THE SOLAR FACTOR OF A WINDOW

1. Introduction

The solar factor of a window can be calculated from the solar factor of the opaque frame and the solar factor of the glazing. In a first section the solar factor of an opaque element is discussed. In a second section the solar factor of the glazing is discussed. Then both solar factors are used to derive the window solar factor.

2. Solar factor of an opaque construction element

The heat transfer flows in a construction exposed to solar radiation is shown in Figure 1. For deriving the solar factor the external surface heat transfer by convection and infrared radiation are combined as shown in Figure 2, assuming equal values of air and sky temperature.

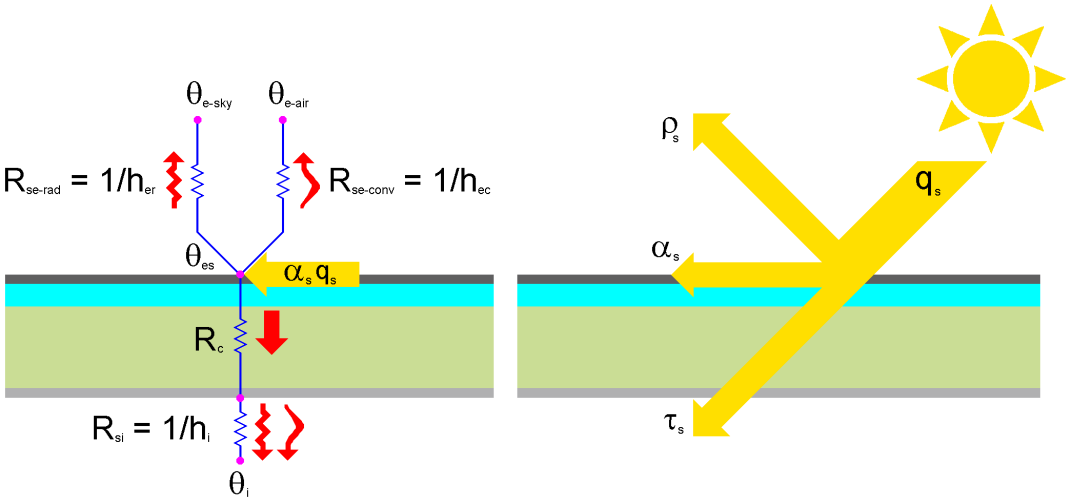

Figure 1. Heat transfer flows in a construction subjected to solar radiation.

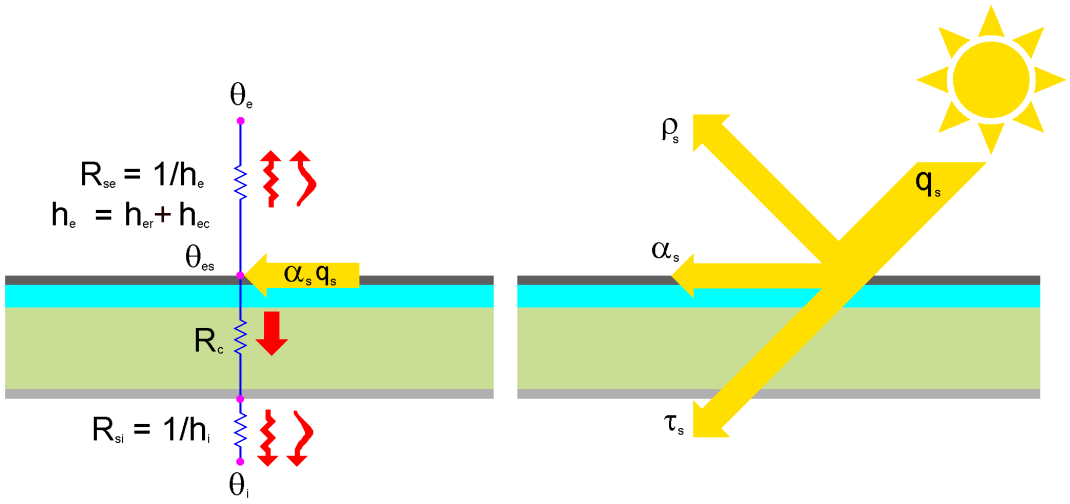

Figure 2. Heat transfer flows in a construction subjected to solar radiation with simplified global external surface heat transfer.

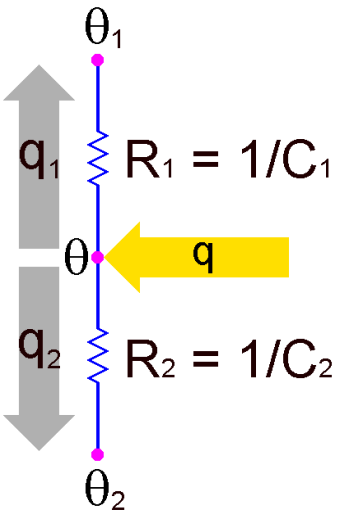

Figure 3. Thermal resistance scheme.

In the thermal resistance scheme of Figure 3, assume known temperatures θ_1 and θ_2 and a known flux q injected in the node with unknown temperature θ.
The unknown temperature θ can be derived as follows.

$$q = q_1 + q_2 = C_1 (\theta - \theta_1) + C_2 (\theta - \theta_2)$$ [Eq. 1]

$$\theta = \frac{q + C_1 \theta_1 + C_2 \theta_2}{C_1 + C_2}$$ [Eq. 2]

Now the flux q_2 can be derived.

$$q_2 = C_2 \left(\frac{q + C_1 \theta_1 + C_2 \theta_2}{C_1 + C_2} - \theta_2\right) = \frac{C_2}{C_1 + C_2}(q + C_1 (\theta_1 - \theta_2)) = \frac{R_1}{R_1 + R_2}(q + C_1 (\theta_1 - \theta_2))$$ [Eq. 3]

Applying Eq. 3 on the scheme in Figure 2, the solar heat flux entering the indoors can be calculated:

$$q_i = \frac{U}{h_e}(\alpha_s q_s + h_e (\theta_e - \theta_i))$$ [Eq. 4]

with U construction thermal transmittance = $1/(R_1+R_2)$

The solar factor g is defined as the entering flux due to solar radiation divided by the solar flux on the external surface, assuming the same temperature for outdoors and indoors ($\theta_e = \theta_i$):

$$g = \frac{q_i}{q_s} \qquad \boxed{g = \frac{\alpha_s U}{h_e}}$$ [Eq. 5]

3. Solar factor of a glazing

The solar factor of a glazing is the proportion of the incoming heat flux due to solar radiation and the solar radiation flux striking the external glazing surface in perpendicular way. The same temperature is assumed indoors and outdoors. The solar factor has 2 components:

1) the primary component, due to the solar radiation passing the glazing, i.e. in Figure 4 the sum of all yellow arrows entering the indoor environment (at the right)
2) the secondary component, due to natural convection and infrared radiation from the internal pane, heated up by solar absorption, to the indoors.

In the program CAPSOL the calculation of the solar factor is based on the Edwards embedding technique [1]. Figure 5 shows the CAPSOL's wall editor program interface for a double glazing. The primary component depends on the solar properties of the glazing panes only (yellow rectangles). The secondary component depends on all thermal properties of panes and gas cavity.

Typically the solar factor of a glazing is given by the manufacturer, together with the glazing thermal transmittance.

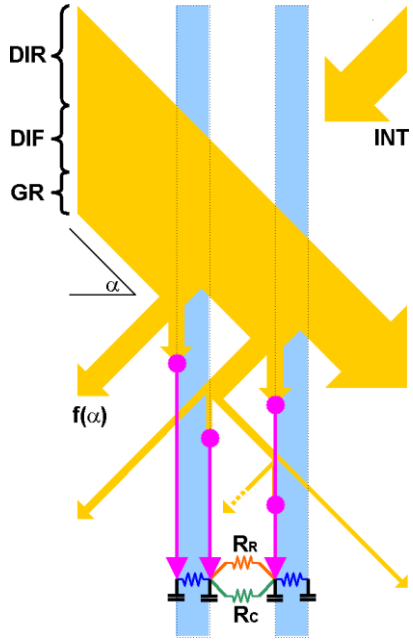

Figure 4. Scheme of solar radiation through a double glazing (from the CAPSOL manual).

DG_U1p1_g40.cwt

side1 => side2												side 1			side 2		
No.	Name	Type	Pat	d [m]	λ [W/mK]	R [m²K/W]	ρ [kg/m³]	c [J/kgK]	Nu [-]	hrb [W/m²K]	τs [-]	s1ir [-]	ρ1s [-]	α1s [-]	s2ir [-]	ρ2s [-]	α2s [-]
1	Planibel Energy NT	NORMAL		0.006	1.000	0.006	2470	750	-	-	0.423	0.84	0.42	0.16	0.02	0.30	0.28
2	cavity Argon 90 %	GAS		0.015	0.018	0.756	1.232	1008	1	5.14918	-	-	-	-	-	-	-
3	Planilux	NORMAL		0.006	1.000	0.006	2470	750	-	-	0.79	0.84	0.07	0.14	0.84	0.07	0.14

dtot=0.027 m, Rtot=0.768 m²K/W with [h1=25.0 W/m²K, h2=7.7 W/m²K] U=1.07 W/m²K , g=0.40

Figure 5. Capsol's "wall editor" allowing the calculation of the solar factor g.

[1] Edwards, D.K., 1977, Solar absorption by each element in an absorber-coverglass array, Solar Energy, vol. 19, pp. 401-402.

4. Solar factor of a window

To calculate the solar factor of a window the following formula can be used.

$$g_{window} = \frac{g_{glazing} S_{glazing} + g_{frame} S_{frame}}{S_{glazing} + S_{frame}} F \qquad \text{[Eq. 6]}$$

g solar factor [-]
S surface [m^2]
F reduction factor [-]

In the reduction factor F ($0 \leq F \leq 1$) fixed obstacles are taken into account[2].

The spreadsheet Window_g-value.xlsx allows the solar factor calculation.

[2] In the French "Règles Thermiques" for example, a reduction factor F = 0.9 is applied for windows aligned to the internal wall surface; for windows aligned to the external wall surface F = 1 is applied.