Technical Bulletin

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GLASS AND ENERGY

Summary

With the advent of low emissivity (low-e) coatings, high-performance tinted glass, reflective coatings, and gas filled insulating units; the choice of glazing materials and options is very large. Due to the fact that many of the coatings and tints are operating strongly in invisible parts of the energy spectrum, a refresher course on the performance characteristics and the reasons for choosing different options seems appropriate.

Windows play a very important role in the design of a building. The psychological and physiological implications of windows and their role in increasing occupant well-being and worker productivity have been well documented. Windows also play an important role in the energy usage of a building. In general, the thermal performance characteristics of any glazing material can be best described by two attributes, which are not obvious to the naked eye: Solar Heat Gain Coefficient (SHGC) and U-Factor.

SOLAR HEAT GAIN COEFFICIENT

The SHGC is the ratio of the solar heat gain through the glass relative to the incident solar radiation on the glazing. SHGC includes both the solar energy directly transmitted through the glazing plus the solar energy absorbed by the glazing and subsequently convected and thermally radiated inward. In Europe this quantity is sometimes called "g value", "solar factor" or "TET" (Total Energy Transmittance).

The Shading Coefficient (SC) is the dimensionless ratio of the solar heat gain of a particular glazing relative to that through clear 1/8" (3 mm) thick glass. As such, the shading coefficient of 1/8" (3mm) clear, glass is 1.0, and glazings which block greater levels of solar energy than 1/8" clear will have lower shading coefficient values. The SC is an obsolete measure of performance, partly because it was never fully defined what 1/8" (3 mm) glass composition, or what exact thickness, should be used. Another reason for not using SC is its name: normally, coefficients have a greater numerical value as their named characteristic increases, but for SC you actually get less solar 'shading' as the SC value increases. SHGC is correctly named: The larger the SHGC value, the greater the 'solar gain'.

Clear glazings having a SHGC near 0.86 (SC near 1.0) are generally desirable for typical residential windows north of a line from Seattle to New York City. But commercial applications are quite different: in large commercial structures in North America, solar gain is not very welcome in interior spaces. Most of these structures generate more heat than they need from lighting, computers, machinery, and people, even on cold winter days. Consequently, to save on cooling costs, the solar gain must be reduced. Note that some buildings such as hospitals needing a large volume of clean, filtered air my often have higher than normal heating requirements in winter.

In order to reduce the solar heat gain into a building interior, solar control glazings having a lower SHGC than that of clear glass should be utilized. Solar control glazings can be defined as: solar transmitting; solar absorbing glass; or solar reflective glass. Note low-e coated glass simply blocks far infrared (IR) heat transmission. Low-e coatings may, or may not, have any particular solar control properties.

Solar Transmitting Glass – Pilkington **Optiwhite™** low-iron glass has the highest solar transmission. When combined with Pilkington **Energy Advantage™** Low-E coatings, you get the best possible free passive solar gains: that is the "advantage" of Pilkington **Energy Advantage™** glass. In general terms it is probably beneficial to incorporate a higher SHGC glazing when the heating costs of a simple building exceed its cooling costs.

Heat Absorbing Glass - The earliest attempts to limit solar gain used heat absorbing Grey and Bronze tinted glasses. Single glazings consisting of Grey and Bronze ¼" (6 mm) thick tinted glasses have SHGC values of 0.57 and 0.62 as compared to Clear glass having 0.81. Pilkington North America, Inc. ¼" (6mm) Pilkington **Optifloat™** Blue-Green tinted glass has a SHGC of 0.62, and therefore provides equivalent solar control to Bronze tint. However, Blue-Green is one of the "spectrally selective" tints: it allows 75% of the sun's visible light to pass into the building interior compared to only 43% and 53% for Grey and Bronze glass. Higher visible light transmittance allows for more natural lighting of building interiors.

High-performance tinted float glasses such as Pilkington **EverGreen™**, Pilkington **Arctic Blue™**, and Pilkington **SuperGrey™** are the latest evolution in heat absorbing glasses. Single ¼" (6 mm)

Pilkington **EverGreen™** has a SHGC of 0.51 and a visible light transmittance of 66%.

Pilkington **SuperGrey™** tint has a SHGC of 0.35 for a single ¼" (6 mm) light.

Reflective Coated Glass - LOF introduced vacuum coated, off-line filmed glass products in the 1960's. These films consisted of mirror-like metallic layers on a glass substrate which were designed to reflect the solar energy away from the glazing, rather than absorbing it as tinted glass did. Today, Pilkington North America, Inc. produces solar control and thermally insulating films using a pyrolytic, on-line operation giving durable, post-temperable, and cost effective glass products. Pyrolytic on-line applied solar control films such as

Pilkington **Eclipse Advantage™** solar control low-e glass can be applied to clear and tinted substrates. Pilkington **Eclipse Advantage™**,#2 surface reflective, offers SHGC values for single ¼" (6 mm) glazings from 0.37 to 0.61 depending on the glass substrate.

Low-e Coated Glass and Solar Control Low-e coatings have thin, metallic oxide layers designed to reflect long wavelength (IR) heat energy, but not the visible energy wavelengths. That is why they are nearly invisible. Low-e coated glass reflects or redirects radiant heat generated from a warm object back towards the source of warmth four to thirty times better than uncoated glass.

When solar energy is incident on a glazing, the sun's heat is flowing into the building interior. All low-e coatings reduce the heat flow through a glazing by some amount, and therefore using a low-e coated glass instead of ordinary glass will always show a reduction in the glazing's SHGC value.

You need to examine the performance values to see if a low-e coating also has solar control properties.

Pilkington **Solar-E™** Glass combines a solar absorption layer with a low-e layer. These coating layers can be on clear or tinted glass for maximum solar control (lowest SHGC).

U-Factor

The second attribute relating to the energy characteristics of a glazing is the U-Factor. "U" describes thermal conductivity, that is, the heat flow through the glazing from the warm side to the cooler side. It is expressed in terms of BTUs per hour, per square foot, per degree Fahrenheit air temperature difference across the window. Most consumers are familiar with the term R-value, due to advertising by fiberglass insulation manufacturers. R-value is thermal resistance from surface to surface (not air to air), whereas U-Factor is thermal conductance. The two are related by: $U = 1/R$ but watch for how the measurement has been mad: air to air or surface to surface. For a given glazing, the lower the U-Factor (higher R-value), the better the performance.

The first attempt to control thermal loss through glazing systems was to reduce air infiltration or leakage around the perimeter of the glass using tighter fitting, better sealed window units. Around 1940, LOF introduced **Thermopane™** insulating glass. By sealing dry air between two panes of glass, the thermal performance of a window was dramatically improved. Improvements to the original insulating glass unit consisted of wider air spaces, three and more panes of glass with multiple air spaces, and, most recently, low-e coatings on glass, and gas fills.

Low-e Glass - Heat flows from warm objects to cold objects. The effect of low-e coatings is to significantly reduce the radiation heat transfer, and correspondingly improve (lower) the U-Factor of the glazing. The reason Low-E coatings are able to reduce radiation heat transfer is because they reflect long wavelength infrared (IR) heat. The lower the emittance of a glazing's surface, the higher the IR reflectance. While the emittance of glass is 0.84, the emittance of low-e coatings vary from approximately 0.21 to as low as 0.03. Use of low-e in an insulating unit instead of uncoated glass lowers the U-Factor by approximately 25% to 40%.

During the heating season, a low-e coating placed on either of the glass surfaces (#2 or #3) in the air space of an insulating glass unit will reduce the radiation flow from the warm, room side, glass to the cooler, outboard glass by an equal amount. Low-e coated glass in place of uncoated glass will reduce both the heating and the cooling costs associated with a glazing.

There are two basic methods of producing low-e coatings. Vacuum sputtered or "soft coat" low-e, which must be incorporated into a sealed insulating unit because the film will degrade if left exposed to air. They also need to have the coating deleted or ground off the glass edge to ensure adequate long-term sealant adhesion. Sputtered films have been produced with emittances as low as 0.03. Pyrolytic or "hard coat" low-e coatings such as Pilkington **Energy Advantage™** are very durable and may be used monolithically as a storm panel to improve the U-Factor of existing glazings, or in an IG unit.

The emissivity of Pilkington **Energy Advantage™** is 0.15, which is 55% lower than first generation pyrolytic coatings. Clear Pyrolytic Low-E coatings have higher solar heat gain coefficients than sputtered films, and therefore allow for more passive solar gain.

Gas Filled IG Units - Since part of the thermal heat transfer through the air space of an IG unit is accounted for by conduction and convection in the air space, another way to reduce the heat transfer (lower the U-Factor) is to substitute a gas other than dry air as the fill medium. By choosing a gas with a lower thermal conductivity than air, a reduction in the heat transfer will be realized. The most common gasses, other than air, are argon or krypton. The 6 to 20% improvement in U-Factor resulting from gas fills is modest compared to the reduction obtained by using low-e coatings. Also, the retention of gasses other than air, in organic, sealed IG units, requires attention to sealing details.

APPLICATIONS

Design professionals have a very wide array of products available today, making the choice of glazing systems more complex than ever. The design professional must first evaluate the environmental conditions at the proposed building site. Location, type, size, and orientation of the building, and specific conditions at the site will largely determine the performance requirements of the glazing.

All windows benefit from reduced U-Factor, in all seasons. If by chance the exterior air temperature is at a more desirable value than the building interior temperature then the energy-free way to change the latter is simply to open the window, or in a commercial building, put the HVAC on an 'economizer' setting to draw in outside air. But for most situations the air outside is either too hot or too cold and so a good U-Factor is required to prevent unwanted heat transfer.

For solar heat gain there is a more complex decision process: a building located in Phoenix or Houston is going to need a lower SHGC than a building located in Seattle. Conversely, a structure in Milwaukee has a greater need for lower U-Factor (IG and low-e) than a similar structure in a temperate climate such as Orlando. Generally with respect to site orientation, a project's north elevation could use clear insulating units incorporating low-e, while the other elevations may require reduced SHGC glazing and low-e. In some cases, local codes or other requirements may dictate a maximum SHGC and/or U-Factor.

Remember that light is energy and that glazings having the lowest SHGC values tend to also have low visible light transmittances, and therefore may not result in the most cost-effective glazing choice. For medium-rise structures in areas such as Boston or Chicago, one can make a convincing argument in favor of high performance tinted glass (insulating glass using Pilkington **EverGreen™** and Pilkington **Energy Advantage™**) or medium performance reflective glass (insulating glass using Pilkington **Eclipse Advantage™**) products by showing that the increased light transmittance of these products can displace some of the need for artificial lighting. This saves not only in lighting costs, but reduces the air conditioning load required to remove the heat generated by the lighting. Any situation such as this would need an in depth analysis to determine the trade off between solar control, lighting requirements, and air conditioning and heating loads.

Computer programs such as RESFEN and COMFEN are available free of charge from LBNL to simulate building energy usage, using daily heat load calculations throughout the year. Such analyses are particularly useful in helping select the right glazing for residences or high rise offices, as well as for enabling various glazing options to be evaluated in terms of their energy usage impact.

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