



Fig. 1: This reflective glass facade shows a whimsical view of the surrounding cityscape.
Photo credit Barbara Erwine

Which glass should I use? Sorting it all out

By Barbara Erwine

Windows, the eyes of our buildings, let our imaginations soar with their views and brighten our interiors with natural light. But they also represent major holes in our buildings through which energy (and money) pours. Each year, American taxpayers spend over \$25 billion on summer air conditioning and winter heating. Although a wealth of new glazing products promises to reduce this energy drain, the challenge of finding the right product for each building can boggle the most adept architect.

So how do you sort through the myriad of products and specifications to pick the right glazing for the job? The energy specifications that describe glazing performance are key indicators of which glazing is best for each application.

Let the Daylight In:

Solar energy is composed of Ultraviolet (UV), Visible and Infrared (IR) radiation. Glazing types differ in how much they transmit in each of these regions. Bringing in daylight through windows and skylights counts on the transmission of energy in the visible part of the spectrum.

Visible Light Transmission (VLT):

This specification indicates the percentage of visible light that is transmitted through the window. Visible transmission is relatively high for clear glass (about 81% for a single pane) but can be reduced by adding a tint to the body of the glazing, or by applying a colored or reflective film or coating to the surface. Most architectural glass already has a slight greenish tint from the iron impurities in it. The clearest glass with the highest transmission is

achieved by reducing the iron, resulting in a “high white” product at an increased price. High white glass is usually only specified for specialty applications, like high-end retail displays.

Most products that reduce visible transmission will also reduce heat gains from the UV and IR portions of the spectrum. So choosing a glazing with a lower visible transmission



Fig. 2: A lightshelf divides the window into upper daylight glazing and lower view glazing. Visible light transmission may be higher in the upper glazing (to increase daylight) and lower in the view glazing (to minimize glare).
Photo credit: Sacramento Municipal Utility District

High Visible transmission values are important to deliver as much daylight as possible, but may produce glare unless the glazing is protected.

may be done either to achieve an architectural effect (color, reflection, etc.) or to reduce glare or heat gain through the window. Some “selective” tints, like Azurelite and Evergreen reduce the UV and IR transmission significantly but leave the visible transmission high. Other tints, like gray and bronze, and some reflective coatings have the opposite performance and actually reduce the visible transmission more than the IR and UV. (See below under Cool Glazing.)

For daylighting applications, high visible transmission values are important to deliver as much daylight as possible, but may provide glare unless the glazing’s above normal viewing angles, shaded by an exterior overhang or shielded by interior louvers or lightshelf protected from direct view. Balancing these contradictory needs frequently dictates the use of two different windows - an upper daylight glazing (with high visible transmission,



>50% VLT) and a lower view glazing (with exterior shading or lower visible transmission <40%VLT).

Warm Glazing: Keeping the Heat In

When outside temperatures are significantly higher or lower than inside temperatures, heat pours through the weakest thermal link in the building envelop - usually this is a window or skylight.

U Factor: This specification describes the heat transfer through a window due to the temperature difference between the inside and outside. The lower the U factor (in units of Btu/sq.ft hour oF), the better the glazing is at reducing heat loss. As with other building products, many people also refer to the resistance to this heat flow, the R Value. The R Value is the inverse of the U factor ($R=1/U$). And in this case, the higher the R value, the better the performance.

U factors of less than 0.35 ($R \geq 2.8$) are recommended for comfort and energy conservation in temperate climates

U factor is important whenever the inside temperature is significantly different from the outside temperature. Since temperature difference is usually greatest in the

winter when the outside temperatures are low, the U factor is most significant for smaller heated buildings (without high internal loads) in cold climates. This is especially true for single family residences and small commercial buildings. Many large compact commercial buildings in coastal areas of the northwest have high internal loads that lessen the heating demand and cause the U factor to be somewhat less important.

Low U factors are achieved by using 1) multiple glazing layers (since the air trapped between the glazing layers conducts less heat than the glazing itself), 2) one or more low-emissivity (low-e) coatings (which block the radiation of heat between the glazing layers), and 3) an inert gas fill, like argon or krypton (which is a poorer conductor than air). Current double glazed products with a single low-e layer can easily achieve U factors of less than .35 ($R \geq 2.8$). These are recommended for comfort and energy conservation in temperate climates, like the Northwest coastal regions. For better thermal comfort and energy performance in more severe climates where winter temperatures frequently drop below freezing, U factors down to .083 ($R=12$) are available (using multiple air spaces and multiple low-e layers).

Note that all these values are the maximum achievable at the center of the glass. The window spacer and frame degrade the performance, so the **whole window** U factor will be higher than the **center of glass** (COG) U factor. Make sure which value is being specified.

Cool Glazing: Keeping the Heat Out

Solar gains from direct sunlight through a window can represent either a wonderfully warm and cozy interior in a cold climate or a stiflingly hot oven in a warmer climate. The glazing's Solar Heat Gain Coefficient describes whether the glazing will welcome or reject solar heat.

Solar Heat Gain Coefficient (SHGC): This specification shows the percentage of solar heat that is transmitted through a window

SHGC: Keep this value lower than 0.4 on unshaded windows to minimize air conditioning costs

(both directly transmitted and absorbed and re-emitted). Keep this value lower than 0.4 (the lower, the better) on unshaded windows to minimize air conditioning costs. To maximize solar gains for a passive solar building, use glazing with a high SHGC. (Note: SHGC is the new industry standard specification to replace the Shading Coefficient (SC). You can convert from one to the other with the formula $SC = 1.15 \text{ SHGC}$.)

Many early attempts to reduce solar gains through glass (dark tints and reflective coatings) drastically reduced visible light transmission. Gray tints and many reflective coatings are especially bad at this, actually reducing the visible transmission more than the solar gains. Newer "selective" tints and coatings (newer versions of low-e coatings) have been engineered to do just the opposite - selectively transmit visible light while blocking UV and IR. Consequently, their specifications show high VLT and low SHGC. The efficiency of a glazing to transmit visible light and reject heat can be expressed by taking the ratio of the VLT/SHGC. Values greater than 1.3 are good - the higher the better! For example, a product with a visible light transmission of 65% and a SHGC of .46 gives a ratio of $.65/.46 = 1.41$. Green and blue/green tints and second generation "selective" low-e coatings will be the most efficient.



Fig 3: Diffusing skylights spread soft daylight evenly across this library space.
Photo credit: SunOptics Skylights



Fig 4: Laminated Photovoltaic glazing at the Thoreau Center generates electricity while filtering daylight through this entry.

Photo credit: Lawrence Berkeley National Labs

What's the best color?

Although tinted glazing affects the color of daylight transmitted, our eyes adapt to color rapidly, and we rarely notice it unless we see a section of clear glass adjacent to the tinted window. We may however, notice that exterior colors appear “muddy” from the effects of a tint. Gray tints have the least distortion on colors viewed through the glass. But this isn't the only concern. As we noted above, gray tints are not very efficient. For best overall performance, choose a tint or coating with efficient performance (high VLT/SHGC ratio) and visually inspect it to ensure it doesn't distort colors viewed through it.

Clear or Diffuse? Which Should I Choose?

Clear glazing preserves the views, but diffuse glazing spreads daylight evenly through the space. Low vertical glazing within normal viewing angles should not be diffusing because it can be a strong source of glare. Most skylights should be diffusing to provide soft, even working light across the space. But there are some exceptions to these rules of thumb. High vertical glazing outside of normal viewing angles may be diffusing (check first to ensure that direct views of this bright glazing will not cause glare). And sometimes, clear skylights are used in residences and public areas of commercial buildings to enliven the space with the dynamic play of direct sunlight.

Laminates, Frits & Holographic films: When Should I Use These?

Laminated glass has an interlayer of plastic or mylar between two sheets of glass. The purpose of this interlayer may be to tint, diffuse, or pattern the glazing, strengthen it, prevent breakage into shards, reduce sound transmission or reduce the SHGC. Usually laminated glass is more expensive than a tint within the glass itself or a coating that is applied to the glass. But many building codes require laminated glass in overhead applications because of its strength and ability to hold together when broken. A beautiful array of patterned, decorative prod-

ucts are available as laminates for interior and exterior window applications. Some laminates with white dots on one side and black on the other act as “one-way windows” (allowing views only in one direction) or allow signage on one side of the glazing while giving an unobstructed view from the other direction. Also available are products with photovoltaic (PV) cells laminated between the layers of glazing. The cells generate electricity when exposed to the sun while spaces between the cells transmit filtered daylight to the space below.

Frits are glass products with a ceramic painted pattern fired onto one surface. Frits are quite durable and are available in a variety of colors and patterns (standard and custom) that serve to provide a decorative screen and/or to reduce transmission through the glass. When light colored fritted patterns are lit from within at night they allow the glass to “read” as a solid surface rather than a “black hole” in the wall or ceiling.

Holographic films are also becoming available which can redirect daylight in the space or break light into a rainbow of colors. Just now emerging on the market, these products promise new opportunities to direct daylight where it's needed most.

Smart Windows

Also new in the market are some amazing new glazing products that can change their transmission properties based on an electric signal (electrochromic), temperature (thermochromic) or amount of available light (photochromic). Currently available in Europe and soon to be introduced into the US, electrochromic “smart” windows turn from light to dark (like photogray sunglasses) to adjust the visible light and heat transmission through the glass. Also available is a polymer dispersed liquid crystal product which switches from clear to diffuse when an electric current is applied. Used currently primarily as a privacy product for interior glazing, this approach promises great advantages for skylights which can respond to sky conditions – changing their transmission between clear and overcast days.

NFRC Ratings: Know What You Are Getting

The National Fenestration Rating Council is an industry organization that established a standardized, voluntary rating system to compare the performance of windows. An NFRC rated window comes with a window sticker that shows the whole window performance (not just the center of glass) for U Factor, Solar Heat Gain Coefficient, Visible Light Transmission, and Air Leakage. When you buy a rated window, you are guaranteed getting the performance you need. Many building codes encourage the use of rated windows (If you don't use a rated window, they assign default values that represent a worst case scenario). For more information on NFRC ratings, check their website at <http://www.nfrc.org/>