A Rediscovery for Fenestration Installation; Correcting the Mistakes of the Past Century

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ABSTRACT

An investigation of the evolution of installation methodologies for fenestration products over the past century leads to new conclusions regarding the value of previous installation methodology. In fact, many of the technology developments over this time period have resulted in a decline in the effectiveness of the fenestration products to divert moisture intrusion into buildings. Fenestration systems of the past (before 1910) were uniquely designed to capture and manage the inevitable moisture leaks that occur, either through or around the fenestration product, and skilled craftsman were employed to ensure this effectiveness. The Industrial Revolution, however, brought on the development of complete pre-assembled fenestration products that were then installed into a building opening, without consideration for the specific details of the installation. As a result of this design change, and combined with lower skilled workmanship, moisture intrustion problems involving fenestration products have become chronic. This study uncovers key design and fabrication changes in fenestration technology over this time period that has resulted in this situation. We then present a revolutionary new installation methodology that takes advantage of the water management principles of the past, combined with the fabrication efficiencies of today.

KEYWORDS

Fenestration, Flashing, Interface, MIFS, Receptor, Water Management, Windows

1 INTRODUCTION

Prior to the twentieth century, fenestrations were created by a two-part mechanism, in which the builder would include the framework of fenestration as part of the building construction process. The fenestration was not an item that was installed separately, but in fact, carefully blended into the "skin", or the envelope, of the structure. To complete the fenestration process, the builder simply installed a sash that was typically produced in a mill. Sashes were stand-alone items, sometimes glazed prior to delivery. Once in receipt of the sash, the builder would simply install them into the framework that was already part of the building and already included sloping sills and complete integration to the building exterior envelope. The integration of the framework included a variety of products to ensure continuity with the siding.

As part of the industrial revolution in the early 20th Centruy, sash manufacturers expanded by creating frames that were pre-assembled and included the hardware and glazing. The sash then were pre-assembled and pre-installed into the framing, thus delivering a complete unit to the builder. This product gives birth to the modern window or fenestration and has been manufactured consistently for the past century. When the completed window fenestration became accepted, the method of integration of the product to the wall was unclear. A variety of techniques have been used that attempt to integrate the entire fenestration into an ever-growing and more complex variety of wall designs. This has led to a number of installation defects and building failures, due to the complexity of using a standard installation method that effectively integrates the fenestration product with the building envelope to prevent moisture intrusion. For many reasons, making the fenestration as a complete unit that includes frame, sash, and hardware, as a permanent part of the envelope is highly problematic.

This presentation will spotlight a completely new method of installing fenestration products, the principle of which goes back more than one hundred years, but encapsulates and enhances current methods of integration with the wall envelope. The new method features a permanent frame to the building, which allows simple and non-invasive replacement of the fenestration product at the end of its useful life. This frame is constructed of a highly durable polymeric material that fully encloses the fenestration product in a continuous, moisture tight encasement that will be much more robust than the methods of integration today. The audience will see a demonstration of the integration of the frame into the wall envelope, and then see the installation of self-contained sash fixtures, literally plugged into the frame, and easily removable.

There is a plethora of benefits to this new method. For example, this method will provide enhanced moisture management, and thermal / accoustical performance. Installation benefits will also be realized, such as a simplified, more standardized method that enables more flexible sequencing of the fenestration installation. Thus, damage to the fenestration product is greatly reduced by intsalling in a sequence that reduces exposure to parts of the construction phase, such as installation of the siding, that can cause premature damage to fenestration product. In addition, the cost of installing fenestration may be reduced, as the installation method will cater to a lesser skill level. Initially, these frames are more suited to standardized fenestration sizes and configurations, making the pre-fabricated or large volume builder the optimal user for this system.

2 BACKGROUND – Evolution of Window Design

Figure 1. Example of typical details available circa 1900 through published books usually written by architects. This method always had the sill running through and beyond and under the balance box and pulley rails, by at least 150 mm, approx. 6 inches, thus diverting corner leakage to the outside, well beyond the plane of the sash.

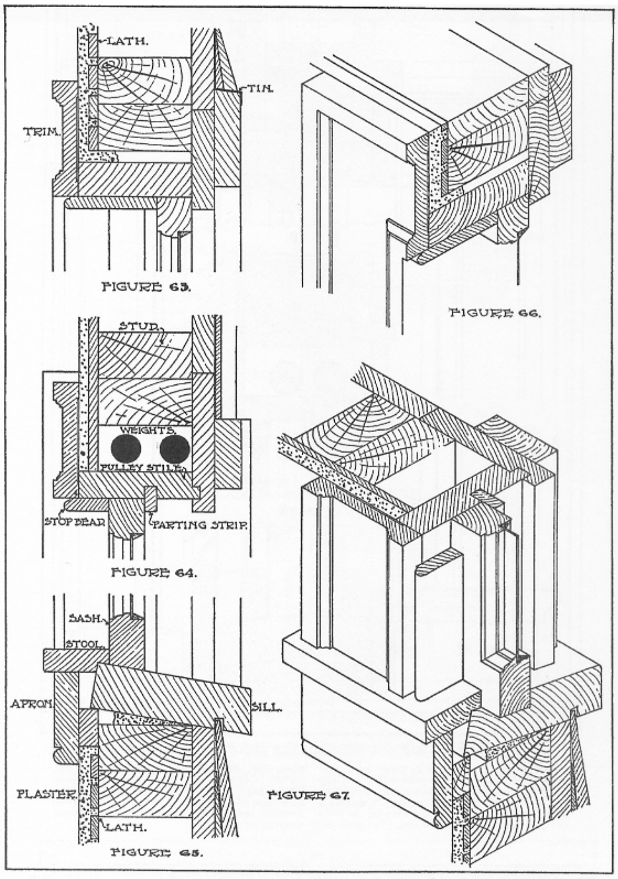


PLATE 51—CHEAP DOUBLE HUNG WINDOW

Arrangement and construction for ordinary inexpensive work, using skeleton frame without ground casings. Fig. 63, section through window head. Fig. 64, section through jamb. Fig. 65, section through sill. Fig. 66, isometric view of window head. Fig. 67, isometric view of jamb and sill. Note tin flashing above window and rabbeted sill to keep out water.

As part of the industrial revolution at the beginning of the twentieth century, evolution dictated that the fenestration products we know today - a single unit consisting of the frame and the sash - was born. As a result of this, the construction methods changed, becoming more industrialized and considered improved. Prior to the turn of the twentieth century, fenestrations were created by a two-part mechanism: Part 1 - the builder, in the construction process, would purchase from a mill those elements that would become the frame and that would be integrated into the building's wall. The frame was not an item that was installed separately and afterward, but in fact, was carefully blended into the "skin", or the envelope of the structure. Those mill items included sills, stools, aprons, jambs or pulley jambs, balance box, parting beads, head stock, blinds stock, and finish trim. Part 2 - to complete the fenestration process, the builder simply installed sash that was typically produced in a mill. Sash were stand-alone items, sometimes glazed prior to delivery.

The builder, once in receipt of the sash, would simply install them into the framework that was already part of the building and already included sloping sills and complete integration to the building exterior envelope. The integration of the framework included mortar grounds, lead or tin flashing materials, and a variety of products to ensure continuity with the siding. Hardware was developed, that would allow the sash to either be balanced for vertical operation or pivoted on any one of four sides to create a variety of operability and ventilation. See Figure 1.

As part of the industrial revolution, fenestration manufacturers replaced sash manufacturers and mills that typically supplied the building trim package, thus a completely assembled fenestration product with glass and hardware was delivered to the job site. These early products gave birth to the modern window or fenestration, which has been manufactured consistently for the past fifty years. The manufacturers addeded features such as integral and non-integral installation fins and a variety of hardware, which made the fenestration easy to operate. As the completed window fenestration became accepted widely in construction, the method of integration of the product to the wall became considerabley more difficult, as an interface needed to be installed, which in essence connected the modern fenestration with the wall. A variety of techniques have been used over the twentieth century, which ultimately ends up with our current methodology, which attempts to integrate the entire fenestration into an ever-growing and more complex variety of wall designs. To this day, we have been unsuccessful in any number of schemes that interface fenestration with the building envelope, as evidenced by the growing number of construction defect claims related to intrusion of moisture through windows and their interfaces.

This paper spotlights the substantial difficulties that resulted when the frame and sash became one unit. Making fenestration as a complete unit that includes frame, sash, and hardware, as a permanent part of the envelope, created unique complications, as well. Fenestration, like many components in a wall, has a useful and predictable life, which is substantially shorter than that of the building it is intended for. Thus, integrating the entire fenestration unit in such a manner as to cause destructive intrusion made it difficult and expensive to remove the product for replacement.. Standardizing a fenestration frame without knowing the installation environment or location of the fenestration in the building was another problem created from this development. Construction sequencing that requires several trades, which typically do not communicate with each other, to work on the rough opening, results in failure to effectively integrate the fenestration with the other wall components; for example, the carpentry, sheathing, membranes, flashings, sealant, and exterior cladding are typically installed by separate contractors. As a consequence, proper sequencing is often compromised.

Fenestrations as we know them today, have limited durability. The consensus is that durability of fenestration would be equal to other items integral to the building, such as water heaters or roofs, which typically have a ten-to-twenty-year life cycle. It is known that the petrochemical portions of fenestration, such as weather-stripping, gasketing, and sealants have limited life cycles, which, when failed, greatly degrade the performance of the fenestration and shorten its useful life. Because of this, one has to wonder: why should it not be as easy to replace a fenestration product as it is to replace other less durable components of the wall, such as light fixtures? Why shouldn't a fenestration product be removed and replaced as simply as or more simply than a water heater, which has approximately the same life expectancy? Shouldn't it be expected to be able to remove a fenestration without causing destruction to a wall and its watertight integrity?

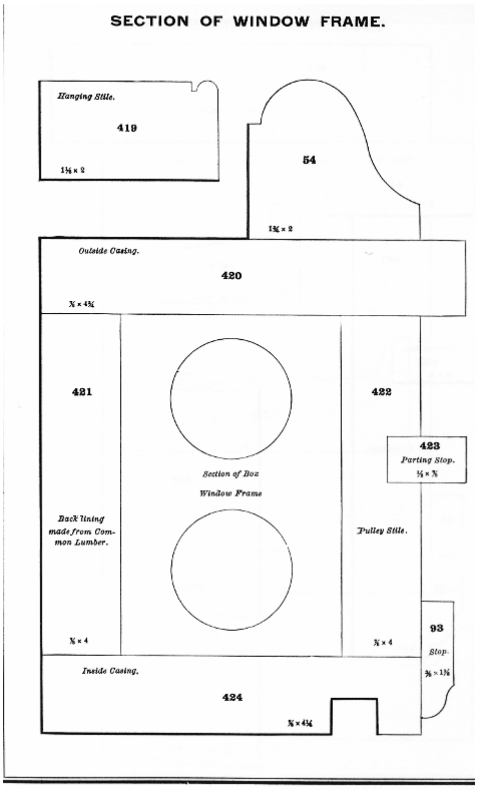
This paper will spotlight a completely new method of installing fenestration, the principle of which goes back more than one hundred years, but encapsulates and enhances current methods of integration with the wall envelope. This method allows a permanent frame to the building, while enabling simple and non-invasive replacement of the fenestration product at the end of its useful life. The integration of the frame into the wall envelope will be demonstrated, followed by the installation of self-contained sash fixtures, literally plugged into the frame, and easily removable.

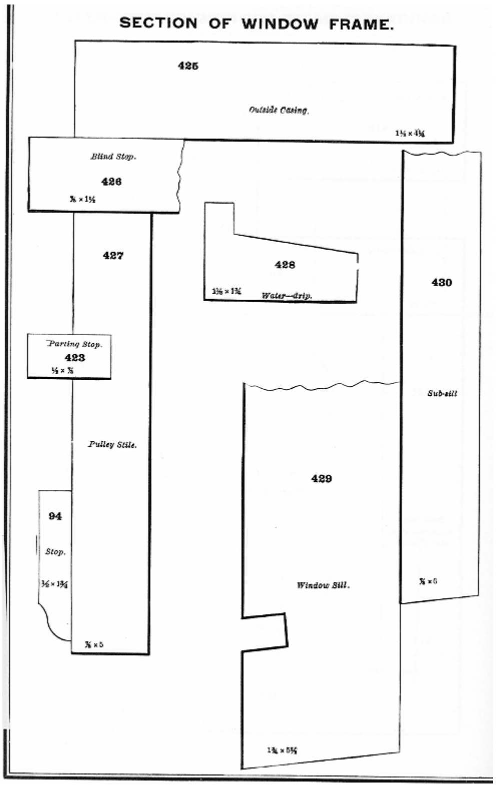
3 EVOLUTION OF FENESTRATION INSTALLATION METHODS AND STANDARDS

At the turn of the last century, books on architectural details were plentiful, accurate, and provided clear assembly details for millwork members. All of the members of a fenestration frame were clearly identifiable, readily avialable at all mills, and easily understood by the carpenter. See figures 2 and 3. Through post-World War II, installation techniques were taught father-to-son, journeyman-to-apprentice, with the wide use of the guild method.

Post-World War II brought about an enormous building boom and the introduction of new materials, which had not been traditionally used in buildings, or new materials that had been previously unavailable. Some examples of new building materials are aluminum, polymer materials, and a complete subset of plastics and chemistries that make up today's building materials. Even the fenestration itself goes from wood to metals to plastics to composites. Newly manufactured fenestration that is comparable to that of one hundred years ago do not exist today, with the exception of custom historic replicas.

Figures 2 and 3. Typical shapes readily available from mills, circa 1900.





Skilled labor and craftsmanship has slowly deteriorated and become largely unavailable, as the post-World War II building boom erupted, the demand for skilled craftsmen was outstripped by the building demand. By 1970, guilds and unions lost membership and a further decline in qualified craftsmen resulted. To overcome this dilemma, we start to see the development of some manufacturers' instructions, most of which are developed on the commercial side of the building industry. Other than the few manufacturers that offered installation instructions prior to 1990, there was no consensus standard for installation of fenestration, nor were there training courses or vocational education in this area. In 1992 the California Association of Window Manufacturers started developing the first consensus-built installation instructions for fenestration installation. That document was CAWM 400-95, Standard Practice for the Installation of Windows with Integral Mounting Flange in Wooden Frame Construction.

In 1995, and using the CAWM 400-95 as a template, ASTM started work on a consensus standard that is now known as ASTM E 2112-01, Standard Practice for Installation of Exterior Windows, Doors and Skylights. In 2002, ASTM starts work on ASTM E 2112, Revision 1, which is currently being balloted. In 2002, AAMA published AAMA 2400, which is loosely based on CAWM 400. Lastly, the Canadian Standards Association (CSA) developed and continues to develop CSA A 440.4, Window and Door Installation. Table 1 describes the advantages and disadvantages of each of these systems.

Also included in Table 1 is the new methodolgy proposed in this document, named the Modular Insert Fenestration System, or MIFS. This system captures many of the design & water management advantages of the pre-industrial revolution design, but in a modernized form that takes advantage of mass production efficiencies. The MIFS concept is described in more detail below.

Table 1 – Overviw of Fenestration Installation Methods & Standards, with key features, advantages and disadvanatages.

Standard Methods	*Description*	*Advantages*	*Disadvantages*
CAWM 400	Addressed one type of fenestration with integral fin, in one type of wall, wood framing, and 4 possible interfaces.	Was simple and emphasized integration of interface with fenestration.	Limited to one type of window. Barrier mehtod: Presupposed there was no leakage from corners of fenestration.
AAMA 2400	Same as CAWM 400, except it generalized the interface methods into two types.	Was simple and emphasized integration of interface with fenestration	Limited to one type of window. Barrier method: Presupposed there was no leakage from corners of fenestration.
ASTM E 2112-01	Windows, Doors, and Skylights, mostly Residential construction. Includes a variety of window frame types and walls.	User can integrate with both barrier and drainage type walls. Gives precise information on sealants, anchoring, and related aspects of installation, recognizes incompatibilities of dissimar materials.	Barrier System: Does not recognize leakage at window corner or around / through wall interface, integration to the wall only with finned windows, only integration of fenestration with wall system.
ASTM E 2112-Revision 1	Same as above	Includes Drainage Method: Assumes that incidental water enters the wall cavity at window joinery or interface, adds pan flashing details with variety of material combinations.	High level of skill is required, costs more than other methods. Window leakage is drained to the Water-Resistive Barrier inside the wall cavity.
CSA A440.4	Window and door installation, based on rainscreen method of wall design	Gives techniques for mulled windows, requires pan flashings of sorts.	Can allow leakage beyond the window sill and is over-reliant on sealant.
MIFS System	Requires a receptor for all fenestration including windows, doors, and other through-wall penetrations.	Simple standardized method, flexible construction sequen-cing, delivers drained water and window corner leakage to the exterior cladding, allows for non-destructive removal of fenestration.	Limited flexibility of size and shape with initial offerings.

4 THE MODULAR INSERT FENESTRATION SYSTEM (MIFS)

The Modular Insert Fenestration System consists of two parts: 1) a ‘receptacle’, which is a rigid or semi-rigid frame that is sealed to a rough opening of a building structure, such that it becomes a permanent, moisture-proof part of the building envelope, and 2) a ‘fenestration product’, such as a window, door, or any other object to be inserted into a building structure, which is designed to connect to the MIFS receptacle in a manner that is structurally sound, yet provides for easy installation and removal of the fenestration product.

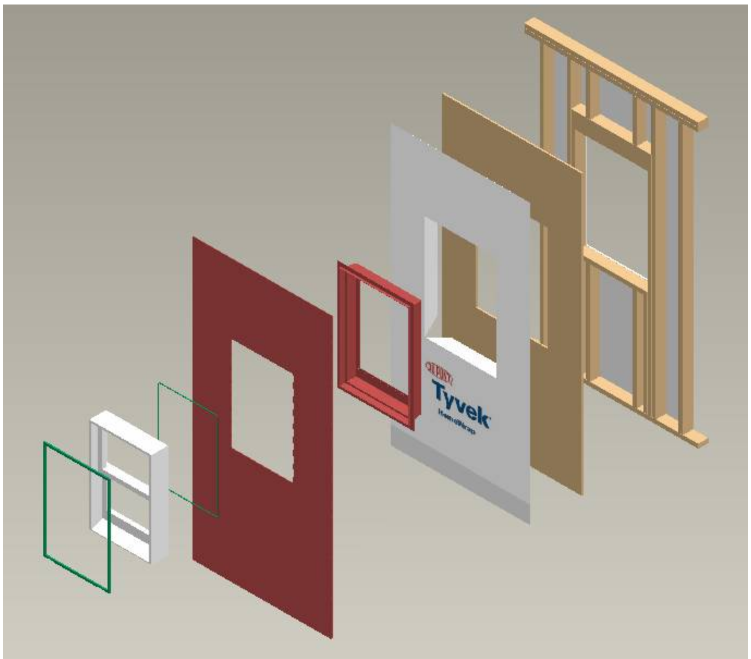
Thus, the fundamental MIFS concept is for the receptacle to form a continuous enclosure around the fenestration product, completely isolating it from the building envelope. The gap between the receptacle and the fenestration product will form a pressure equalized cavity, sealed at the interior joint between the fenestration product and the interior frame of the receptacle, providing a drainage path directed out the exterior sill of the receptacle for any moisture intrusion that occurs at or around the fenestration product. A schematic of the MIFS system with the insert receptacle is shown on Fig. 4, where the insert receptacle (shown in red) is installed and made a permanent part of the building opening. The fenestration product can then be installed at any time during the construction sequence, either before (as shown on Fig 4) or after the siding.

Key advanteges that are anticipated for the MIFS concept are highlighted as follows:

- **Provides a Robust Moisture Seal** – the seal is at the interior of the receptacle, which is protected from environmental exposure. The resulting fully encapsulated, pressure equalized chamber will direct any moisture intrusion on or around the fenestration product to the exterior. In addition, we expect that thermal, acoustical, and hygrothermal transfer performance is enhanced because of the isolation of the fenestration from the wall.
- **Greatly Improved Installation Method** – fenestration products can be inserted into the receptacle through screws or clamping mechanisms in a greatly simplified, more standardized method than exists today.
- **Flexible Installation Sequencing** – the receptacle will be installed, plumb, level and square in the wall opening first. The fenestration product can then be installed at any time during the construction process. Construction critical paths are enhanced, allowing perfect on-time sequencing. This will protect the fenestration product, which is very expensive and fragile, from damage during harsh conditions during the construction phase, such as exposure to siding, bricks, electrical cords, tools, etc. . It is possible to plug in the fenestration sash module after the building has been completely finished, painted, cleaned; thus eliminating damage to the fenestration product by those processes.
- **Material Durability** – the MIFS receptacle will be produced from a material that will be durable for many years as a permanent part of the building envelope. It will provide structural integrity through environmental exposure and be of sufficient toughness to withstand hammer impact and other harsh exposure (falling bricks) during the construction phase
- **Numerous Cost Advantages** – The simplified, standardized installation practice will enable better results with a lower skilled workforce, which is typically what is available. Installation time will decrease, as well as loss due to damage to the fenestration product; and the cost of incorrect installation, both during the construction phase and in the life cycle of the building, will be reduced. This is a critical and key point, as the skill levels of the craftsmen of yesteryear have not transferred to the present, and we can no longer rely on skilled personnel for the future.
- **Enhanced Ability to Replace Fenestration Products** – Fenestration products will be easily removed without the need to disrupt the siding building, as is the case with flanged windows today. Thus, a homeowner can take advantage of new advances in glazing technology or 'seasonal' glazing choices.
- **Full Integration into the Building Envelope** – the receptacle will contain robust flanges that will be fully integrated and sealed (through self-adhered flashing or adhesive means) onto the building envelope. Because this material will be more durable than current flanges and the receptacle will be installed and squared into the building rough opening before the fenestration product (which is heavy and difficult to install correctly), the installation of the receptacle will be more robust.

This system is currently in the prototype phase and end use testing to prove out and demonstrate the advantages listed above will be done through independent test labs in the next several months. A concern may lie in the ability for the MIFS frames to conform to all the sizes and shapes available to fenestration products. Thus, the initial offerings will likely be more suited for large volume builder or pre-fabricated construction, which utilize a more limited range of fenestration configurations. As this system becomes more widely accepted, a broader offering of size and shape will become more feasible.

Figure 4: Schematic of MIFS insert receptacle system. The receptacle is permanently installed into the rough opening and window can be inserted at any time during the construction sequence (i.e., either before or after the siding is installed).



5 SUMMARY AND CONCLUSIONS

Over the past century, the design and installation of fenestration products have evolved in such a way that production efficiencies have greatly increased, which of course is by necessity due to the massive growth in building construction. However, these same production efficiencies have resulted in a loss in the fundamental design principles practiced in pre-industrial revolution techniques, in that the mass-produced fenestrations of today are poorly designed to manage the inevitable moisture intrusion in and around the fenestration. As a result, building failures at the window-wall interface are common. A new methodology, named the Modular Insert Fenestration System, that combines the design principles of the past with the mass-production efficiencies of today, has been developed. This methodolgy has the potential to usher in a new, more robust, era for fenestration installation and performance in the 21st century.

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