LIGHTER DAYS, BRIGHTER DAYS

Daylighting as an Energy-saving Tool

By Randy Heather

Daylighting, a term that has become synonymous with the use of natural light in buildings, created a flurry of literature beginning in the 1980s and continues to be one of the most researched topics in construction.

New curtain wall systems, sun control products, glazing materials, and skylight technology have created an opening to new design and construction opportunities. And, perhaps not as widely understood, is the fact that daylighting has become an important energy-saving tool.

Effective daylighting design introduces natural light while balancing the elements of artificial lighting, heat loss through glazing, solar heat gain, and internal sources of heat gain. To be an effective energy-saving tool, daylighting must be integrated with electric lighting, lighting controls, and heating, cooling, and ventilation systems.

Many glazing contractors say that daylighting is still perceived as “energy wasting,” but in reality it has become an important part of energy conservation programs in construction projects across the country. According to the Public Utilities Commission in California, energy efficiency programs in building construction – many of which are devoted to daylighting – saved 2.3 billion kWh of electricity from 1999 to 2001.

According to the California consultancy Energy Design Resources, skylighting offers potentially large energy savings. Past studies showed that the average grocery store, for example, may save up to 32 cents per square foot in energy savings through daylighting; schools typically save about 23 cents per square foot; and industrial buildings save up to 12 cents per square foot.

According to the U.S. Department of Energy (DOE), artificial lighting accounts for as much as 10 to 20 percent of energy consumption in industry. The DOE also reports that daylighting can reduce those costs significantly.

Once used primarily in museums, boutiques, and architectural showplaces, today, daylighting is an increasingly integral part of building design. Studies have shown that daylighting as part of an integrated design can not only reduce building energy consumption but also improve the health and performance of those who work within it.

Four different studies by the Heschong Mahone Group of Fair Oaks, California, concluded that the presence of natural light can improve student performance in schools, worker performance in office buildings, and sales in retail stores.

The educational study and follow-ups show that elementary students in classes with the most natural light showed about a 20 percent learning improvement over students in classrooms with the least amount of natural light. The Heschong Mahone Group’s studies of retail sales concluded that sales were positively affected and that

The use of curtain wall, such as at Empire College in Saratoga Springs, New York, is one way to bring natural light into a building.

the profit from these increased sales could be as much as 19 percent higher in stores with daylighting.

Design and Construction

Due to the fact that natural daylight creates less heat per unit of illumination than many artificial lights, daylighting can reduce cooling costs when it replaces artificial lighting. And, as part of a passive solar heating system, sunlight can provide additional building heat to reduce the cost of heating in winter.

However, if glazed areas that allow daylight into a building are not designed properly, they can contribute to heat loss in the winter and undesirable heat gain in the summer, leading to added heating and cooling costs, which may offset any savings from decreased lighting costs.

Therefore, daylighting designs must be analyzed to ensure that the energy savings achieved from reduced artificial lighting are not lost through increased cooling or heating needs. This analysis involves some understanding of how a given glazing system transmits visible light and heat.

First, visual transmittance (Tvis) is a measure of the portion of visible light that passes through a fenestration product. This is perhaps the most important characteristic to determine when looking to displace the use of artificial lighting for energy savings.

Second, fenestration products transmit heat. The solar heat gain coefficient (SHGC) is the measure of the amount of heat associated with the transmitted light. The higher the SHGC value, the more heat transmitted. Fenestration products also transmit heat through conduction, as well as convection through the material itself. The measure of the amount of heat moved in this manner is denoted as the U-factor. A higher U-factor means that more heat is transmitted this way.

When dealing with buildings in predominantly cold climates where the cost of heating the building is the major cost, the U-factor is the characteristic that should be considered. In predominantly warm climates where air conditioning is the principal cost, the SHGC is more important than the U-factor.

When considering the SHGC, look for a product that has a light-to-solar heat gain (LSG) ratio of more than 1. The LSG is an index of how much light a system offers in proportion to the amount of solar heat transmitted. A ratio of 1 or more indicates the system is producing more light with less heat, thus making for an efficient product.

Vision vs. Daylighting Glazing

It is important that designers and contractors consider vision glazing versus daylighting glazing when planning a building. The two perform different functions. Vision glazings usually use lower transmittances and are transparent to provide views of the outdoors. Daylighting glazings, which are used to provide interior illumination, generally have a higher visible transmittance and are translucent, which allows them to diffuse light. This ability to diffuse the light is known as haze. For effective distribution, the haze percentage of the glazing should be above 90 percent.

The Mall at Millennia in Orlando, Florida, features a massive skylight system.

Daylighting falls into two general categories: sidelighting and toplighting. For buildings with long, shallow floor dimensions, it is feasible to daylight up to 70 percent of the footprint with a sidelighting system. When reviewing a sidelighting system, consider the following options:

- Light shelves to throw the light deeper into the building,
- Orientation of the window with respect to the path of the sun, and
- Exterior light shades to control direct light and heat and provide shaded, indirect light to enter the building.

Toplighting feasibly can light more than 90 percent of a building area through clerestories, skylights, and roof monitors. Natural light through rooftop openings can deliver light deeper and more evenly, and their orientation is not dependent upon the building orientation. When considering toplighting systems, it is necessary to determine how to diffuse the entering light. Use glazings with a haze of more than 90 percent or place diffusing structures below large, clear-glazed openings to break up the direct light.

To be cost-effective, lighting controls are a must. The savings on lighting and cooling must offset the costs of buying, installing, and operating daylighting features in a reasonable amount of time. Usually, the payback period is from two to five years, but this depends on the percentage of the total construction budget that is devoted to daylighting. And the amount of energy savings always depends on location, climate, energy load, and the design of the building.

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FENESTRATION INSTALLATION:

Somehow We Have Forgotten the Past

By Barry G. Hardman and James D. Katsaros, PhD

Evolution of Window Design

Prior to the turn of the twentieth century, fenestrations were created by a two-part mechanism:

- **Part 1 –** In the construction process, the builder purchased from a mill those elements that would become the frame and that would be integrated into the building's wall. 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 a sash that was typically produced in a mill and sometimes glazed prior to delivery. The integration of the built-in framework included sloped sills that ran past the jambs and drained to the exterior of the cladding. The integration 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 either to be balanced for vertical operation or to be pivoted on any one of four sides to create varied operability and ventilation. See *Figure 1.*

As part of the Industrial Revolution in the early 20th century, however, in our zeal for efficiency and design improvement, evolution dictated that the fenestration product we know today – a single unit consisting of the frame and the sash – was born. Now the sash was pre-assembled with glazing and pre-installed into a frame. The complete assembly, including hardware, was manufactured by a single fenestration manufacturer and delivered to the builder or the job site.

Fenestration products have been manufactured consistently this way for the past century. Construction methods have changed, becoming more industrialized and supposedly "improved." However, in this process, we forgot the water management design concepts of the past and failed to consider installation methodologies to match the new products.

For many reasons, making the fenestration a complete unit that includes frame, sash, and hardware as a permanent part of the envelope, is highly problematic. When the complete window fenestration became accepted, the method of integration of the product to the wall remained 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

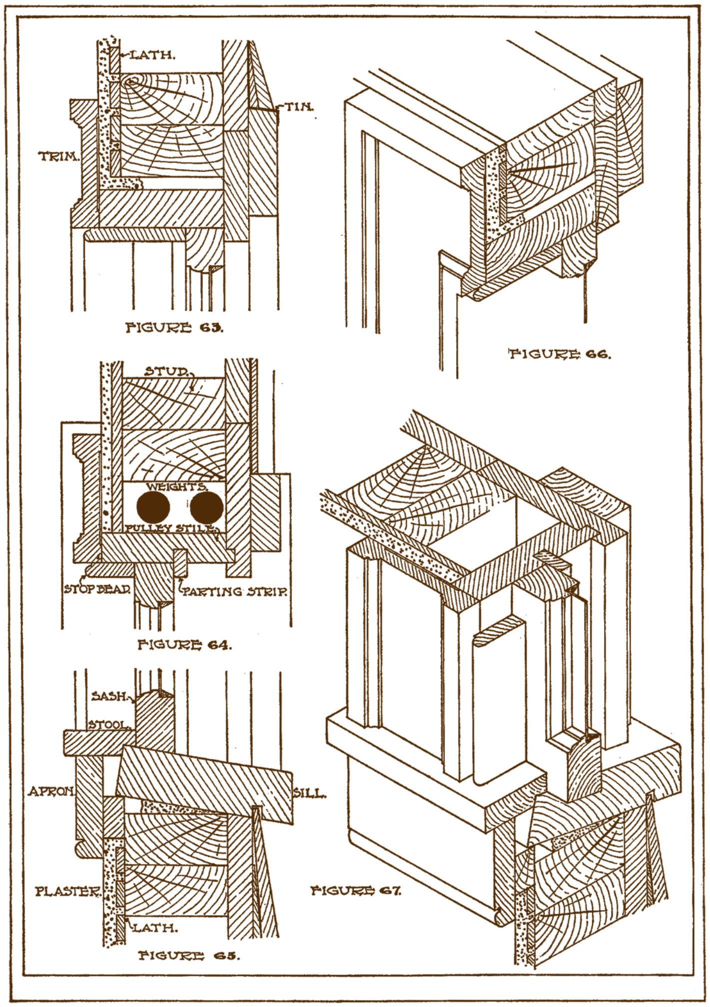


PLATE 51—CHEAP DOUBLE HUNG WINDOW

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.

Figure 1 – Example of typical details available circa 1900 through published books usually written by architects. This method always had the sill running through, beyond, and under the balance box and pulley rails by at least 150 mm (approximately 6 inches), thus diverting corner leakage to the outside, well beyond the plane of the sash. (Radford's Portfolio of Details of Building Construction, 1911.)

a number of installation defects and building failures due to the lack of water management installation details that would effectively integrate the fenestration product with the building envelope to prevent moisture intrusion. Construction sequencing was not thought out.

Manufacturers added features such as integral and non-integral installation fins and a variety of hardware that made the fenestration easy to operate. As the completed window fenestration became widely accepted in construction, the method of integration of the product to the wall became considerably more difficult because 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 20th century that ultimately led to our current methodology. This process 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 article spotlights the substantial complications that resulted when the frame, sash, and hardware became one unit as a permanent part of the envelope.

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.

Looking Realistically at Durability

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 create a permanent installation makes it difficult and expensive to remove the product for replacement. The consensus is that durability of fenestration should 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 weatherstripping, gaskets, and sealants, have limited life cycles which, when they fail, 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 we expect to be able to remove a fenestration without causing damage to a wall and its watertight integrity?

Evolution of Fenestration Installation and Standards

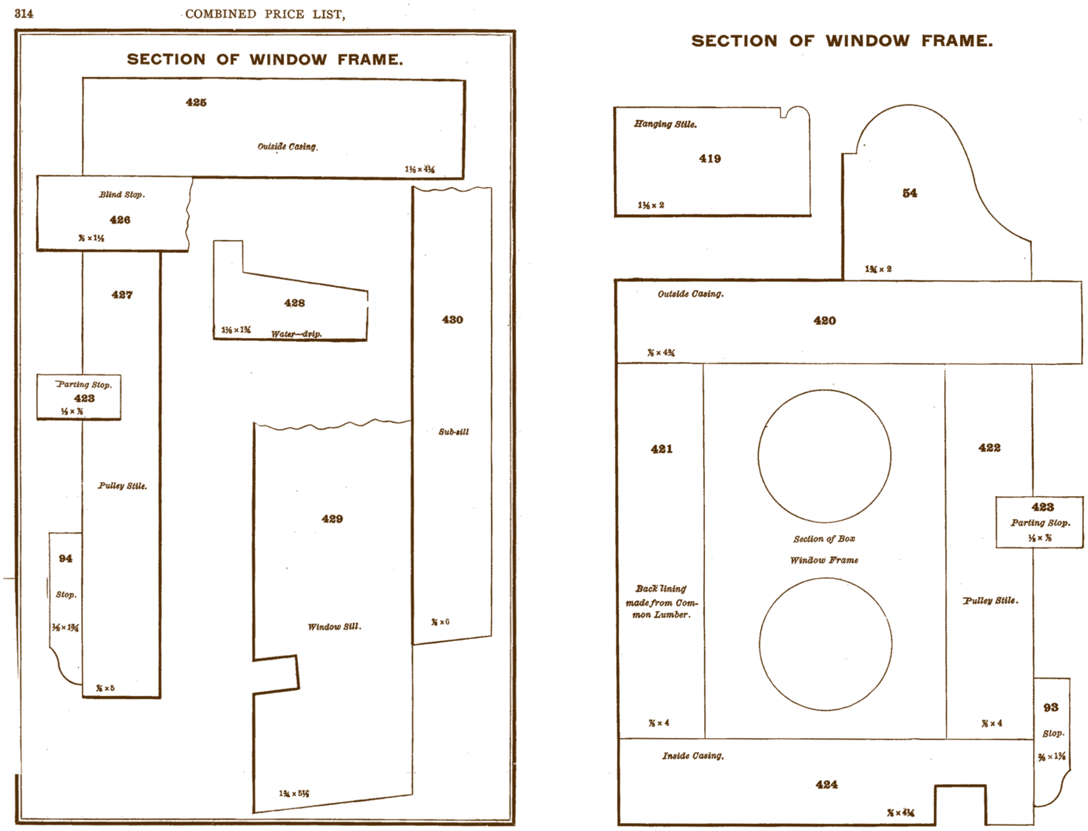
At the turn of the last century, books on architectural details were plentiful, accurate, and provided clear assembly details for millwork members. All of the members of a fenestration frame were clearly identifiable, readily available at all mills, and easily understood by the carpenter (see *Figures 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 introduc-

Standard Methods	Description	Advantages	Disadvantages
CAWM 400	Addressed one type of fenestration with integral fin, in one type of wall, wood framing, and four possible interfaces.	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.
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 dissimilar materials.	Barrier system: Does not recognize leakage at window corner or around/through the wall interface. Integration to the wall only with finned windows. Only integration of fenestration with wall system.
ASTM E 2112-07	Windows, doors, and skylights. Mostly residential construction. Includes a variety of window frame types and walls.	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 windowsill and is over-reliant on sealant.

Table 1 – Overview of fenestration installation methods and standards, with key features, advantages, and disadvantages.

tion of new materials that had not traditionally been 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. Even fenestration itself ranges from wood to metals to plastics to composites. Newly manufactured fenestration that is comparable to that of 100 years ago does not exist today, with the exception of custom historic replicas.



Figures 2 (above left) and 3 (above right) – Typical shapes readily available from mills, circa 1900. (Mulliner Catalog of 1893, republished in 1995.)

Skilled labor and craftsmanship have 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 activity. By 1970, guilds and unions lost membership and a further decline in qualified craftsmen resulted.

To overcome this dilemma, we started to see the development of some manufacturers' instructions, most of which were written on the commercial side of the building industry. With only a few manufacturers offering 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 (CAWM) started developing the first consensus-built installation instructions for fenestration installament. That document was *CAWM 400-95, Standard Practice for the Installation of Windows with Integral Mounting Flange in Wooden Frame Construction.*

Using CAWM 400-95 as a template, ASTM started work in 1995 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 started work on *ASTM E 2112, Revision 1*, which is currently published as *E 2112-07*. 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.

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.

Builders, architects, developers, and window designers must come up with new systems that allow for simple exchange of the window without damaging the wall and the interfaces in the process. We must make room to exchange old windows for new, energy-efficient models. Windows should never be installed permanently as they are today, literally buried by the claddings, membranes, and finishes. These new installation technologies would be extremely beneficial, and we are still in the process of developing new systems that will manage water and still allow for simple removal and exchange of fenestration.

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