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DEVIL'S DETAIL

GLASS EVOLUTION

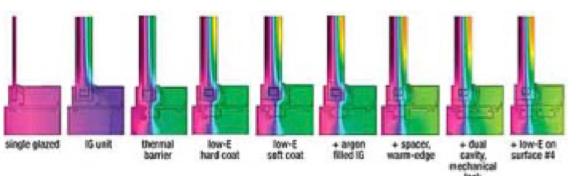
It's about the glass . . . clearly!

A thorough review of the many aspects of windows and window walls would not be complete without an in-depth look at the glass. By delving into the glass, we can understand how the complex components of a glazing system combine to perform as an assembly.

To begin, let's examine how glass evolved and explore some fun facts. About a thousand years ago, during the time of the Crusades, glass manufacturing was developing in Venice. The city would become the glass making center of the western world. In 1291, glass making equipment shifted to the Venetian island of Murano, just across the Laguna Veneta. During 15th century, Venetian glass blower, Angelo Barovier, created Cristallo, a nearly colorless, transparent glass. By the late 1500s, many Venetians had migrated to northern Europe where they established factories and brought the art of Venetian glassblowing. By 1575, English glassmakers were making glass in the Venetian fashion. In 1674, English glassmaker George Ravenscroft invented lead glass similar to what we see in stained glass church windows.

Around the same time in the U.S., the first glass factory was built in Jamestown, Virginia, in 1608. As the new country grew rapidly during the 1800s, there was a great demand for window glass, which was called crown glass. The age of blowing individual bottles, glasses and flasks ended with the New England Glass Company's use of molds in the 1820s, and by the 1870s, the first semi-automatic bottle machine was introduced.

Workers' organization coincided with new technology in glass manufacture. Pittsburgh, Pennsylvania, saw the first organization of window glass workers in the 1870s. By the late 1880s, early unions initiated a structured system and regulations for glass production, apprenticeships, and wage control that lasted until the 20th century.



	1950	1960	1970	1980	1990	2000	2005	2010	2011
U-factor	1.00	0.66	0.50	0.44	0.41	0.39	0.37	0.32	0.28
Condensation Resistance*	16	28	52	54	55	56	61	65	66
U-cog (Btu/h ft^2°F)	1.03	0.49	0.49	0.36	0.29	0.24	0.24	0.24	0.19

Figure A: Advances in glazing technology over the last 60 years

As glass use and development increased rapidly, machinery was developed for precise, continuous manufacture of a host of products. In 1902, Irving W. Colburn invented the sheet glass drawing machine, which made possible the mass production of window glass. Then in 1959, Sir Alastair Pilkington introduced a revolutionary new float glass production system, by which 90 percent of flat glass is still manufactured today.

Over time, single-pane products advanced into insulated glass units (IGU), slowly replacing the once-popular storm panel applied to a single-glazed window. Insulating glass came next, offering significant benefits in thermal performance and energy conservation.

By the 1970s, the use of insulating glass in residential and commercial applications grew in popularity. In these units, a cavity between two glass panes acts as an insulator, preventing hot or cold air from transferring through the glass. Further advances, such as adding inert gases (e.g. argon or krypton), to the IGU reduced convection by up to 10 percent compared to typical units.

SUNLIGHT

Taking a look at sunlight helps illustrate how advances in glass have improved performance. Short-wave energy comes directly from the sun. The sun's energy arrives in the form of infrared light, visible light, and ultraviolet light. Long-wave energy is not derived directly from the sun, but is re-radiated or bounced off other surfaces. In Figure B, long-wave energy, depicted by squiggly lines, is deflected or re-radiated off an IGU. The long-wave energy is re-radiated off a coating, referred to as low-emissivity, which is depicted by the blue layer in the airspace of the IGU.

In an insulating glass unit, there are four potential glass surfaces. The #1 surface is the outboard lite, or the pane of glass that faces most directly outdoors. The #4 surface is the pane of glass that faces most directly indoors. The #2 and #3 surfaces are the two surfaces that face each other inside the insulating glass unit. When it comes to achieving both a specific aesthetic and a high level of environmental performance, advances in glass technology have given designers more choices than ever.

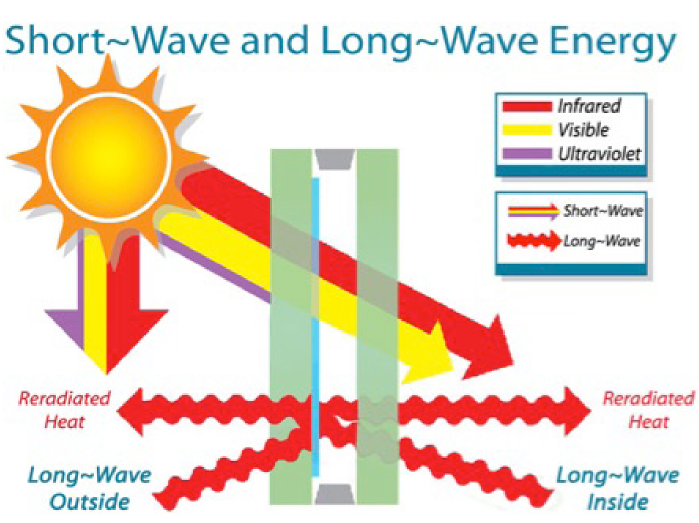


Figure B: Solar Radiation

FRAME OF VIEW

How significant is the framing? Early on, steel was the most common metal used in window frames. Around 1950, single pane units offered minimal thermal performance as the frames were not thermally broken. Single-pane glass, together with highly conductive metal framing materials, offered little or no energy savings. They were both thermally inefficient and offered paths for weather to infiltrate the building, including condensation and frost.

Around 1970, with the introduction of insulating glass, the frame quickly became the most thermally inefficient component of the glazing system.

Glass coatings introduced in the 1980s enabled better thermal performance. Around this time, aluminum was introduced as a framing material. It is highly structural, yet still a very conductive metal. Advances in polymers allow the aluminum frame to be separated without compromising structural integrity. When used in a frame, this composite material achieves better thermal performance characteristics (Figure A).

THERMAL BREAKS

Many manufacturers now offer higher performing thermal storefront (Figure D) and curtain wall systems (Figure E) that achieve much higher thermal resistance to meet or exceed building code requirements without exotic glass. In fact, thermally enhanced storefronts and curtain walls can reach U-Factors under 0.39 Btu/hr.ft2 °F.

A thermally improved storefront system can achieve a seven percent improvement in performance using the same IGU as in a traditional thermally broken system (Figure G). In a thermally improved curtain wall, there is an 18 to 20 percent improvement over a traditional thermally broken curtain wall system using the same IGU (Figure H).

Figure C: Poured and debridged thermal break in action

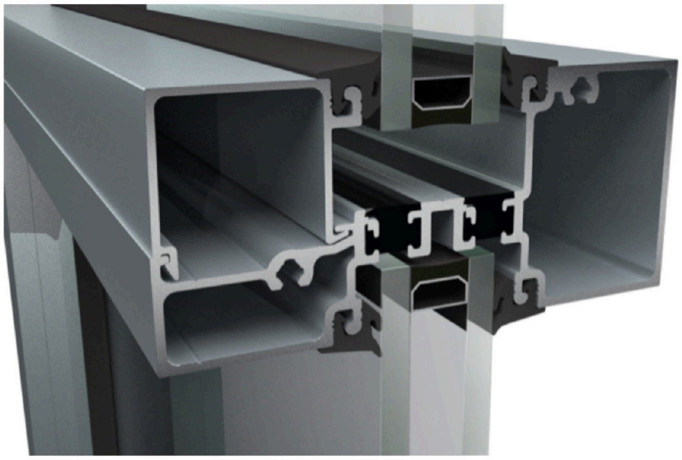


Figure D: Storefront, double thermal break (poured and debridged)

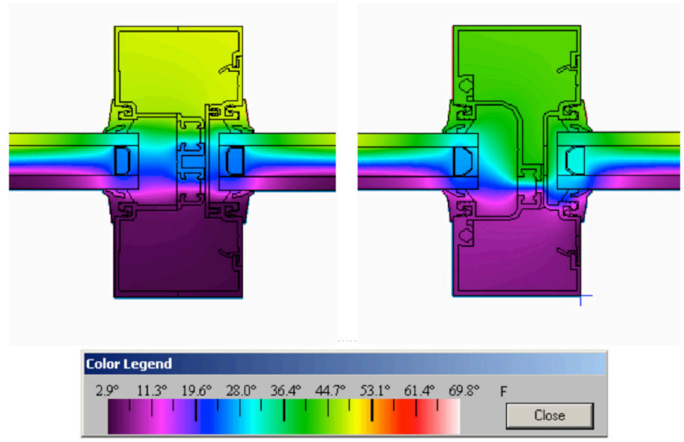


Figure G: Thermal analysis of single vs. double thermal break

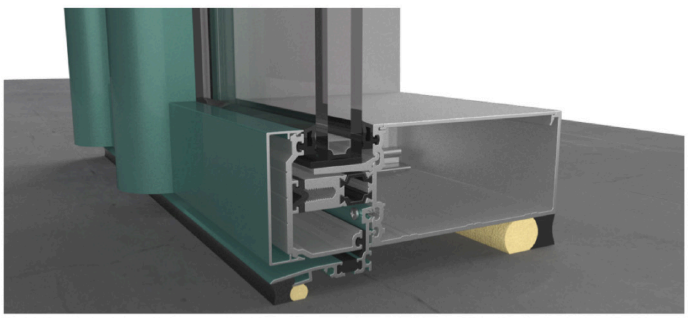


Figure E: Curtain wall, polyamide insulating profile (Insulbar)

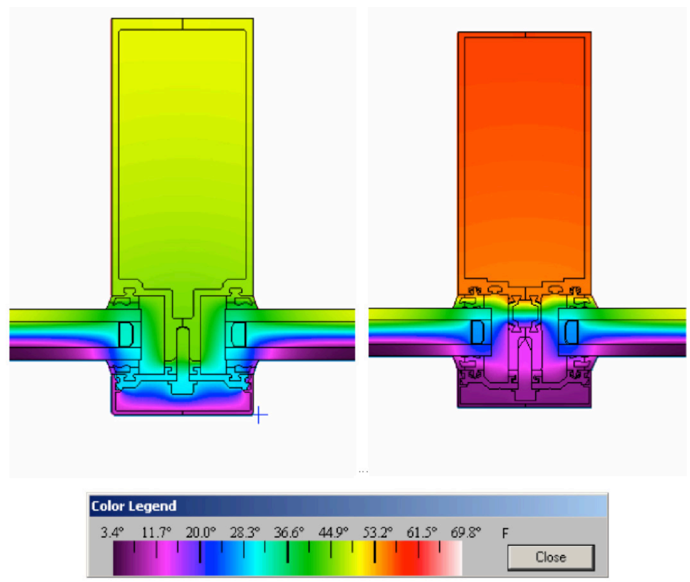


Figure H: Thermal analysis of standard CW vs. high performance CW

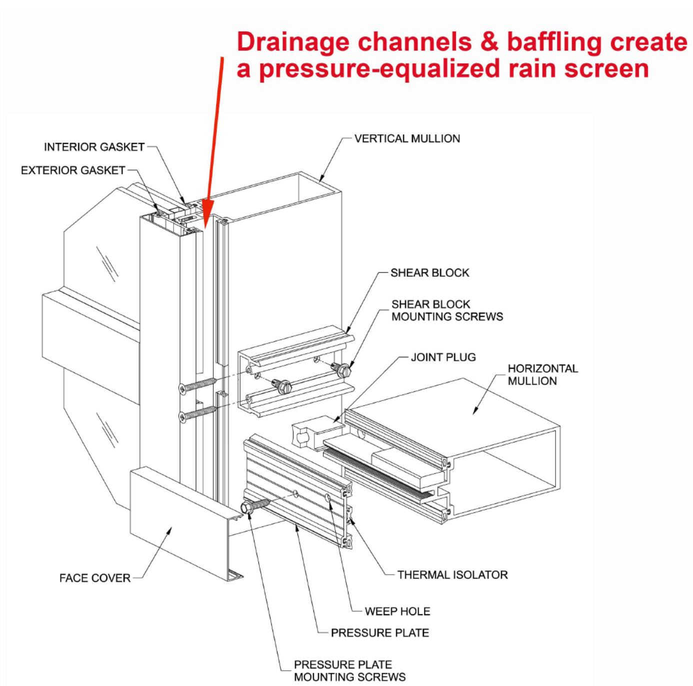


Figure F: Pressure-equalized rain screen detail

ADVANCED PERFORMANCE

Advancements in curtain wall technology have also improved performance. Today's pressure-equalized rain screen systems provide the highest levels of resistance to air and water infiltration for fixed frame curtain wall systems. Pressure-equalized rain screen systems block all of the forces that can drive water across a barrier. Design includes all of the glazing components as an airtight barrier. The outside face of glass, exterior glazing materials, and the outer exposed face of aluminum framing function as a rain screen, shedding water away from the window. Between the exterior rain screen and the interior air barrier, a pressure-equalization chamber is formed in the glazing pocket, which serves to reduce water penetration by eliminating or equalizing the pressure difference across the assembly.

ALL THOSE ACRONYMS

Defining the thermal performance characteristics of a fenestration system will provide an understanding of the many acronyms associated with glazing (e.g. U-Factor, SHGC, VT).

U-Factor refers to the rate of heat loss through an exterior assembly. It is the inverse of R-Value, which may be a more familiar term. U-Factor is expressed as the number of BTUs lost over an hour through the assembly, compounded by the temperature difference across the assembly from inside to outside.

Solar Heat Gain Coefficient (SHGC) is the ratio of solar heat gain entering the space through the fenestration product to the incident solar radiation. Simply, SHGC is the percentage of heat felt when the sun penetrates the glass. This makes the carpet and the interior window frame warmer. SHGC has a unitless value between 0 and 1; as with U-Factor, a lower value is better.

Visible Transmittance (VT) is the amount of light that the human eye can see coming through the fenestration system. The higher the quality of daylight, the higher the VT, so higher is better. VT is typically a unitless value between 0.30 and 0.80. For example, if the assembly U-factor is 0.41, the elevation was 100 square feet, the outside temperature was 70 degrees F, and the inside was 0 degrees F, then (0.41 x 100)*70 = 2870 BTU per hour lost. The infrared photo below illustrates thermal performance of installed glazing.

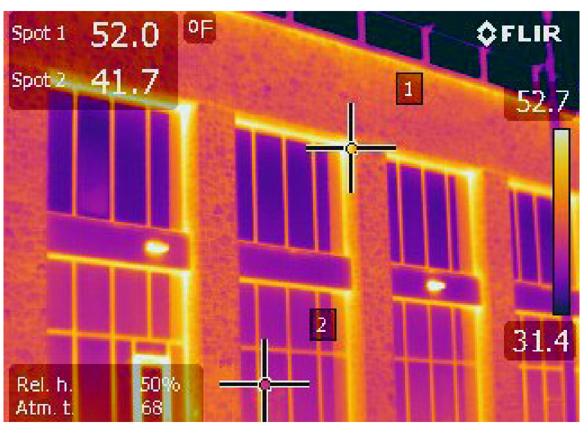
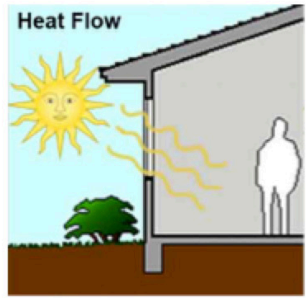


Figure J: Infrared image of exterior glazing system

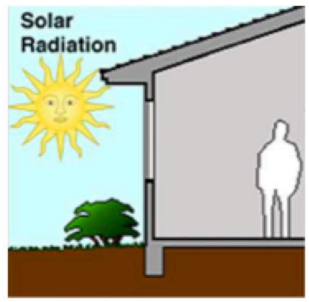
Defining the Thermal Characteristics of Fenestration Systems



U-Factor: Rate of heat loss. The lower the U-Factor, the better the fenestration's resistance to heat flow.

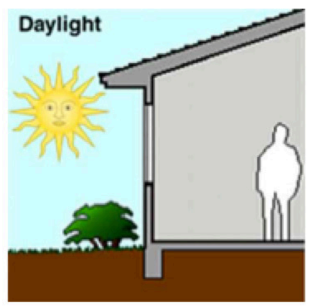
U-factor is the inverse of R-Value.

U-Factor is denoted as BTU/hr.ft2.oF (W/m2.oC)



Solar Heat Gain Coefficient (SHGC): Ratio of the solar heat gain entering the space through the fenestration product to the incident solar radiation. The lower the SHGC, the less solar heat it transmits, and the greater its shading ability.

SHGC is denoted as a value between 0 and 1 without units.



Visible Transmittance (VT): Optical property that indicates amount of visible light transmitted. The higher the VT, the better the quality of daylight allowed through the fenestration system. Note: Framing blocks all daylight.

VT is denoted as a value between 0 and 1, but most VT values fall between 0.30 and 0.80.

FOR MORE INFORMATION

For more about the history of glass, visit these websites:

History of Glass: http://www.historyofglass.com

Corning Museum of Glass: http://www.cmog.org

University of Toledo History of Glass in the U.S. 1820s-1900: www.utoledo.edu/library/canaday/exhibits/oi/OIExhibit/Batch,Blow.htm

Glass Facts: History of Glass: http://www.texasglass.com/glass_facts/history_of_Glass.htm

About the Devil's Details

The AGI educational series illustrates and describes common glazing challenges as a means to communicate best practices for the design and construction industry, not as a sole source for design guidance. AGI recommends design professionals consult with an AGI contractor regarding specific project challenges. AGI contractor profiles may be accessed at www.theagi.org. To share a devilish detail of your own, contact info@theagi.org.