Reflective glazing units

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Reflective Glazing Units

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Please note

The heat that enters or leaves a building through each square foot of window is usually several times larger than that through a similar area of opaque wall. It is important, therefore, that a building designer give careful consideration to the size, position, and type of window he will use. Several ways of controlling solar heat gain through windows were discussed in **CBD 39**; and **CBD 52** dealt with heat transfer through a window by convection, conduction, and long-wave radiation. Since these Digests were prepared much work has been done in developing reflective glazing units with improved heat control characteristics. As these units are now marketed by several manufacturers, it seems timely to bring the previous discussions up to date, and to show how the new types of units compare with types that have been in use for many years.

Like walls, windows have to serve as separators between the uncontrolled outside environment and the controlled environment inside a building; but unlike walls, windows must also transmit light. Any objective comparison of different types of windows has to be related therefore, to how well or how poorly the windows fulfil these roles.

One of the most important aspects of the window's role as an environmental separator is its heat gain and heat loss characteristic. The heat exchange between inside air and outside air is characterized by the over-all thermal conductance or U-value for the window; and the propensity to admit solar heat is given in quantitative terms by the shading coefficient. The thermal performance of windows can be compared, therefore, in terms of these two indices. The light transmission characteristic is given by the value of light transmittance.

U-Value

The U-value is the rate at which heat is transferred through one square foot of window when there is a difference of one degree between the air temperature outside and the air temperature inside a building. Stated another way, it is the reciprocal of the total thermal resistance between inside and outside air. A sheet of glass, by itself, has a resistance of only 0.02 units(the unit of thermal resistance is $ft^2hr°F/Btu$, i.e. degrees for 1 Btu per hour through 1 square foot); and almost the whole resistance of a single-glazed window is provided by the boundary layers at the inside and outside surfaces. For ordinary uncoated glass surfaces these resistances are about 0.7 units at the inside surface and 0.3 units at the outside. A low emissivity coating on either of these surfaces increases the resistance for the coated surface.

With double glazing there is an additional resistance provided by the air space between the panes. The value of this resistance depends on the nature of the surfaces that enclose the air space, the temperature of the air in the space, and the thickness of the space. A half-inch thick air space bounded by ordinary uncoated glass has a resistance of about 0.7 units for summer conditions and about 0.9 units at the lower temperatures that occur in winter. When one of the glass surfaces that enclose the air space has a low emissivity coating such as a thin layer of gold or aluminum, the resistance of a half-inch air space is more than doubled, making the double glazing equivalent to triple glazing with uncoated glass. Coating both surfaces facing the air space is only slightly better than having a coating on only one of the surfaces. The increase in the total thermal resistance of a window is an important benefit arising from the use of reflective coatings on glass; the primary reason for using a coating, however, is to reduce the solar heat gain.

Shading Coefficient

The total solar heat gain through a window is the sum of the transmitted solar radiation plus that portion of the absorbed solar energy dissipated to the inside of the building. The shading coefficient for a window is the ratio of the total solar heat gain through it to the total solar heat gain through a standard sheet of clear glass under exactly the same conditions. Thus shading coefficients are dimensionless numbers that have values between zero and one. The smaller the value of the shading coefficient the better the window is at stopping the entry of solar heat.

Values of shading coefficient for three types of single glazing and three types of double glazing are given in Table I, along with the corresponding values of light transmittance, solar transmittance, and U-value. These show that the reflective type of glazing without blinds or curtains can have a lower shading coefficient than other types of double glazing combined with inside shades.

Table I. Shading Coefficients and U-Values For Some Single- and Double-Glazing Units

Type of Window and Shading	Transmittance without Shades		Shading Coefficient				U-Values Btu/ft²hr°F	
	Light	Solar Heat	No Shade	With Curtain Min	With Curtain Max	With Venetian Blind	No Shade	With Curtain or Blind
Single Glazing								
1/8" Clear Sheet Glass	0.90	0.80	1.00	0.45	0.65	0.55	1.0	0.8
1/4" Regular Plate Glass	0.87	0.77	0.95	0.45	0.65	0.55	1.0	0.8
1/4" Heat Absorbing Plate Glass	0.50	0.45	0.70	0.40	0.50	0.47	1.0	0.8
Double Glazing								
1/4" Regular Plate	0.77	0.60	0.83	0.40	0.60	0.50	0.6	0.5

1/2" Air Space 1/4" Regular Plate								
1/4" Heat Absorbing Plate 1/2" Air Space 1/4" Regular Plate	0.45	0.35	0.55	0.33	0.43	0.36	0.6	0.5
1/4" Regular Plate Reflective Film 1/2" Air Space 1/4" Regular Plate	0.35	0.16	0.25				0.3	

Heat Absorbing vs Heat Reflecting Windows

It was pointed out in **CBD 60** that glass is not uniformly transparent to all wavelengths, and that by a judicious choice of ingredients a glass can be produced that is markedly more transparent to the visible than to the infrared. This type of glass is commonly called heat absorbing. A pane of ordinary plate glass that has a thin film of gold (or some other metal) on one surface is also more transparent to the visible than to the infra-red, but because it acts as a semi-transparent mirror this type is called heat reflecting glass.

Figure 1 shows the proportions of incident solar radiation that are transmitted, reflected, and absorbed by typical double-glazing units of the absorbing and reflecting type. The lower total admission of the reflective type unit is mainly due to lower solar transmission. When the reflective coating is on the inside surface of the outer pane, that pane absorbs almost as much as if it were heat absorbing glass, but the transmission is reduced because of the higher reflection. The total admission is also reduced because less of the energy absorbed by the outer pane of the reflective unit is transferred to the room. This is a direct consequence of the higher resistance of the air space in the reflective units.

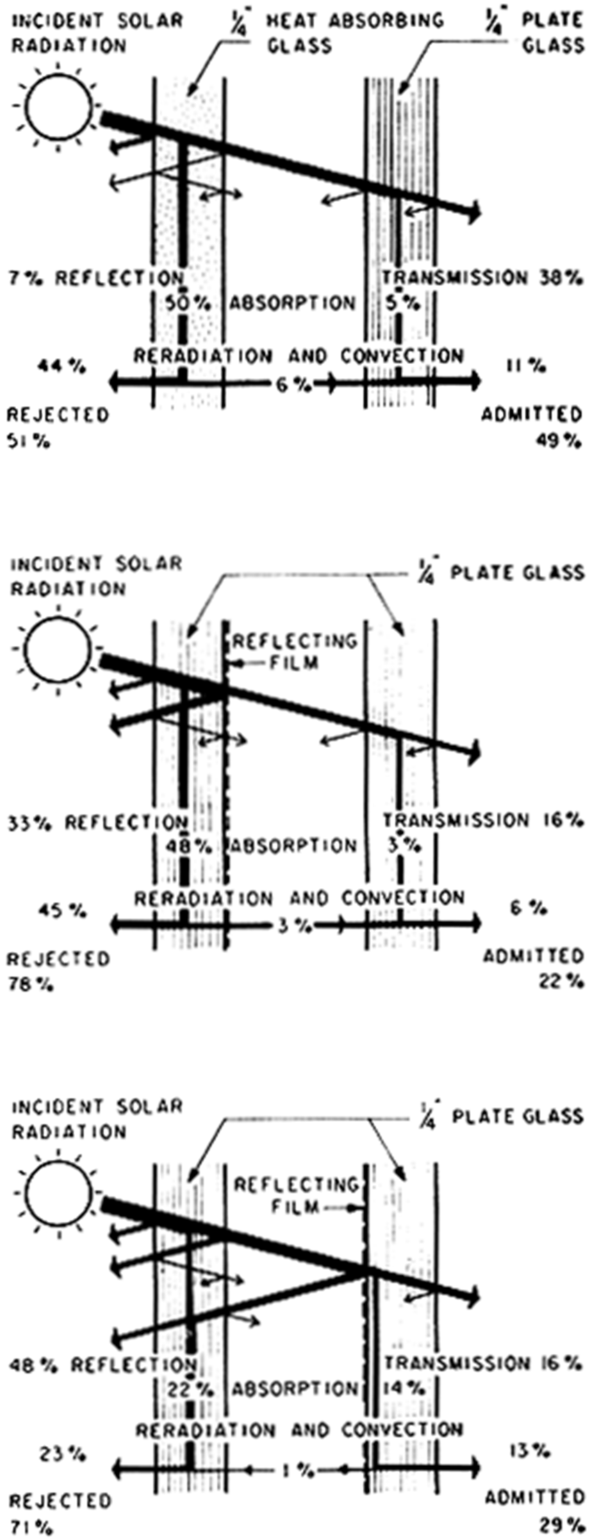

Figure 1. Components of solar heat admission and rejection for heat absorbing and heat reflecting double-glazing units.

When the reflective film is on the outside surface of the inner pane the over-all reflection of the unit is greater but the total admission is also higher. This is because the energy absorbed by the coating on the inner pane is mostly transferred to the room side. Thus, from the point of view of minimizing heat gain, the best place for a reflecting film is on the inside of the outer pane.

With the coating on the outside pane, however, the outer pane gets quite hot when it is in strong sunlight. There is, therefore, an increased chance of thermal breakage with this arrangement and some manufacturers recommend installing their reflective units with the coated pane inside. They thereby sacrifice part of the shading coefficient advantage to reduce the chance of thermal breakage.

Most metallic films are not robust enough to be used on an exposed surface and are applied mainly in double-glazing units. It is possible, naturally, to protect a reflective film by over-coating it with a hard transparent material to make a reflective single-glazing unit. These units have a lower shading coefficient than non-reflective types of single glazing, but they do not have the reduced U-value that is such an important by-product of a reflective coating in a double-glazing unit.

Heat Gain Through Windows

The total heat gain through a window is given by:

$$\frac{\text{Heat Gain}}{\text{Area}} = U(\Delta T) + \text{Shading Coefficient (SHGF)}$$

- where ΔT is the difference between the air temperatures outside and inside the building, being positive when the outside is warmer than inside;
- and SHGF (solar heat gain factor) is the solar heat gain that would occur through a single pane of ordinary sheet glass in the same situation.

The U-value and shading coefficient are characteristics of the window and are independent of where it is installed, whereas the ΔT and SHGF are characteristics of the environment and are independent of the particular type of window.

The significance of the difference between one shading coefficient and another depends on the magnitude of the SHGF and a difference in U-value depends on the magnitude of ΔT. Table II gives the daily maximum values of SHGF for windows facing the cardinal directions at 45 degrees north latitude. These data show that east and west exposures have high values of SHGF during the whole summer, and low values in winter; the situation is just the opposite for windows facing south. Thus windows with a low value of shading coefficient have much more benefit on east and west facades than on south exposures, and the value of the shading coefficient has very little significance for north-facing windows.

Table II. Maximum Values of Solar Heat Gain Factors

Date	Direction		
	N	East West	S

21 Jan	16	134	251
Feb	21	176	249
Mar	26	210	221
Apr	32	222	176
May	36	219	137
June	37	215	120
July	37	215	133
Aug	34	213	169
Sept	28	197	214
Oct	22	169	240
Nov	17	131	246
Dec	14	108	244

Values are in Btu/ft²hr.
These data are taken from NRC 9528.

The magnitude of the U-value is most significant in winter when ΔT has a large negative value. Thus the longer and colder the winters, the more advantage in using windows with a low U-value. For south exposures the benefit of the low U-value of reflective windows is offset to some extent by the reduced solar heat gain during winter, when it would often be welcome. Even on south exposures, however, reflective windows will usually reduce the total cost of heating under the conditions that prevail in Canada.

Light and Heat

There is no fundamental difference between light and other forms of radiation such as X-rays or radiowaves. There is a difference only in the eye of the beholder. A human eye can detect radiation if the wavelength is between 380 nm (nano metre = one millionth of a millimetre) and 750 nm; radiation between these limits is visible and is called light. About half of the total energy of solar radiation is associated with the visible wavelengths, the other half with wavelengths longer than 750 nm. This latter half is usually referred to as near infra-red radiation.

Heat absorbing and heat reflecting types of windows are more transparent to visible than to near infra-red radiation. It is wrong, however, to imagine that any type of window can completely filter out solar heat and still let light through. The energy associated with the light will always appear as heat when the radiation is absorbed.

The ratio of light to heat emanating from any light source is a measure of the luminous efficacy of the source. The efficacy of different light sources can be compared directly only when all heat gains are expressed in the same units. As the watt is the internationally recognized unit for power and rate of heat transfer, and the lumen the unit for light output, luminous efficacy is usually expressed in lumens per watt. The higher the value of this ratio the less heat is associated with a given level of illumination. Window heat gain rates that are in Btu/hr can be converted to watts simply by dividing by 3.41 (i.e. 1 watt = 3.41 Btu/hr).

The luminous efficacy of a window is related to the light transmission and shading coefficient by:

$$\text{Luminous Efficacy} = \frac{125 \times \text{Light Transmission}}{\text{Shading Coefficient}}$$

The factor 125 applies when the incident radiation is direct sunlight; this constant should be about 170 for diffuse light from a clear sky. using the value of 125 with the light transmittance and shading coefficient data in Table I gives a luminous efficacy of about 115 lumens/watt for a double-glazing unit with regular plate glass. A similar unit with an outer pane of ¼-in. heat absorbing plate has a value of 100 lumens/watt; and a double unit with a reflective film of gold on the inside of the outer pane has an efficacy of 175 lumens/watt. These values compare very favourably with artificial light sources; fluorescent lamps give about 70 lumens/watt and tungsten filament lamps are only between 10 and 20 lumens/watt. Thus, a room that is designed to take full advantage of daylight will not necessarily have a higher heat gain than a windowless room with artificial light.

Conclusion

One special feature of reflective type windows is that they achieve a low U-value and shading coefficient without obstructing the view. They are, therefore, of special value in circumstances where the view is important. Reflective windows act like "one-way mirrors" in that when it is much brighter outside than inside it is possible to see out but not in through them. This provides privacy during the daytime, but blinds or curtains are needed to ensure privacy after dark when the room is brightly lighted. An ordinary clear glass window with a blind or curtain has an advantage over reflecting or heat absorbing windows on dull days; the blind or curtain can be opened when it isn't needed, permitting more light to enter and not obscuring the view with a strong reflected image of the objects in the room.

Another point to consider is that replacement units should match the originals in transmittance and reflectance. This may be more difficult with reflective units than with ordinary clear glass. In fact, it may be desirable to order spare glazing units at the outset to ensure having matching units to replace any that are broken. Reflective type units probably are a little more prone to thermal breakage than regular double glazing, and this should be taken into account in the design of sealed glazing units and the glazing system.

The low U-value and shading coefficient of reflective windows reduce the maximum value of both heating and cooling loads and consequently the size and first cost of an air-conditioning system. There is also a reduction in the operating cost for both heating and cooling. Whether these savings are sufficient to justify the extra cost of reflective windows depends on the particular circumstances, and an economic analysis should be made for each individual project.

The thermal and light transmitting characteristics of a window can be specified in terms of light transmittance, shading coefficient and U-value. A performance specification should give the maximum allowable values for shading coefficient and U-value and a minimum allowable light transmittance.