Reprint of Traditional Building Article, 1996
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High Performance Glazing in Custom Window and Door Applications

"Look Beneath The Surface; Let Not The Several Quality Of A Thing Nor Its Worth Escape Thee". Marcus Aurelius Antonius

Often, I have to decide whether or not to recommend the use of high performance glazing materials, not only in historic replications but in most custom contemporary and classical architecture window and door applications. It's certainly a complex and debatable issue, and my recommendations are based on two primary factors; Design Conformance and Cost.

Design Conformance is typically an aesthetic issue but also includes various structural requirements that may be driven, for example, by required historically accurate materials and fabrication methods.

Aesthetic requirements or architectural fenestration is the coordinated arrangement, proportion, and design of windows and doors in a building including the considerations of dimensional criteria, molding profiles, paint colors, glazing appearance and, to some extent, hardware.

Structural requirements include the use of Materials (i.e. wood species, glass types, preservative treatments, hardware and weather-stripping), Fabrication Methods (i.e. coped and pegged mortise and tenon wood joinery), Operating Function (i.e. a doublehung function with weight and pulley counterbalances), and Performance Standards (i.e. energy efficiency, structural loading, air and water infiltration, impact resistance, etc.).

Cost, of course, is a ratio. A rate of return, if you will. What are the benefits generated by a specific investment? And remember, benefits are often more than mere dollars and cents. While energy efficiency, performance and maintenance costs are tangible, the value of an attractive design or an approved permit should not be underestimated.

What is High Performance Glazing?

Typically, High Performance Glazing includes the use of materials that provide above average Structural Load capability, Impact Resistance, Resistance to Sound Transmittance, Light Wave Reflectivity and Energy Efficiency.

Structural Load requirements typically address wind loads. For example, at ground level, a 25 mph wind creates 1.56 lbs. psf of uniform load. A 50 mph wind creates 6.24 lbs. psf. , an 88 mph wind creates 20 lbs. psf, a 125 mph wind creates 40 lbs. psf and a 153 mph wind creates 60 lbs. psf..

Impact Resistance is qualified by esoteric definitions. Glass that can withstand the impact of a specific weight dropped from a specific height is one method of analyzing the category. Bullet resistance by caliber, projectile weight and powder charge is another. In Dade County, FL, an entire window and door unit is often required to resist a small missile impact of 30 pieces of #6 aggregate roof gravel propelled through a canon at 50 mph. The Dade County large missile impact standard requires the window or door unit to resist a 9 lbs. southern pine 2x4 shot like a dart at 34 mph.

Sound Transmittance measures the transmission loss of a specified range of sound frequencies from one side of a window or door to another. Typically, the more dense the glass and the more layers of glass in varying density, the greater the resistance.

Light Wave Reflectivity controls to various frequencies in the light spectrum typically from Ultra Violet light to Infrared light. Laminated glass reflects Ultra Violet light, Low E glass reflects radiant heat or Infrared light. Ultra Violet light can fade color from fabric. Infrared light creates heat loss or gain. Mirrored and tinted glass reflect the visible light spectrum.

Energy Efficiency is typically enhanced by using Multiple Layers of various glass types or composite films, with and without a combination of reflective properties, to create a sandwich of neutrally pressured airspace between the layers of glass. Sometimes the airspace can include inert gas to further enhance the resistance to heat transfer. That resistance to heat transfer is most often listed as R-Value or U-Value. U-value is simply the inverse function of R-Value. In other words, the higher the R-Value and/or the lower the U-Value, the more energy efficient the unit. Multiple Layering (i.e double and triple glazing) is typically achieved in two distinct fabrication techniques.

The **first** and oldest method of multiple layering is the use of a single glazed Primary Sash with one layer of glass in it, in combination with a secondary Storm Sash containing another single layer of glass. Recent variations of this method replace the Storm Sash with what has been commonly called a Storm Panel. Typically, a Storm Panel is a piece of glass, sometimes in a frame and sometimes not, that is let in to either the outside or inside face of the Primary Sash.

The **second** method, and one that is becoming the most widely used in today's window and door markets, is the use of what is commonly called a sealed Insulating Glass unit (I.G.). Sealed I.G. typically includes a non corrosive spacer, a moisture desiccant and sealant sandwiched between two pieces of glass. Some I.G. units include an additional layer or two of a composite film stretched and suspended between the pieces of glass thereby creating two and sometimes three separate airspaces. There are several I.G. fabrication processes including Single Seal and Double Seal. Available spacer types include aluminum, stainless steel and composites. Sealants typically include silicon, poly-sulfide and poly-isobutylene.

Architecturally Correct:

Clearly, a museum accurate specification for replicating a sash or door originally fabricated during the 17th or 18th centuries would not include Bullet Resistant glass, Laminated, Low E or sealed I.G. glass units. Most window and door Primary Sash included small true divided panes of glass because large pieces of glass were not readily available. Remember, mass production float glass manufacturing processes were not yet perfected. The ramifications of a broken window were diminished by the use of small panes because only one or two pieces of the sash glass were usually broken at any given time. Storm Sash consisting of small true divided panes of glass were occasionally used in period applications.

Whether or not the panes of glass in a given sash or door are small or large, the only aspect of High Performance Glazing that is really visible to the eye, other than perhaps the absence of imperfections typical to Antique or Restoration glass, is the use of sealed Insulated Glass. Bullet Resistant glass, Laminated and Low E glass does not, in itself, modify the appearance of a single glazed Primary Sash or Storm Sash. Yes, some Low E glass has a unique tint and Bullet Resistant glass is typically quite thick. But it is very difficult to tell the difference between a piece of clear float glass and clear laminated glass when it's in the sash.

Catch 22:

The profound design and cost consideration, however, rests with the use of sealed **Insulating Glass**.

Sealed I.G. units, including the air space, are anywhere from ½" thick to 1" thick or more. Sash must be thick enough to accept I.G. glass. There is a minimum bar and muntin width, from 7/8" to 1 ½" depending upon the manufacturer, that is required to cover the sight line of the I.G. spacer and sealant. And, let's face it, sealed I.G. is doomed to seal failure at some point during the life of a properly fabricated custom window or door. Weight and pulley double hung windows, fabricated with coped and pegged mortise and tenon joinery, and a premium grade jamb assembly, have proven to survive for 100 years and more. Sealed I.G., on the other hand, is typically warranted for 10 years, and in some cases 20 years. Some large custom I.G. or bent glass I.G. applications are warranted for 5 years or less. So should sealed I.G. be avoided? I think not. But let's consider the pros and cons.

The Comparison – I.G. vs. Single Glazing:

Traditional single glazing does not eliminate the risk of failure and costly repairs. Traditional single glazing is typically installed into an exterior sash rabbet, held in place with metal glazing points that will rust unless they're made of stainless steel or another non-corrosive material. And remember, even galvanized steel will rust sooner or later once the galvanic coating is cracked or worn.

Single glazed glass is typically bedded and sealed with glazing compound. The wood surface in which the glass is bedded should not be painted or the glazing compound won't stick to the wood. Silicone compounds that stick to paint are not designed to be applied in such thick and exposed applications. And whether or not glazing compound or silicone is used, compound glazing creates a water trap in the glazing rabbet. Finish paint has to be applied after the glass is installed with the paint lapping over the compound and on to the edge of the glass to provide at least some semblance of a water tight seal.

Glazing compound does not maintain the elasticity of silicone. The joint between the compound and the glass eventually opens. Water penetrates to the glass rabbet, expands and contracts, or freezes and thaws, eventually allowing more water to reach the wood joinery. The wood begins to deteriorate and the paint begins to peel because the sash rabbet was not painted and the sealant created the water trap. The paint finish between the exterior bars and muntins and the glass must, therefore, be monitored and repainted more often. And anyone who has ever painted a multi-light sash knows that it's not the easiest kind of painting to do.

And then there's **Condensation**. If there is one aspect of I.G. that is significantly beneficial when compared to Single Glazed sash, it is I.G.'s resistance to the formation of condensation. Condensation typically forms on the inside of a Single Glazed window or door in the winter. But it can also form on the outside in the summer. The average house residence creates gallons of water vapor every day. From the kitchen to the bathroom, water vapor condenses on the panes of glass of those windows and doors most exposed to the moisture. Condensation also collects in the glass rabbet and exacerbates the moisture problems.

You can easily see the tell tale signs of condensation on a Single Glazed sash bar or muntin. Usually, there are signs of water staining on the interior flat molding surfaces at the bottom of each pane of glass. Later, paint begins to peel from the sharp edges of the molding profiles and the corners of the bars, muntins and the joints between the sash stiles and rails. Finally, the joints between the stiles and rails fail. Often, after advanced deterioration, only the glass and glazing materials are left holding the sash together. If the sash happen to be painted with urathane, the wood at each joint may have rotted inside the paint film before the damage becomes visibly apparent on the exterior.

Why not use a Storm Sash to increase the energy efficiency of the window and prevent condensation? Yes, a Storm Sash will increase the energy efficiency of the Single Glazed window. But the Storm Sash is single glazed too, and it's susceptible to the same deficiencies of the Primary Single Glazed Sash. Condensation is still a problem. Water vapor is a tenacious intruder. And while condensation on the Primary Sash may be limited by a Storm Sash, the condensation will find it's way to the Storm Sash rather easily unless the

Primary Sash is sealed in place, defeating the purpose of an operable window or door. And if the Storm Sash is on the interior, the condition is simply reversed.

But what if I have to replace panes of Insulating Glass every 10-20 years? And that's a good question.

I converted to using I.G. for my personal use and recommending it to many of my clients several years ago. I decided that it was worth replacing the I.G. glass at $15 per pane once every 10-20 years or so, rather than repair or replace the entire sash because of condensation damage. And I have to say, after replacing hundreds of sash in historic landmark replications, I've found that many, if not most, had been replaced at least once since the window was originally manufactured. Many sash at least showed signs of previous repairs. Yes, the jambs and weight and pulley counterbalance systems were often original, but often the sash were not. And I suspect that I know why…. Condensation.

I also decided that I didn't want to have to remove Storm Sash every spring and clean them, or store them, or replace them with Screen Sash, or reglaze, repoint or repaint them. And I wanted to be able to see through my windows in the winter rather than peer at condensation and frost.

And I.G. is more energy efficient than a Single Glazed Primary Sash with Storm Sash. When the air space between the Primary Sash and the Storm Sash reaches an inch or two between sash, air currents are created within the air space diminishing energy efficiency. Even an I.G. unit without Low E or an inert gas is more energy efficient than a single glazed Primary Sash and Storm Sash. Especially given that the Storm Sash ought to breath to the exterior to allow the water vapor that gets past the Primary Sash to escape.

Finally, I considered the potential for improvements in I.G. technology. Because I can paint my I.G. windows and doors before the glass is installed, effectively sealing all wood surfaces from the woes of moisture penetration, the sash and doors will last longer. As long as the sash are fabricated in such a way as to anticipate the future need for that inevitable I.G. replacement, hopefully without a major effort, I considered the I.G. much the same as I do the tires on my car. While I used to get 20,000 miles to a set of tires, I get 50,000 miles now. And while my car lasted 3 to 5 years and traveled 100,000 miles in the past, now I expect my car to last 10 years or more and travel 200,000 miles. And just as tire technology has improved, so has Insulated Glass technology. Some I.G. units, and I'm referencing Southwall Technologies Heat Mirror glazing here, now provide as much energy efficiency as a 2 x 4 stud wall insulated with fiberglass. And I.G. longevity will surely increase as sealants and fabricating processes improve.

Conclusion:

Proper fabrication is extremely important in the use of High Performance Glazing. Contrary to traditional glazing methods, I.G. should be installed from the interior side of the sash or door, not the exterior. Compatible sealants are a must. Wooden glazing stops should be applied on the interior side of the glass rabbet. The glazing stops should not be sealed. Rather they should allow the space in which the I.G. rests to breath or weep. Proper expansion clearances must be maintained. And I believe this fabrication method is best for Single Glazed sash too.

Especially beware of "simulated" true divided panes of glass. These are no more than full light sash frames with grilles permanently applied to the surface of large I.G. units. If these I.G. units fail, and they will, the entire sash has to be replaced because the units are not designed for I.G. retrofitting. The joinery methods used in simulated divided panes of glass are typically miter joints that are prone to open and allow moisture penetration. And remember, traditional coped and pegged mortise and tenon joinery is designed to maintain a seal even as the wood expands and contracts at a butt joint between a stile and rail.

Consider then that a properly fabricated period 12 light over 12 light wooden weight and pulley doublehung window with true divided light insulating glass includes approximately 412 individual sash components, 54 jamb components, 250 fasteners attached through 150 copes, mortises, ploughs and rabbets. Each piece is variable three dimensionally. Each piece is available in a variety of materials. And each piece must be compatible with various aspects of the others.

Sill angles can vary by fractional degrees. Wall thickness and corresponding jamb widths often vary by fractions of an inch. Weights change in length and width as the window size changes. Sash frames, bars and muntins change in size to correspond to landmark molding profiles. Glass types, light emmisivity and reflectivity, sound transmittance, wind load and energy efficiency affect glass and sash thickness. And a variation in any one of these components, from glass thickness to wood species to sill angle, affects the size and placement of every other component in the window.

When a custom window and door manufacturer offers virtually infinite flexibility in its products that must conform to a variety of performance criteria within dimensional tolerances of, let's say, one thirty-second of an inch, that manufacturer better have a specification model that maintains control of every one of those 866 components. The model must allow the use of new materials and technologies, coordinate custom hardware applications, provide clear illustrations for review; including itemized specifications, hardware cut sheets, elevation and section drawings. The model must provide for related performance standards and engineering reviews, coordinate complex inventories and accurately determine costs and production schedules.

If you are considering a custom window and door manufacturer, don't hesitate to ask for a description of their modeling program, as well as the specification and drawing presentation used for review and approval.

Whether or not I.G. is specified, ask:
- Is the wood joinery coped or mitered? tenoned, doweled or waffered? pegged, nailed or glued?
- Are the frames and jambs screwed and glued, stapled or nailed together?
- Are fasteners stainless steel, brass, bronze, aluminum, galvanized steel, steel or plastic?
- Are the units finished prior to assembly?
- Does the manufacturer offer dimensional flexibility for all components or just overall width and height?
- Is there a variety of available hard and soft woods, molding profiles, glass types, and wood finishes?
- Are a variety of functional hardware applications available?

Consider the experience of the manufacturer. Computer Aided Design and Manufacturing, online download capabilities and email are valuable specification tools. Compare warranties. Compare performance tests from independent test laboratories including air and water infiltration, structural load, operating force, sound transmittance, R and U values, Ultra Violet filtering, and impact resistance. And, of course compare the costs and production schedules of apples to apples. To do this, insist upon itemized schedules of value and firm contracts based upon approved shop drawings.

In the final analysis, wooden windows and doors are fabricated from renewable resources. Well managed wooden window and door manufacturing creates less waste than manufacturing windows with aluminum, steel, vinyl and plastic. Wooden windows and doors can be customized more easily and less expensively than windows fabricated from other materials. A wider variety of finishes can be applied to wooden windows and doors. Wooden windows are more energy efficient than those made of metal and plastic. And proper fabrication and finishing will insure that wooden windows will last longer than the trees from which the lumber is milled.

Proper fabrication standards are well documented. And, as a matter of fact, the traditional methods are usually the best methods. The American Woodworking Institute, for example, describes Premium Grade standards for window materials, joinery, finishing and installation. Coped, pegged, mortise and tenon joinery is preferred. Avoid miter joints whenever possible. Preservative treat, prime and paint all surfaces before assembly. Use only non-corrosive fasteners. Stainless steel, brass and bronze are best.

Consult with a professional. Responsible specification and fabrication requires knowledge, experience, communication and control. And the ever increasing responsibility for managing a complex custom window and door specification process rests not only with the manufacturer but the client as well. Yes, it's easy to specify generic, off-the-shelf products. And architectural results often reflect the effort. But with responsible specification and fabrication systems, unique fenestration providing high tech performance is more cost efficient than ever before. Landmark or new construction …… Don't Compromise.