

The study of convection heat transfer in triple glazing systems.

The goal of this study is to ascertain how thickness of glazing cavities and its geometry influence on thermal performance of whole glazing system. For modeling convection heat transfer in vertical rectangle and not rectangle glazing cavities we used the program FIDAP [1] of the solution of the dynamics and heat exchange of flows of a fluid by means of finite elements method.

1. Unit glazing systems with vertical parallel glasses.

We modeled convection heat transfer in glazing systems with two air filled cavities with various thickness and the same summarized thickness of UG cavities (40mm) and internal glass (thickness 3mm). As a basic UG for comparison thermal properties we take air filled glazing system 20-3-20 (mm) at height $H = 0.8$ m.

Geometry and the boundary conditions accepted in numerical modeling are shown in figure 1.

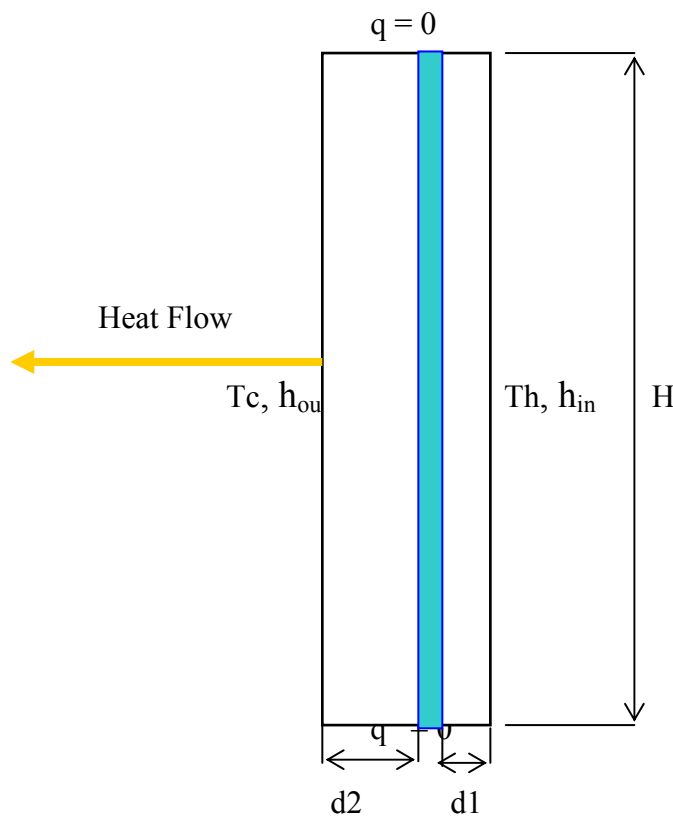


Figure 1. Designations and boundary conditions of the model of triple UG.

We defined film coefficient $h_{out} = 23$ W/(m²°C) and $h_{in} = 7$ W/(m²°C), temperature $T_c = -20$ °C and $T_h = 20$ °C.

Comment A.F.: These figures are to some degree arbitrary, because the main is comparison of obtained changes of properties.

Results of numerical modeling for aspect ratio $A = 20$ and $A = 40$ are summarized in the Table 1.

Table 1.

The overall thermal resistance R_o (U-factor) and minimal hot surface temperature of triple UG for various position of the internal glass and the same summarized thickness of UG cavities ($\Delta T = T_1 - T_2 = 40^\circ\text{C}$, $H = 0.8\text{m}$).

Thermal properties	Heat flow direction	Distance between glasses, d2-d1, mm			
		20-20	25-15	30-10	34-6
R_o , $\text{m}^2\text{C}/\text{W}$	\leftarrow	1.14	1.10	1.05	0.90
U_o , $\text{W}/(\text{m}^2\text{C})$	\leftarrow	0.877	0.909	0.952	1.11 (26%)
T_{\min} , $^\circ\text{C}$	\leftarrow	3.4	4.4	5.7	7.7
T_{\min} , $^\circ\text{C}$	\Rightarrow	3.4	4.3	5.1	4.2

Temperature distributions along hot glass surface for some glazing systems are shown on figure 2.

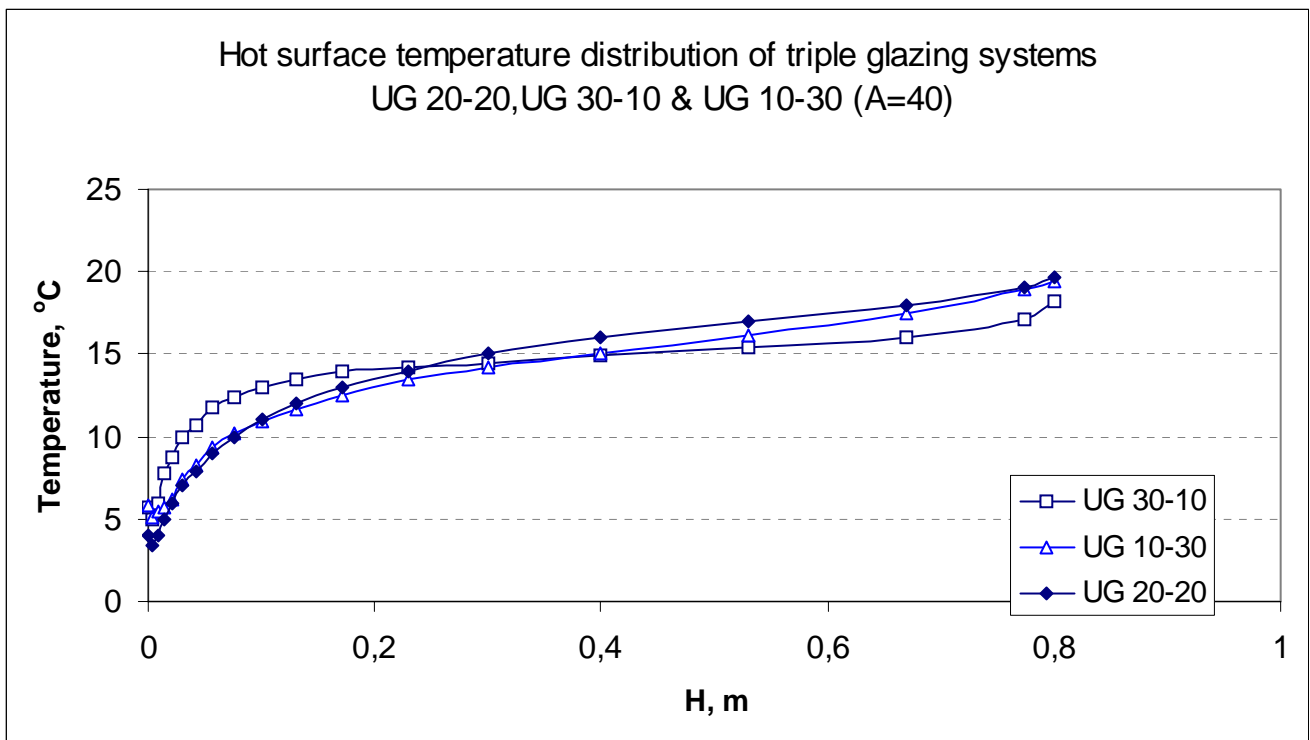


Figure 2. Comparison temperature distributions for various positions of internal glass and directions heat flow.

Conclusions

The results of numerical modeling convection heat transfer in triple glazing systems show us that thin inside (warm) cavity increase inside surface temperature (Table 1) but decrease thermal resistance of glazing more then 20% that is not acceptable. The best solution for triple glazing systems with vertical parallel glasses is using cavities with equal thickness.

2. Unit glazing systems with the inclined internal glass (N-type).

For countries with cold winter (Canada, Russia, Finland and partly USA) that widely used triple glazing in fenestration it is important not only overall thermal resistance (U-factor) of glazing but and temperature on inside glass surfaces. The low surface temperature creates uncomfortable conditions in a room and reduces durability of fenestration (condensation effect).

Upper we see that the thin inside cavity increase inside glass temperature (Table 1). This effect can be received without great reducing of glazing thermal resistance by applying glazing design with inclined internal glass that we name N-type glazing. The main distinguishing these systems from glazing systems with vertical parallel glasses is squeezing (or jamming) gas flow and convection motion in bottom part of glazing that increase temperature in this part of glazing system.

Comment A.F.: It is presumably that this construction of glazing system has also improved acoustic properties and of course ones must be tested.

In figure 3 it is shown geometry and the boundary conditions accepted in numerical study of N-type glazing systems.

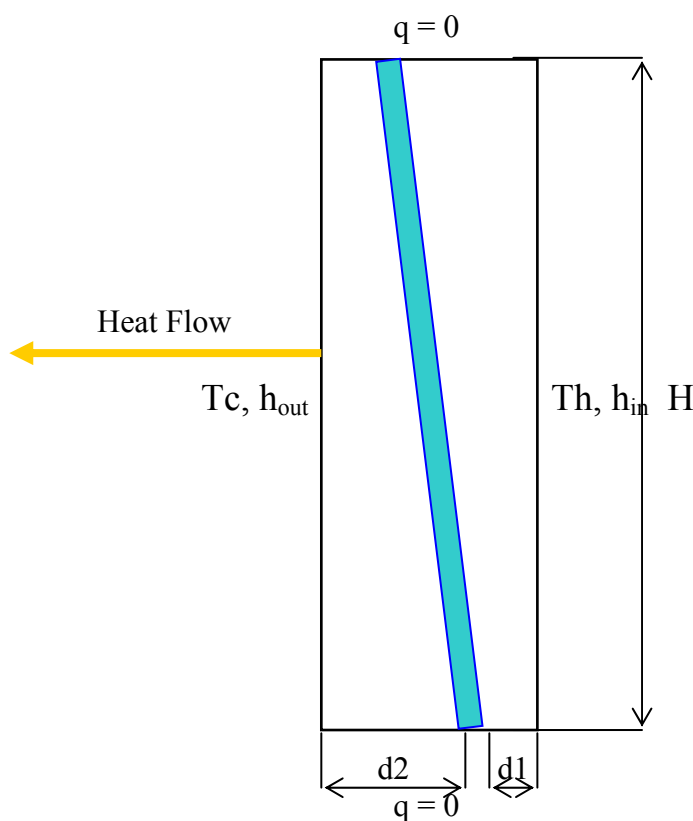


Figure 3. Geometry, designations and boundary conditions of the model triple UG with inclined internal glass.

Film coefficients were defined as $h_{out} = 23 \text{ W}/(\text{m}^2\text{°C})$ and $h_{in} = 7 \text{ W}/(\text{m}^2\text{°C})$, and temperatures: $T_c = -20 \text{ °C}$ and $T_h = 20 \text{ °C}$.

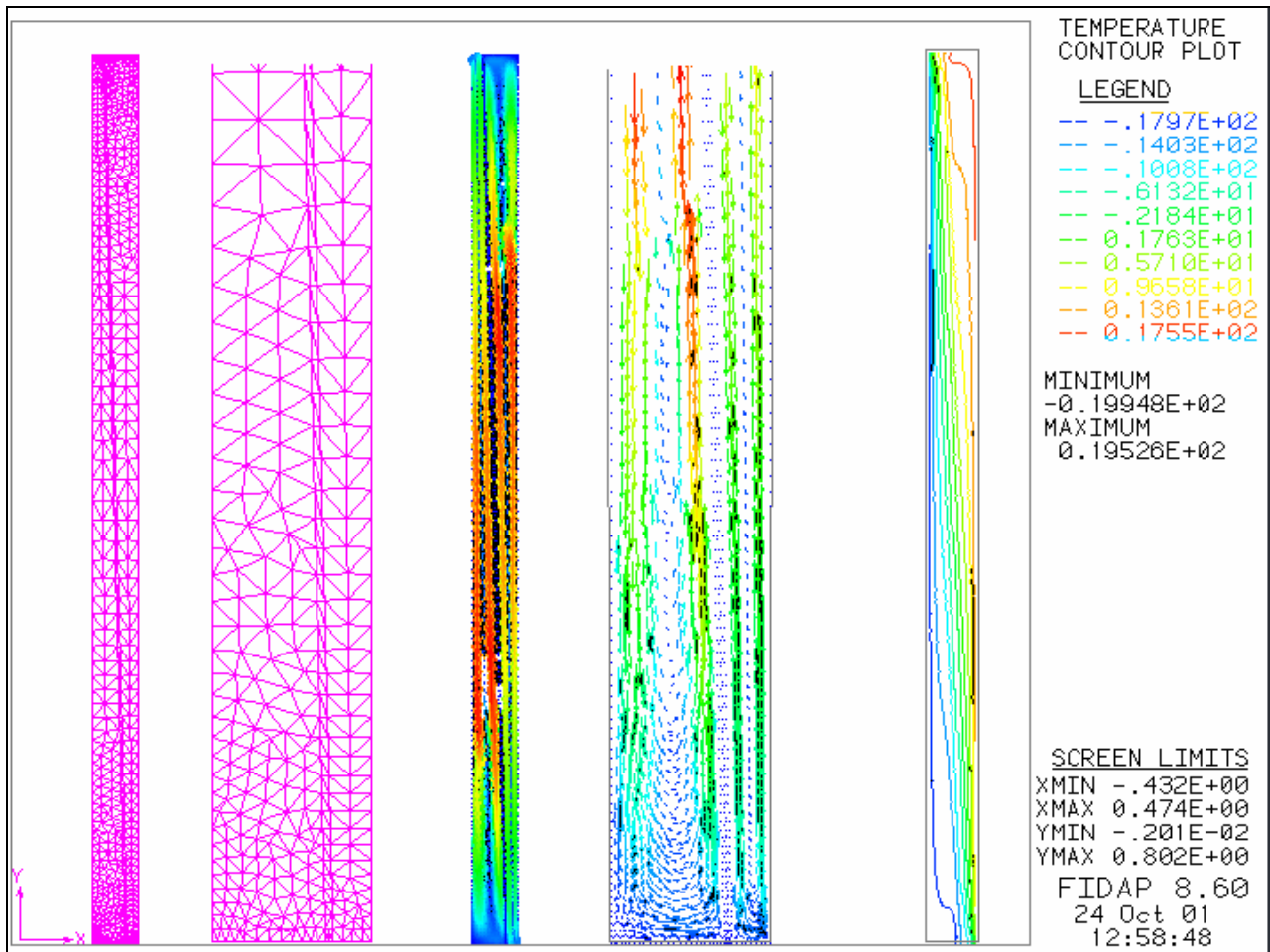


Figure 4. The mesh, velocity vector and temperature distribution in the model of triple N- type UG.

The results of numerical study are summarized in the Table 2. As a basic UG for comparison thermal properties we take air filled glazing system 20-3-20 (mm) at height $H = 0.8$ m.

Table 2.

The comparison of overall thermal resistance R_o (U-factor) and minimal hot surface temperature of usual (basic triple system) and N-type triple UG for various position of the internal glass and the same summarized thickness of UG cavities ($\Delta T = 40^\circ\text{C}$, $H = 0.8\text{m}$).

Thermal properties	Heat flow direction	Distance between glasses at the bottom of UG, d2-d1, mm			
		20-20	N: 25-15	N: 30-10	N: 34-6
$R_o, \text{m}^2\text{C}/\text{W}$	\leftarrow	1.14	1.11	1.11	1.08
$U_o, \text{W}/(\text{m}^2\text{C})$	\leftarrow	0.877	0.90	0.90	0.926 (5.6%)
$T_{\min}, ^\circ\text{C}$	\leftarrow	3.4	3.7	4.6	7.6
$T_{\min}, ^\circ\text{C}$	\Rightarrow	3.4	4.3	5.1	4.2

Temperature distributions along hot glass surface for basic glazing system and N-type system are shown on figure 4.

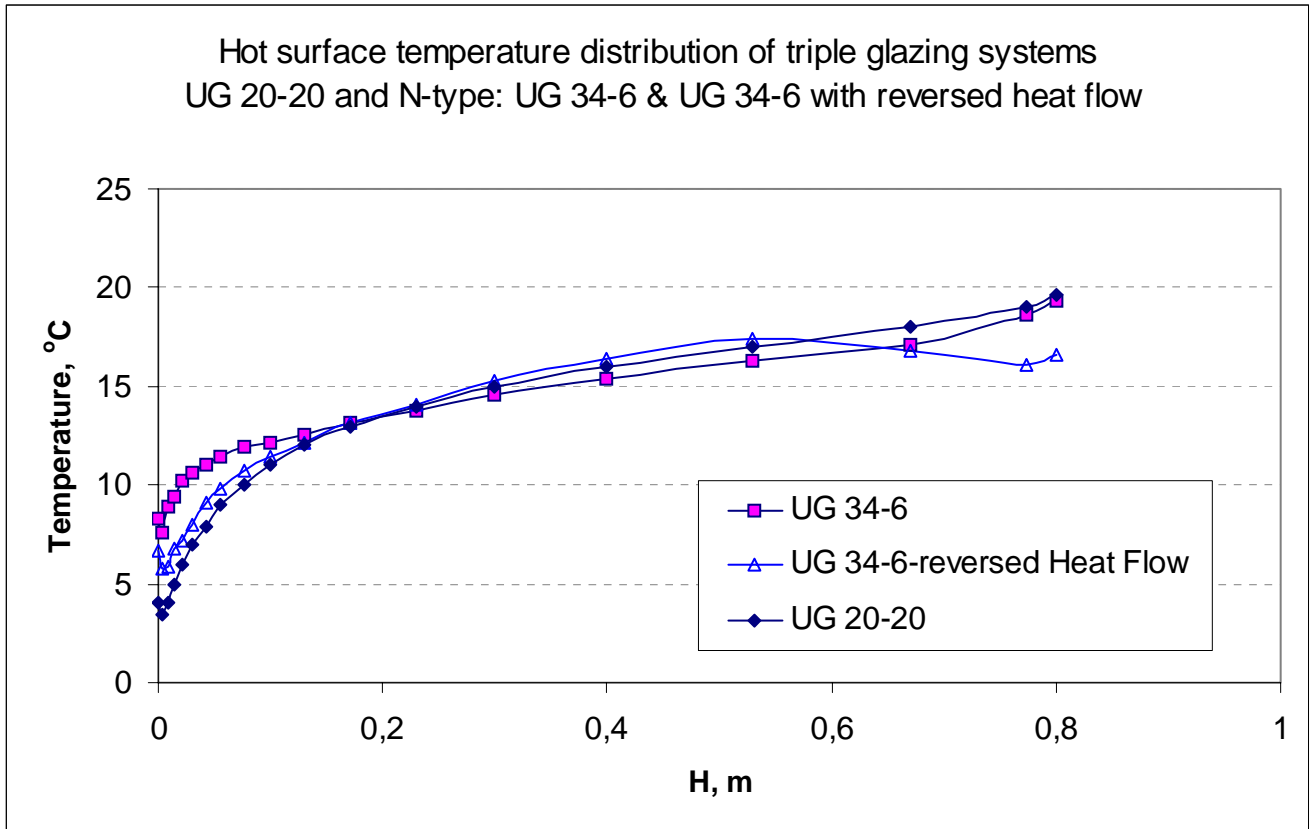


Figure 4. Comparison temperature distributions for various glazing systems and directions heat flow

Conclusions

The geometry of N-type UG positively affects on temperature in lower part of inside glazing surface and the increasing of the temperature from 3.4 °C (for basic glazing) to 7.6 °C not accompanies the strong decreasing of thermal resistance (not more than 5.6%).

The results given in table 2 and figure 4 show that N-type triple UG has not equal thermal properties for contrary directions of heat flow. The N-type triple UG has better thermal properties if one used as shown on figure 3.

The results obtained in present numerical study need to be confirmed by testing laboratories.

3. Unit glazing systems with two inclined glasses (V-type).

These glazing systems are further developing of an idea of gas flow jamming and have two narrowing in the lower part of glazing system.

Comment A.F.: The assumption about acoustic properties these systems must be checked.

The geometry of this type glazing and the boundary conditions accepted in numerical study give below in figure 5.

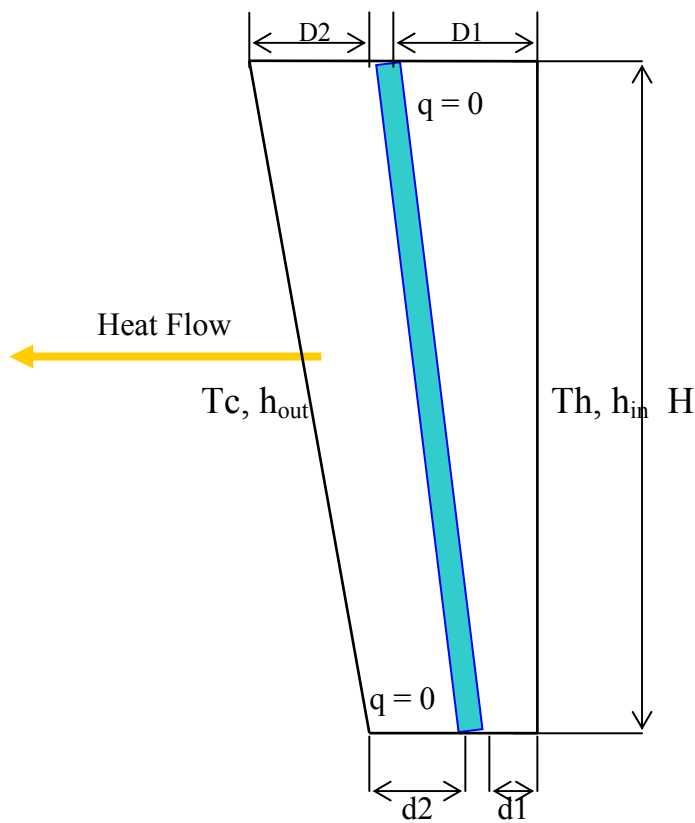


Figure 5. Geometry, designations and boundary conditions of the model of triple V-type UG.

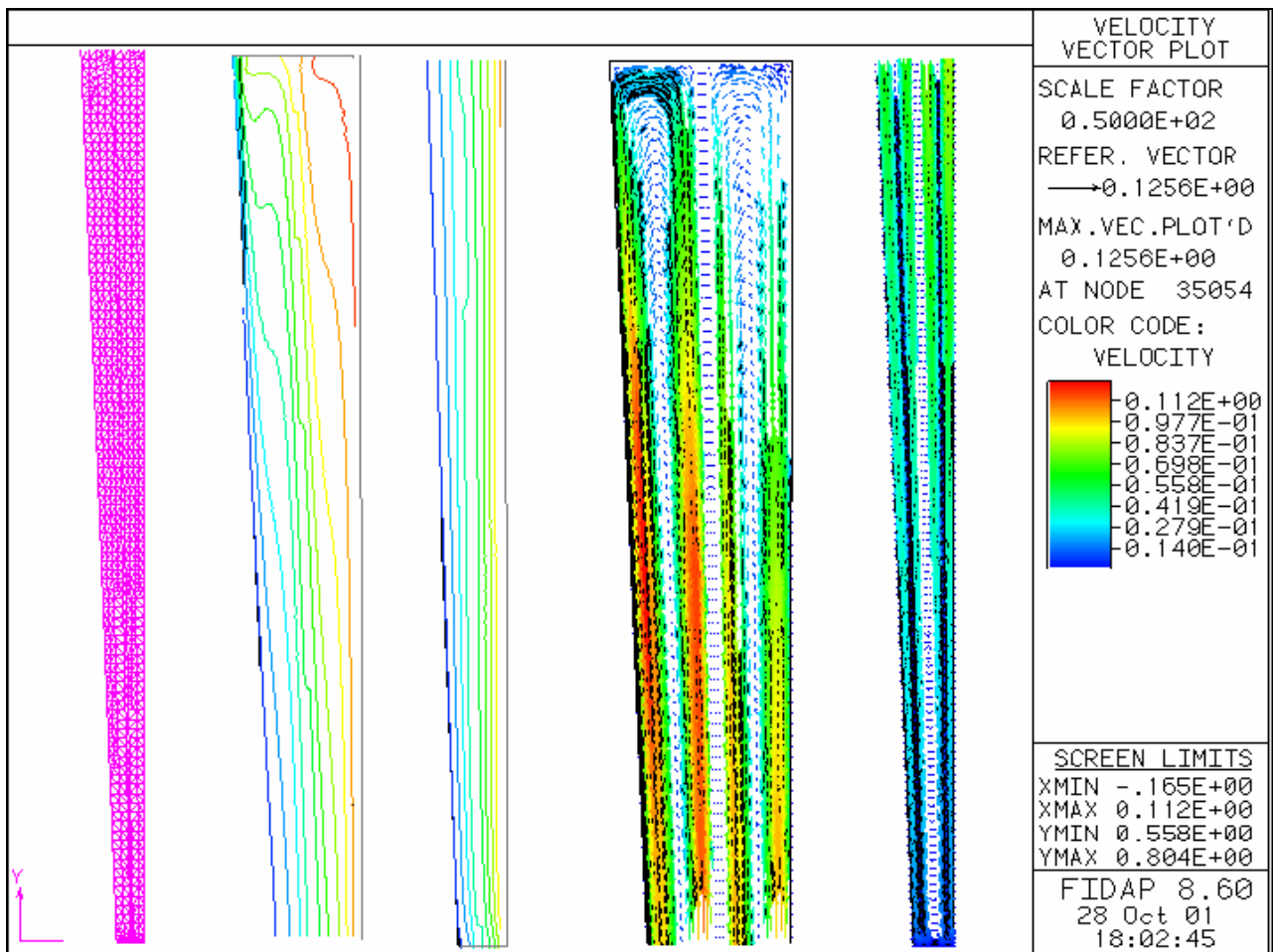


Figure 6. The mesh, velocity vector and temperature distribution in the model of triple V- type UG.

The results of calculations are summarized in the Table 3. All represented V-type systems have thickness in the middle section about 20mm that is why as a basic UG for comparison thermal properties we also used air filled glazing system 20-3-20 (mm) at height $H = 0.8$ m.

Table 3.

The comparison of overall thermal resistance R_o (U-factor) and minimal hot surface temperature of usual ($A=40$) and V-type triple UG for various distance between glasses at the top/bottom of UG. ($\Delta T = 40^\circ\text{C}$, $H = 0.8\text{m}$).

Thermal Properties	Distance between glasses at the top/bottom of UG, D2-D1/d2-d1, mm			
	20-20/20-20	V: 24-24/8-7	V: 24-24/9-7	V: 24-34/10-6
$R_o, \text{m}^2\text{C}/\text{W}$	1.14	1.08	1.09	1.08
$U_o, \text{W}/(\text{m}^2\text{C})$	0.877	0.926	0.917 (4.6%)	0.926
$T_{\min}, ^\circ\text{C}$	3.4	8.9	8.8	8.8

Conclusions

V-type glazing systems give more increasing of inside surface temperature (to 8.8 °C) and less decreasing of thermal resistance (about 4.6%, that is in the limits of uncertainties of testing methods).

These glazing systems compare favorably with considered upper N-type glazing systems because ones have better thermal properties. But of course they are more complicated in the manufacturing.

The results obtained in present numerical study need to be confirmed by testing laboratories.

The study of convection heat transfer in double-glazing systems with the inclined outside glass (V-type).

These glazing systems also used of an effect of gas flow jamming and have one narrowing in the lower part of glazing system.

The geometry of this type glazing and the boundary conditions accepted in numerical study give below in figure 7.

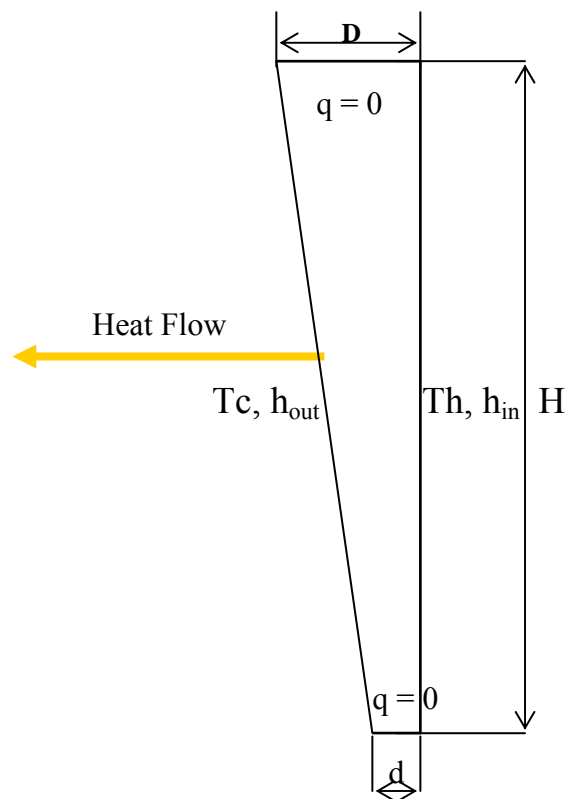


Figure 7. Geometry, designations and boundary conditions of the double UG model.

Results of numerical modeling are summarized in the Table 4.

Table 4.

The comparison of overall thermal resistance R_o (U-factor) and minimal hot surface temperature of usual ($A=40$) and V-type double UG ($\Delta T = 40^\circ\text{C}$, $H=0.8\text{m}$).

Thermal Properties	Distance between glasses at the top/ bottom of UG, D/d, mm			
	20/20	V: 30/9	V: 30/9 argon filled	V: 32/8 (H = 1m)
$R_o, \text{m}^2\text{C}/\text{W}$	0.653	0.625	0.816	0.638
$U_o, \text{W}/(\text{m}^2\text{C})$	1.531	1.60 (4.5%)	1.225	1.567
$T_{\min}, ^\circ\text{C}$	-0.3	2.1	4.6	2.5

Temperature distributions along hot glass surface of the “basic” glazing system and V-type glazing systems are shown on figure 8.

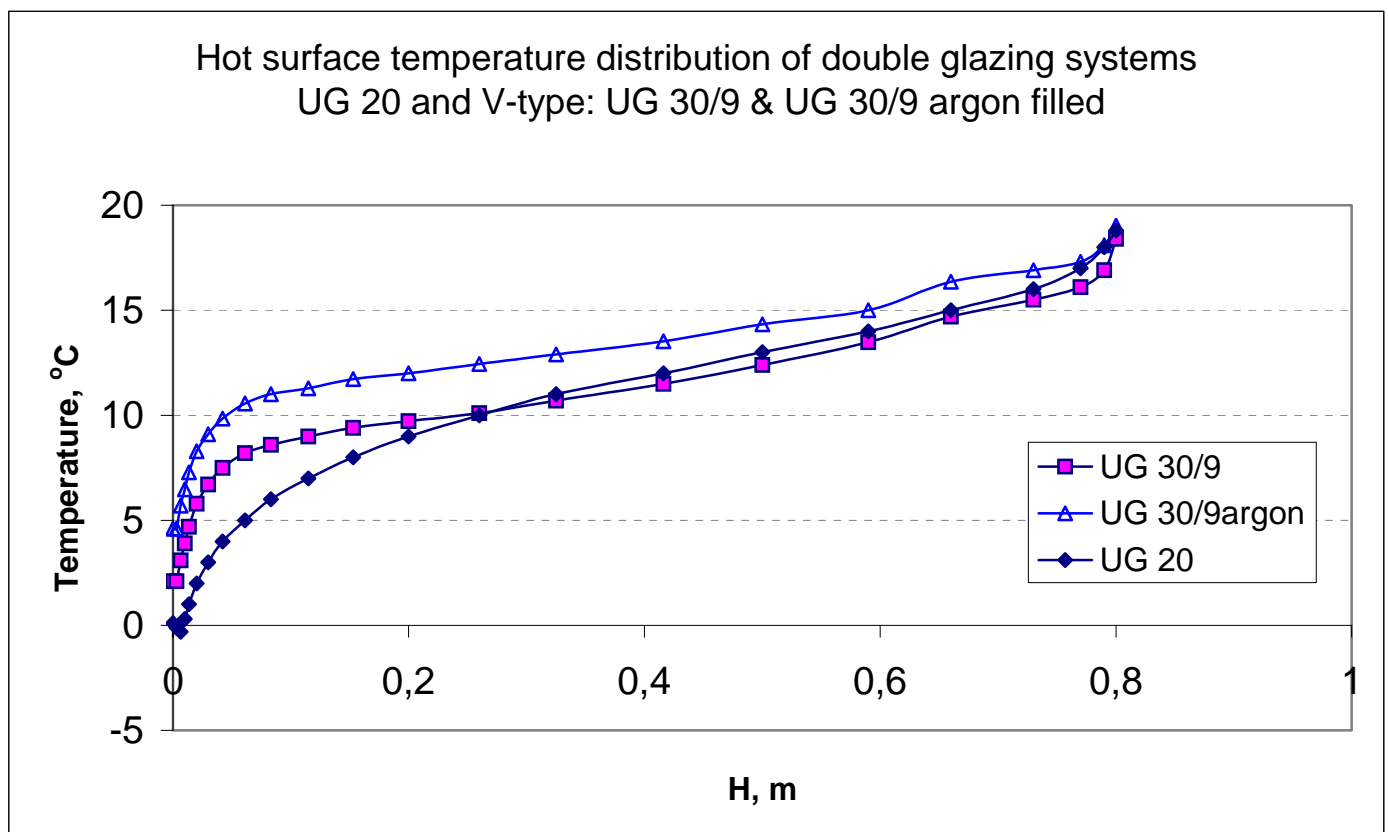


Figure 8. Comparison of temperature distribution for various glazing systems.

Conclusions

V-type double glazing system gives also increasing of inside surface temperature (see Table 4) but naturally less than V-type triple systems. The decreasing of thermal resistance very small (4.5%) that is in the limits of uncertainties of testing methods.

The thermal and acoustic properties of V-type glazing systems need to be confirmed by testing laboratories.

Comment A.F.: Dragan, it seems we have not bad work and interesting results here. Of course it do need to check by experimental methods. But now I suppose to organize patent searching analogue glazing constructions and searching similar results.

References

1.FDI.2000. FIDAP 8.52 Users and Reference Manual. Fluid Dynamics International, Fluid Dynamics Analysis Package Revision 8.52, Evanston, IL.