, along with interior stops and parting beads, and the repair, preparation and painting of the frames. New wooden frames were required for openings previously filled with glass block or masonry.

The exterior of the wooden frames were not to be panned or covered in aluminum. Thus it was important both for aesthetic consideration and good paint performance that the wood frames be repaired and surfaces properly finished. Work on the frames consisted largely of making dutchman repairs to the pulley stiles where required; renailing or replacing brick molding; replacing some sills; and scraping, filling and sanding wood surfaces. Painting consisted of priming and two coats of alkyd oil paint *(see figure 6)*.

Installation of the new sash went quickly and smoothly. First, the sub-frame was inserted in the prepared opening from the room side, shimming to plumb, line and level before attaching screws through the head and jambs into the old frame. The sash were then installed and the windows were caulked on both the interior and exterior to complete the work *(see figure 7)*.

Costs

In the first two phases of the project, wooden window frames were repaired and new aluminum sash installed in 522 windows. In addition, new wooden windows were installed in a highly visable entrance location of the first floor. Work on another 1,031 windows remain to be undertaken under the third phase of the project. The standard window averaged about 3½′ by 7′ or about 25 square feet in area.

Because of the large number of windows needing replacement at the Boott Mills, the associated development costs for the new window were within reason—approximately ten dollars per window. Smaller projects can now benefit from the development of this window system. It is estimated by the manufacturer that an order of 100 windows, involving a 12-over-12 light window like that at Boott Mills (3½′ x 7′), would cost today around $28 per square foot or $686, plus shipment and installation.

Evaluation

The sash replacement work undertaken to date at the Boott Mills represents an advance in the way in which aluminum windows can be designed to capture more fully the authentic appearance of historic windows in larger buildings while providing good overall performance. The treatment of the muntins and the sash framing elements, the piggy-back glazing panel, and the retention of the exposed historic wooden frame all combined to create a window that was aesthetically pleasing and that retained many of the important historic qualities of the original windows *(see figure 8)*.

Particularly notable was the development of a true divided-light hung-sash window in aluminum where the muntins reproduced the narrow widths of the historic wooden sash. The use of the piggy back panel to provide double glazing facilitated matching the appearance of the muntin on the primary glazing. By having the primary glazing set within true muntins, the characteristic nuance imparted by individual panes of glass is visible on the outside of the building.

The relatively small size of these mill windows (3½′ x 7′) made possible the use of true-divided lights with aluminum muntins that matched the dimensions of the historic ones. For very large windows, additional engineering and testing would be necessary to establish the feasibility of this approach.

Another important component of the overall success of the Boott Mill window approach was that new rail and stile framing components closely matched the sight lines of their wooden counterparts. This is especially important with respect to the narrow meeting rail typically found in historic windows. The retention of the historic wooden frame as a finish element of the window system was also an important feature of this project. This avoided the normal practice when installing aluminum replacement units of either removing the wood frame altogether or sheathing it in break metal or an extruded pan,

Figure 7. The retention of the exposed outer face of the historic wooden frame and the sill detailing were important qualities of the window treatment. Before and after photos: Charles Parrott

trimmed with an extruded molding. In the latter case, such work results in the widening of the sight lines of the frame. In addition, the use of aluminum at the frame introduces visible and often additional assembly joints.

Figure 8. Replacement window sash after installation. Photo: Charles Parrott

With the Boott Mills project, the old wooden frame served as a convenient anchor for the replacement window system. With no technical need to cover the historic frame on the outside, it was therefore possible to preserve all the visual qualities of the original wood frames. For the developer, the achievement of the perceived operating and maintenance advantages of a new aluminum window system ended at the old frame, thus allowing its retention as an aesthetic and historical feature. Although the new design is set up for use in the existing wooden window frame, the lengthening of the jamb and head extrusions and redesign of the frame would permit its use in cases where the wooden frames are missing or severely deteriorated beyond repair.

As with any successful window solution, there are opportunities for refinement. Modification of the glazing vinyl gasket and associated extrusions was subsequently acknowledged as an area for potential improvement, to approximate more fully the historic muntin profile around the sash frame. The sill of the aluminum sub-frame could also have been detailed better, following more the slope of the original wood sill.

This special application of aluminum window technology in response to historic preservation concerns in the rehabilitation of the Boott Mills was the result of a unique combination of individuals and events. Although the cost of this window solution was about the same as a custom replacement wooden window, in terms of historic preservation, it represents a substantial design and technology improvement in aluminum windows (see Tech Note Windows No. 13).

While in many cases the historic character of specific buildings would preclude the use of such a retrofit solution, it has applicability to many large-scale buildings where the existing windows are beyond repair and where replacement with wooden windows, even though upgraded in thermal performance, is not a viable alternative. It illustrates the need for advance planning and the willingness of the developer, the window manufacturer and preservation groups to work together, as they did in this case, to improve the quality of replacement windows installed in historic buildings. In the end, these parties discovered that to achieve a much closer match of a wooden window, the aluminum window had to be built very much like it *(see figure 9)*.

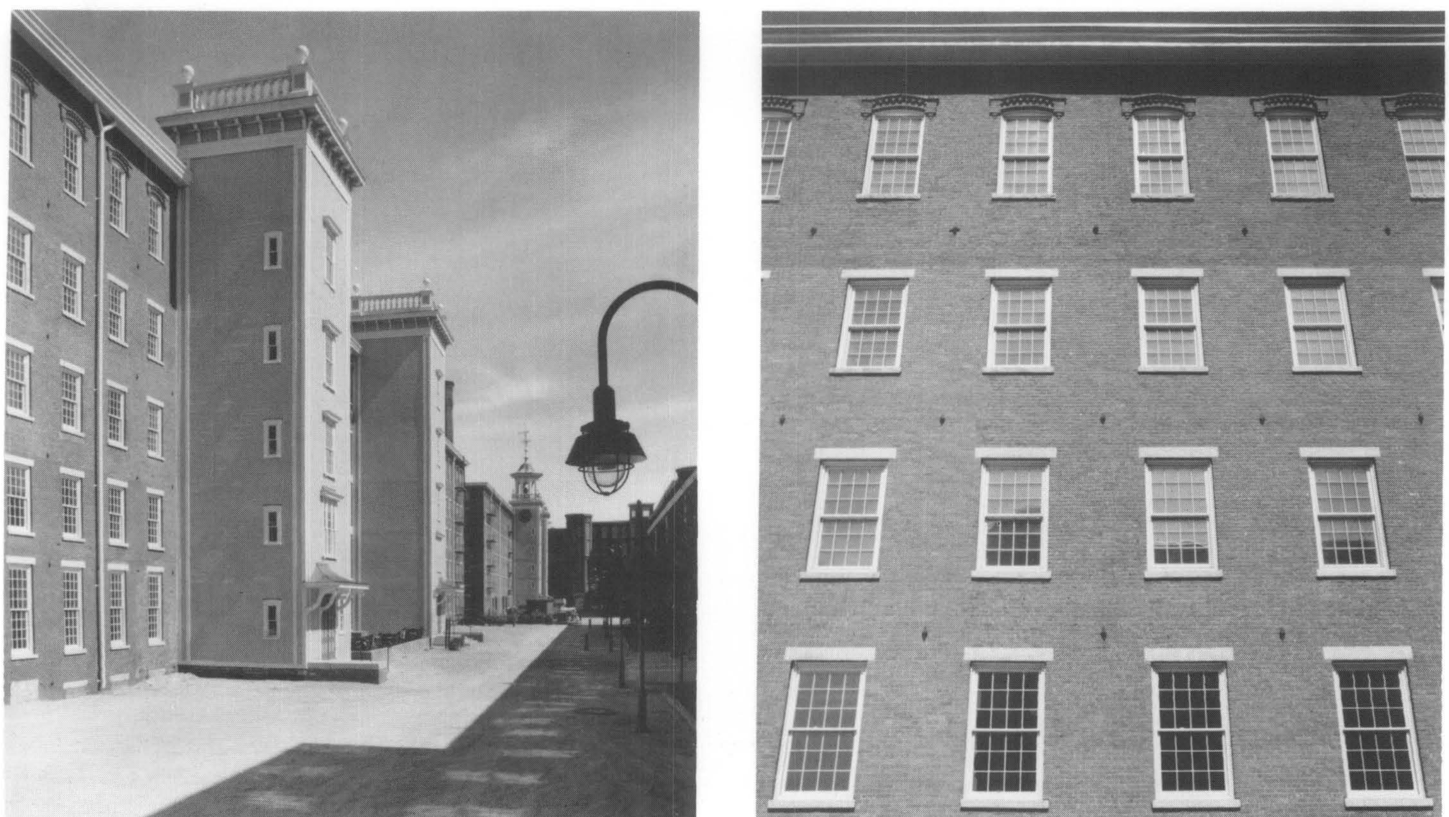

Figure 9. The window solution represents an important advance in the way in which aluminum windows can be designed to capture more fully the appearance of historic windows in larger buildings. Right photo shows wood sash in bottom row and aluminum in the upper three rows. Photos: Jim Higgins ©

PROJECT DATA:

Building:
The Boott Mills
Lowell, Massachusetts

Developer:
Congress Group Properties
Boston, Massachusetts

Project Date:
1988 —

Developer Representative:
Richard Graf, Vice President
Congress Group Properties

Architect:
Amir Mann
Project Architect
Huygens DiMella Shaffer
Boston, Massachusetts

Preservation Consultant:
William MacRostie
Heritage Consulting Group
Washington, D.C.

Window Manufacturer:
Custom Window Company
Englewood, Colorado

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This and many of the PRESERVATION TECH NOTES on windows are included in "The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings," a joint publication involving the National Park Service and the Georgia Institute of Technology. For information write: Historic Preservation Education Foundation, P.O. Box 27080, Central Station, Washington, DC 20038.

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

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

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