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TECHNICAL NOTE

LIMITED DISTRIBUTION

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PREPARED FOR Members of ASHRAE T C2. 5 (Heat gains through fenestrations)

SUBJECT DETERMINATION OF SHADING COEFFICIENTS FOR WINDOWS
WITHOUT SHADING DEVICES

The heat transfer through fenestration areas exposed to solar radiation is usually calculated by the following expression:

$$\frac{\text{Room Heat Gain}}{\text{Area of Fenestration}} = U (T_{outside} - T_{inside}) + \text{S. C. (SHGF)}$$

The first term on the right side of this expression is the rate of heat transfer through unit area of fenestration due to the difference between outside and inside air temperature. The second term is the heat gain associated with solar radiation.

The solar heat gain factor, SHGF, is the solar power that would enter a building if the glazing was one square foot of double strength sheet glass. This factor depends on the orientation of the window, time, date and latitude. Tables of SHGF are available for many combinations of these parameters[1, 2].

The shading coefficient, S. C., for any fenestration is the ratio of the rate of solar heat gain through that type of fenestration to the solar heat that would be admitted through a

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1.   ASHRAE Handbook of Fundamentals 1967 Chapter 28.

2.   Stephenson, D. G.   Tables of solar altitude, azimuth, intensity, and heat gain factors for latitudes from 43 to 55 degrees north.   National Research Council of Canada, Division of Building Research, Ottawa.   April 1967.   NRC No. 9528.

single pane of double strength sheet glass in the same situation.
The shading coefficient for any fenestration without shading devices
can be calculated if the following data are known:

> (1) Transmission and reflection factors for the glass
>
> (2) Inner and outer surface heat transfer coefficients
>
> (3) Thermal conductance of the interpane air space
> (if there is one).

This note describes a procedure for determining the transmission
and reflection factors for a glazing unit and illustrates how these
data can be used to compute the shading coefficient for the glazing
unit.

TRANSMISSION AND REFLECTION FACTORS

The solar transmission and reflection factors for glazing
units can be determined by a simple test using natural sunlight
as the radiation and a bolometer or thermopile type of radiation
sensing device. The glazing unit should be installed in a frame
that will hold it vertical but free to be turned to face the sun.
Figure 1 shows schematically the arrangement of the apparatus for
measurement of transmission and reflection factors.

The radiometer should have a fairly small field of view
so that all the radiation entering the instrument has nearly the
same angle of incidence. An instrument with a field of view of
0.025 stradians has been used and has proved quite satisfactory.
The procedure for measuring the transmission factor is:

> (1) The radiometer is aimed so that the sun is
> in the field of view and the voltage, e_1,
> generated by the thermopile is measured
>
> (2) The glazing unit is placed in front of the radiometer
> and positioned so that the direct rays from the
> sun have the desired angle of incidence at the
> glass surface. The thermopile output voltage,
> e_2, is measured.

The solar transmission factor for the glazing unit is simply

$$\tau = e_2/e_1 .$$

It is important to ensure that there is a negligible amount of radiation entering the radiometer by reflection and emission from the back side of the glazing unit. This is the reason for the shade behind the glazing unit shown in Figure 1. The only radiation entering the radiometer by reflection comes from the black painted underside of this shade; this surface is not illuminated by direct sunlight so its brightness is very low. Thus very little radiation enters the radiometer by reflection compared with the solar radiation that comes through the glass. The long-wave radiation emitted by the glass is excluded from the radiometer by a quartz window at the entrance to the radiometer tube.

The procedure for determining the reflection factor is similar, viz:

(1) The radiometer is aimed at the sun and the voltage, e_1, generated by the thermopile is measured

(2) The glazing unit is placed behind the radiometer and positioned so that the direct rays from the sun have the desired angle of incidence at the glass surface. The radiometer is then aimed at the image of the sun produced by the glazing unit. The thermopile output voltage, e_3, is measured.

The solar reflection factor for the glazing unit is simply

$$\rho = e_3/e_1.$$

In this case it is important that the brightness of the background seen through the window by the radiometer be very low compared with the brightness of the sun's image. The black-painted shade behind the unit as shown in Figure 1 ensures that this is the case.

CALCULATION OF SHADING COEFFICIENT

The calculation of the shading coefficient for a single glazing unit is quite simple. The necessary data are: the solar transmission factor τ, the solar reflection factor ρ, and the inside and outside surface heat transfer coefficients h_i and h_o respectively. The fraction of the incident solar energy that is transferred through the glass is

$$X = \tau + \frac{h_i (1 - \tau - \rho)}{h_i + h_o}.$$

The shading coefficient is just the value of X for the particular glass divided by X for standard double strength sheet glass.

The values of τ and ρ used to calculate X for the sample and the reference glass should be for an incident angle of about 30 degrees, as this is the condition at which the maximum heat transfer takes place through vertical windows. The value of $\dfrac{h_i}{h_i + h_o}$ depends on the way the air is circulated within the building: if the air flow near the windows is by natural convection this factor should be about 0.3 but if there is forced circulation the factor should be about 0.5.

Example:

For an incident angle of 30 degrees the transmission and reflection for double strength sheet glass are:

$$\tau_{30} = 0.868 \qquad \text{and} \qquad \rho_{30} = 0.081.$$

Thus, if $\dfrac{h_i}{h_i + h_o}$ is taken as 0.3,

$$X_{standard} = 0.868 + 0.3 \times .051 = 0.883.$$

The values for a $\frac{1}{4}$-in. sheet of heat absorbing plate that transmits 50 per cent at normal incidence are

$$\tau_{30} = 0.484 \qquad \text{and} \qquad \rho_{30} = 0.056$$

so $X_{HA\ Plate} = 0.484 + 0.3 \times 0.460 = 0.622.$

Thus the shading coefficient for the heat absorbing plate is

$$S.C. = \frac{X_{H.A.\ Plate}}{X_{standard}} = \frac{0.622}{0.883} = \underline{0.705.}$$

For a double-glazing unit the calculation is slightly more complicated. The first step is to calculate the absorption factor for each of the panes from the measured values of total transmission and total reflection. This requires either a separate transmission and reflection test for one of the two panes or an assumption of the τ and ρ based on the type of glass. The procedure is best shown by an example:

Assume that it has been determined by test that the over-all values for a double-glazing unit are

$$\tau_{30} = 0.105 \quad \text{and} \quad \rho_{30} = 0.535,$$

the outer pane being $\frac{1}{4}$-in. regular plate glass and the inner pane being $\frac{1}{4}$-in. plate with a reflective coating. The transmission and reflection factors for the regular plate are 0.781 and 0.073 respectively for solar radiation at an incident angle of 30 degrees.

Regular Plate   Reflective Plate

1.000

0.146

0.073

0.105

0.462   0.086
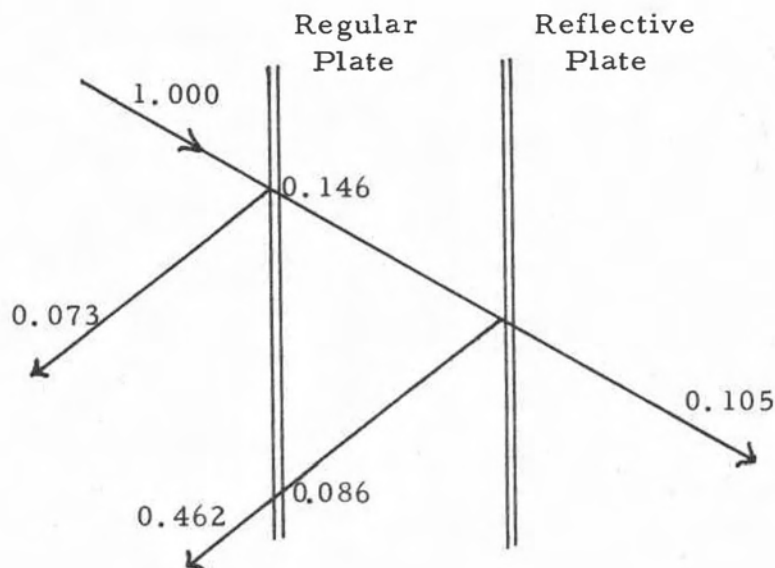
Thus when a unit of solar radiation strikes the outer pane 0.073 units are reflected and 0.146 (i.e., 1 - 0.781 - 0.073) units are absorbed. The total reflection factor is 0.535 so that 0.462 (i.e., 0.535 - 0.073) must be due to the radiation reflected by the inner pane and transmitted out through the outer pane. If the transmission through the outer pane is 0.462 the concomitant absorption by the $\frac{1}{4}$-in. regular plate is $0.462 \times \dfrac{0.146}{0.781} = 0.086$ so the total absorption by the outer pane is 0.146 + 0.086 = 0.232.

The absorption by the inside pane can now be found from the fact that the total absorption by the unit is 1.000 - 0.535 - 0.105 = 0.360 so absorption inner pane = 0.360 - 0.232 = 0.128.

The fraction of the absorbed solar energy that is transferred to the inside depends on the resistance to heat flow to the inside and to the outside from the plane where the energy is absorbed. The inward flowing fraction being $\frac{R_{out}}{R_{total}}$.

The values of the thermal resistances for the unit considered in the previous example are:

Layer	Resistance
Outside Surface	0.33
Outside Pane	0.05
Air Space ($\frac{1}{2}$ in.)	1.61
Inside Pane	0.05
Inside Surface	0.68
Total	2.72

For the outer pane the resistance to the outside is $0.33 + \frac{0.05}{2} = 0.355$ and for the inner pane

$$R_{out} = 0.33 + 0.05 + 1.61 + \frac{0.05}{2} = 2.015$$

Therefore the fraction of the incident solar radiation that is transferred to the inside is:

Transmission	=	0.105
Inward flowing part of absorption at outer pane	= $\frac{0.355}{2.72}$ x 0.232	= 0.030
Inward flowing part of absorption at inner pane	= $\frac{2.015}{2.72}$ x 0.128	= 0.095
$X_{double\ unit}$	=	0.230

The value of X for a single sheet of double strength sheet glass is 0.883 so the shading coefficient for the double glazing unit is:

$$\text{S. C.} = \frac{0.230}{0.883} = \underline{0.261}$$

It may be noted that the resistance of the $\frac{1}{2}$-in. air space in the example is higher than for an ordinary double-glazing unit with $\frac{1}{2}$-in. air space. This is because the reflective coating on the inner pane has a much lower emissivity than a clean glass surface so the long-wave radiation transfer across the gap is less than for normal double glazing.

The value of the shading coefficient obtained by this type of procedure is quite dependent on the values of the inner and outer surface resistances and on the transmission and reflection factors assumed for the clear pane of glass. It is important, therefore, to make sure that these data are as accurate as possible.
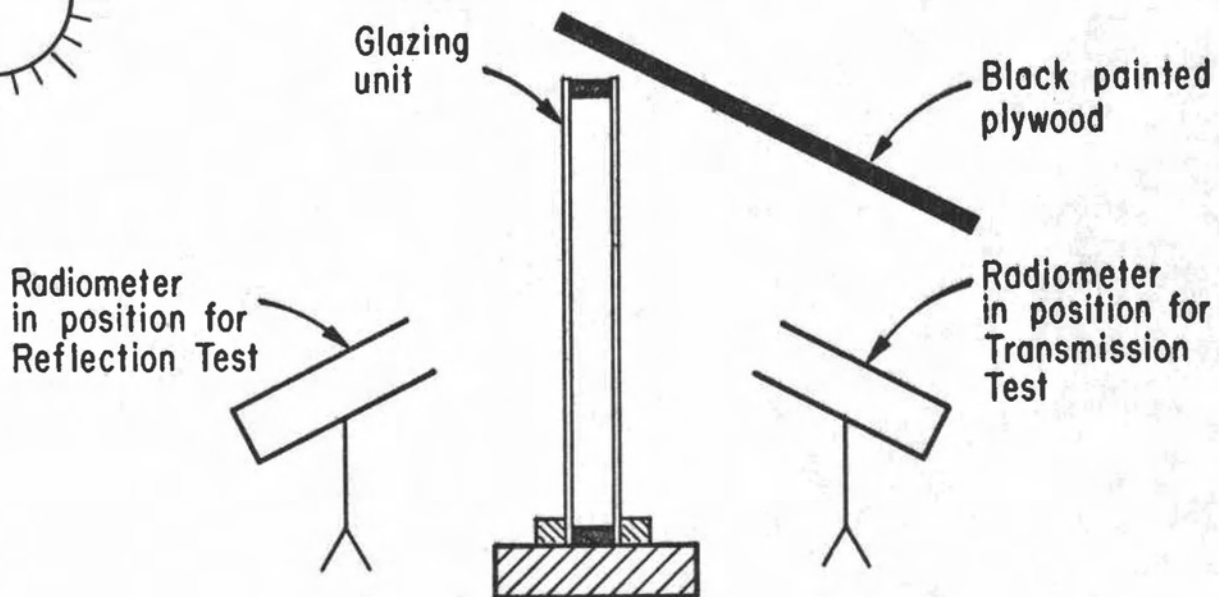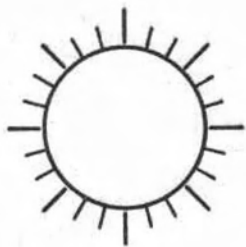
FIGURE I

ARRANGEMENT FOR TRANSMISSION AND
REFLECTION TEST ON GLAZING UNIT

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