THERMAL SIMULATION OF VACUUM GLAZING

1. Introduction

Creating a vacuum layer between 2 glazing panes, of which one has a low emissivity coating, results theoretically in a glazing with a very low thermal transmittance, due to a very low heat transfer by conduction and radiation over the cavity. However, practically border and punctual spacers are required to maintain the vacuum. These spacers will cause a supplementary 3D conduction heat transfer effect, increasing the thermal transmittance. The vacuum glazing is simulated in 3D using the program TRISCO with the RADCON module.

2. Vacuum glazing description

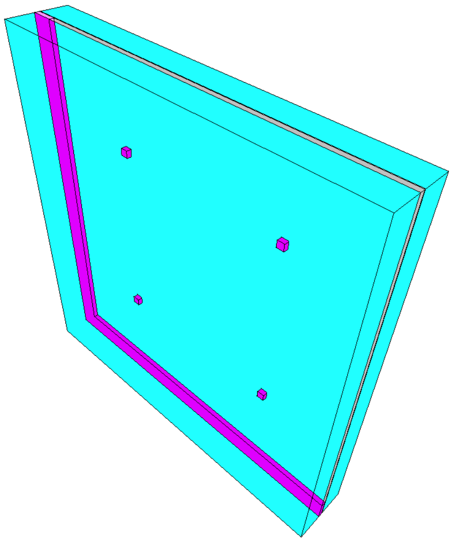

Figure 1. Corner part of a vacuum glazing with border and punctual spacers.

Figure 1 shows a corner part of a vacuum glazing. 2 glazing panes of 4 mm thick are separated by a vacuum cavity of 0.7 mm. One of the panes is covered by a low emissivity coating (ε = 0.02). At the border a 3 mm wide spacer (thermal conductivity λ = 1 W.mK) is applied. Punctual spacers (1 mm x 1 mm wide, thermal conductivity λ = 1 W.mK) occur each 50 mm (in 2 directions).

The glazing separates 2 environments:

- outdoors: temperature θ_e = 0°C, surface heat transfer coefficient h_e = 25 W/m^{2}K
- indoors: temperature θ_i = 20°C, surface heat transfer coefficient h_i = 7.7 W/m^{2}K.

The thermal transmittance U is calculated for 3 cases:
1) vacuum glazing without spacers (theoretical case),
2) vacuum glazing with punctual spacers only (theoretical case),
3) vacuum glazing with punctual and border spacers, with glazing dimensions 1 m x 1 m.

3. U-value of vacuum glazing without spacers

TRISCO data vacuum_glazing_without_spacers.trc
spreadsheet U_double_glazing_EN673.xlsx

TRISCO data highlights:

- The vacuum cavity is simulated as a TRANSMAT type, i.e. assuming conduction through the cavity and infrared radiation between the glazing surface. The thermal conductivity is assumed to be 0.0001 W/mK (quasi vacuum).
- The inner glazing pane is covered by a low emissivity coating (ε = 0.02). The outer glazing pane has an emissivity ε = 0.837 according to EN 673[1].

The thermal transmittance of the vacuum glazing is $U_{vg\_without\_spacers}$ = **0.234 W/m²K**.

As the heat transfer is 1D, the thermal transmittance can also be easily calculated using a spreadsheet:
U_double_glazing_EN673.xlsx (Figure 2).

The thermal transmittance of the vacuum glazing is $U_{vg\_without\_spacers}$ = **0.235 W/m²K**.

layer	name	thickness	thermal conductivity	surface heat transfer coefficient	emisivity	heat source flux	Nusselt number	convective resistance	radiative resistance	total thermal resistance	temperature
		m	W/mK	W/m^2K		W/m^2		m^2K/W	m^2K/W	m^2K/W	°C
	outdoors			25.000						0.040	0.0
						0.000					**0.2**
1	glass 1	0.0040	1.0000							0.004	
					0.837	0.000					**0.2**
2	quasi vacuum	0.0007	0.0001				1.00	7.000	9.765	4.077	
					0.020	0.000					**19.4**
3	glass 2	0.0040	1.0000							0.004	
						0.000					**19.4**
	indoors			7.700						0.130	20.0

Figure 2. Spreadsheet calculation of the vacuum glazing thermal transmittance.

4. U-value of vacuum glazing with punctual spacer

TRISCO data vacuum_glazing_punctual_spacer.trc

A representative glazing part of 50 mm x 50 mm is considered. In fact considering a part of 25 mm x 25 mm only would be sufficient.
The thermal transmittance of the vacuum glazing is $U_{vg\_with\_punctual\_spacer}$ = **0.483 W/m²K**.
Figure 3 shows the heat flow density on the internal surface.

[1] EN 673: 2011 Glass in building - Determination of thermal transmittance (U value) - Calculation method

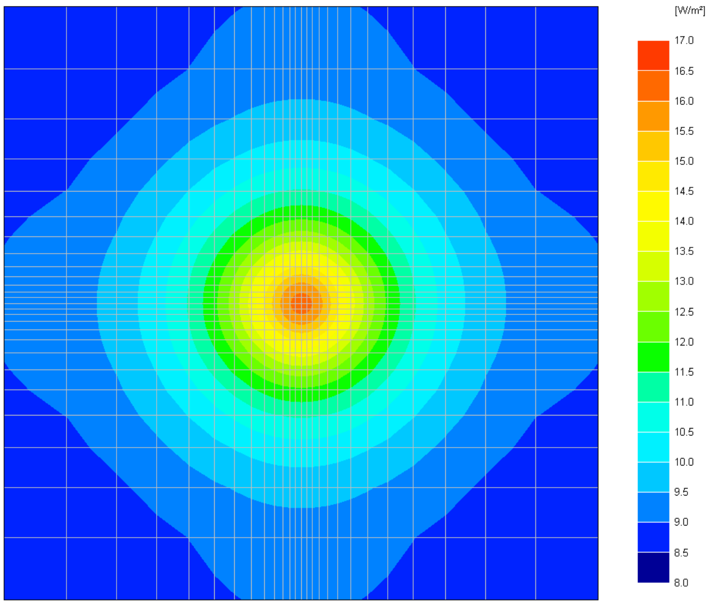

Figure 3. Heat flow density on the internal glazing surface.

5. U-value of vacuum glazing with punctual and border spacers

TRISCO data [vacuum_glazing_punctual_and_border_spacers.trc]

A representative glazing quarter of 500 mm x 500 mm is considered.

The thermal transmittance of the vacuum glazing is $U_{vg\_with\_punctual\_and\_border\_spacers}$ = 0.952 W/m²K.
Figure 4 shows the heat flow density on the internal surface.
Figure 5 shows the isotherms on the internal surface.
The isotherms correspond qualitatively very well with the isotherms of the infrared image Figure 6.

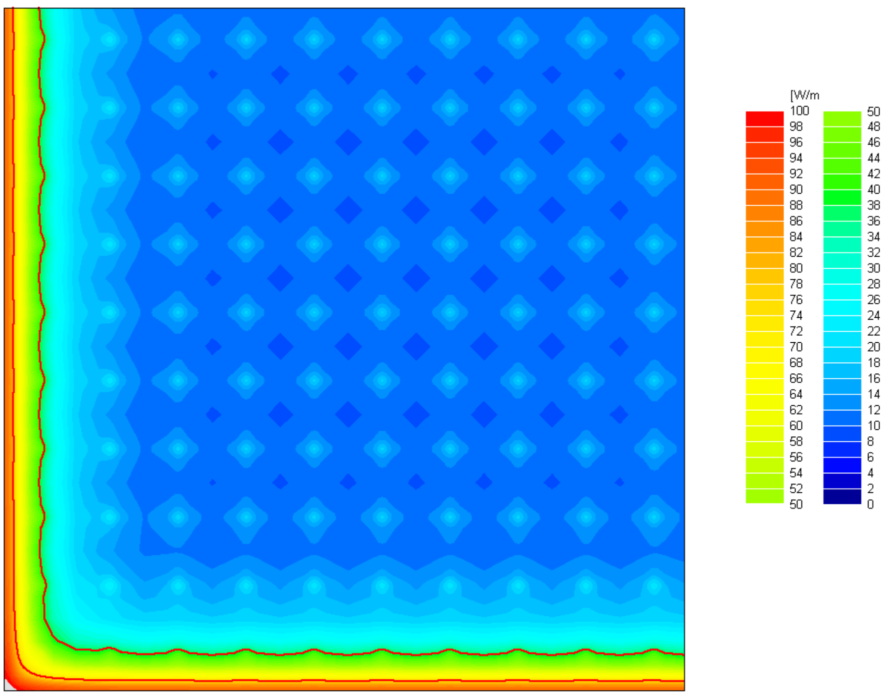

Figure 4. Heat flow density on the internal glazing surface.

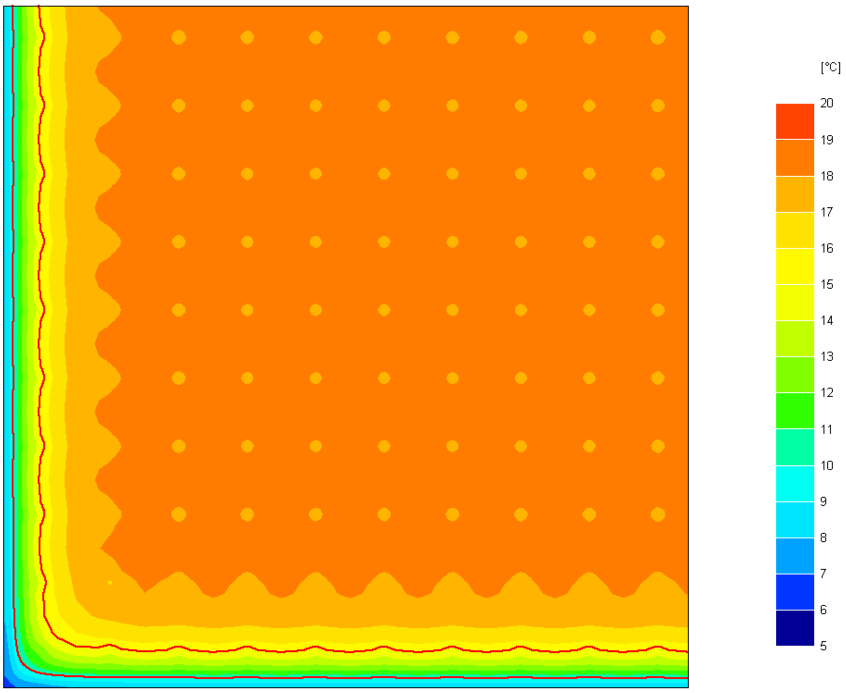

Figure 5. Isotherms (colour increment 1 °C, line increment 5 °C) on the internal glazing surface.

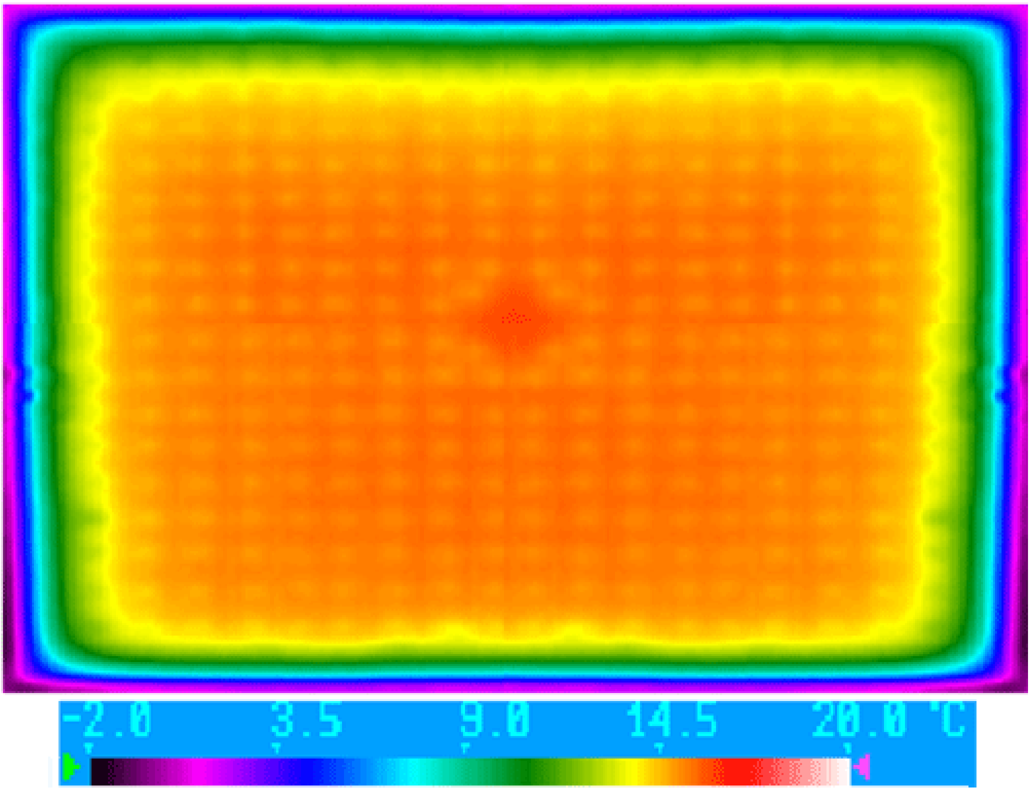

Figure 6. Infrared image of vacuum glazing (from https://chicagowindowexpert.com/thermal-images-of-insulated-glass-types/)