Windows as Renewable Energy Sources for Europe
Window Energy Data Network

Project supported by DG for Energy and Transport of the European Commission

www.windat.org

contract NNE5-2000-122

Evaluation of U-value algoritms in WIS

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WinDat document N3.05 - Public **May 2004**

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Research funded in part by
THE EUROPEAN COMMISSION
in the framework of the Community activities
in the Field of the specific programme for RTD and demonstration on Energy, Environment and Sustainable Development

Contents

1. Evaluation strategy

The aim of this investigation is to evaluate WIS in relation to the calculation of U-values as described in the standard EN 673.

The strategy chosen is to compare WIS generated results with results obtained by other programs.
It is not practical to compare all possible variations. Instead it is chosen only to make comparisons with a set of input parameters which in principle are near the end of the range of the possible values.

It is especially important to have sets of input-values, which provides heat transfer where the convection in the air space gives a significant contribution to the total heat transfer through the glazing. This is due to the relative complexity of these algorithms compared to other types of heat transfer.

It is also important to test the case of triple glazing with one of the spaces having a larger thermal resistivity than the other is. This is done by having one low emissive surface in one of the spaces and surfaces with emissivity of normal glazing in the other space. This will test if the algorithms can handle the iteration procedure described in the standard.

By this procedure all the following important algorithms and conditions will be covered:
- Convection
- Conduction
- Infrared radiation exchange
- Temperature dependence
- Boundary conditions

2. Evaluation

2.1 Input parameters

According to the principles described above following input parameters have been selected:

- Number of glazing: 2 and 3.

- Slope: Vertical, 45 ° and horizontal.
- Corrected emissivity: Normal glazing (ε = 0.837) and low emissive glazing (ε = 0.05 and 0.17)
- Air space: 8, 12, 16 and 20 mm.
- Gas type: Air, argon/air (90/10%) and krypton/air (90/10 %).

A number of combinations have been selected in the performed calculations.

The effect of glass thickness is not evaluated due to it's small impact on the U-value:

Glass thickness: 4 mm

The following input parameters are boundary conditions and are given in the standard:

In EN 673: Section 8

Boundary temperatures:	Temperature of the inside surface of the warm side glass pane: T_i = 17.5 °C.
	Temperature of the inside surface of the cold side glass pane: T_e = 2.5 °C.
Surface resistances:	Internal: R_i = 0.125 m^2K/W.
	External: R_e = 0.0434 m^2K/W.

In EN 673: Section 8, is the standardised boundary condition for the temperature difference ΔT defined as "temperature difference between bounding glass surfaces " and the reference value is given as 15K. It is normally considered as being the temperature difference across the gas gap – which is across the inside surfaces of the glazing. To take it as the outside surface of the glazing would make the calculation more difficult.

2.2 Calculation methods

The results obtained in WIS are compared with results from other methods. Following methods are chosen:

- Program WIS 2.0.1.
- Program UVindue, ver. 2.03 from Danish Technological Institute.
- Program GLAS-98 from Pilkington.
- NPL spread sheet method

The methods above are developed independent of each other and are in principle in accordance with the standard EN 673.

Some of the methods only cover a part of the configurations described above.

3. Results

Below are the results of WIS-calculation. Ver. 2.0.1.

Double-glazed units: WIS

Emissivity	Slope	100 % air		90% argon+10% air		90% krypton+10% air	
		12 mm	20 mm	12 mm	20 mm	12 mm	20 mm
High ε	Vertical	2,86	2,75	2,70	2,64	2,60	2,63
	45°	2,96	2,94	2,81	2,79	2,75	2,73
	Horizontal	3,10	3,04	2,92	2,88	2,83	2,80
Low ε	Vertical	1,65	1,43	1,32	1,19	1,11	1,16
	45°	1,86	1,82	1,55	1,51	1,42	1,39
	Horizontal	2,12	2,03	1,78	1,69	1,60	1,52

Table 3. Error! Unknown switch argument. **U-values of double-glazed units: WIS (W/m^2K)**

Differences obtained by calculation with the program UVindue (from Danish Technological Institute). (UVindue results - WIS-results):

Figure 3.1 U-values of double glazed units. (W/m^2K)

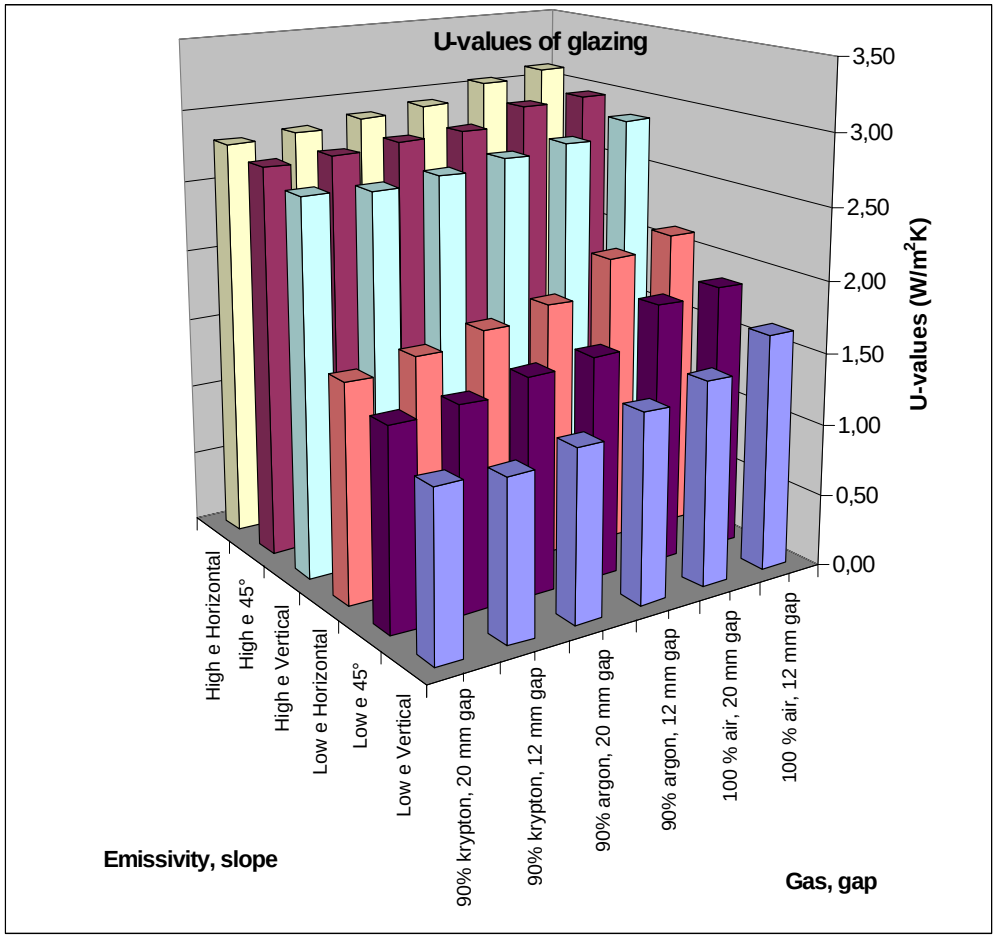

Table 3.2 U-values of double glazed units. Difference: UVindue-WIS (W/m^{2}K)

Emissivity	Slope	100 % air		90% argon+10% air		90% krypton+10% air	
		12 mm	20 mm	12 mm	20 mm	12 mm	20 mm
High ε	Vertical	0,00	0,01	0,01	0,01	0,01	0,00
	45°	0,01	0,01	0,00	0,01	0,01	0,01
	Horizontal	0,01	0,01	0,01	0,00	0,01	0,00
Low ε	Vertical	0,00	0,00	0,00	0,00	0,00	0,00
	45°	0,00	0,00	0,00	0,01	0,01	0,01
	Horizontal	0,01	0,00	0,01	0,01	0,01	0,01

Triple glazed units: WIS, with two the same type of air in the two spaces and in the case of low emissive glazing one low emissive layer in each space.

Table 3.3 U-values of triple glazed units: WIS (W/m^{2}K)

Emissivity	Slope	100 % air		90% argon+10% air		90% krypton+10% air	
		12 mm	20 mm	12 mm	20 mm	12 mm	20 mm

	Vertical	1,90	1,72	1,76	1,64	1,62	1,63
High ε	45°	1,90	1,87	1,77	1,76	1,73	1,72
	Horizontal	2,01	1,96	1,86	1,83	1,80	1,77
	Vertical	0,96	0,67	0,75	0,55	0,52	0,53
Low ε	45°	0,96	0,92	0,76	0,74	0,69	0,68
	Horizontal	1,13	1,07	0,91	0,86	0,81	0,76

Differences obtained by calculation with the program UVindue (from Danish Technological Institute). (UVindue results - WIS-results):

Table 3.4 U-values of triple glazed units. Difference: UVindue-WIS (W/m^{2}K)

Emissivity	Slope	100 % air		90% argon+10% air		90% krypton+10% air	
		12 mm	20 mm	12 mm	20 mm	12 mm	20 mm
	Vertical	0,00	0,00	0,00	0,00	0,01	0,00
High ε	45°	0,00	0,01	0,01	0,00	0,00	0,00
	Horizontal	0,00	0,01	0,01	0,01	0,00	0,01
	Vertical	0.00	0,00	0,00	0,00	0,00	0,01
Low ε	45°	0,00	0,00	0,00	0,00	0,01	0,00
	Horizontal	0,01	0,00	0,00	0,00	0,00	0,00

It has also been tested if the combination with triple glazing with 20 mm spacing and one of the cavities having high emissive layers and 100 % air while the other cavity has one low emissive layer and 90 % krypton and 10 % air. For both programs the U-values for vertical and horizontal slopes gave the U-values of 1,14 W/m^{2}K and 0,88 W/m^{2}K respectively.

The results show close agreement between the two calculation methods.

A few values have also been calculated with the program Glas-98 from Pilkington. (Glas-98 results - WIS-results).

Table 3.5 U-values of double glazed units. Difference: Glas98-WIS (W/m^{2}K)

Emissivity	Slope	100 % air		90% argon+10% air		90% krypton+10% air	
		12 mm	20 mm	12 mm	20 mm	12 mm	20 mm
High ε	Vertical	0,00	0,01	0,00	0,00	0,02	0,01

Below results from NPL spread sheet method.

Table 3.6 U-values of double glazed units and difference: WIS-NPL (W/m^{2}K)

Gas-fill	Gap size (mm)	Cor ε Surface 1	Cor ε Surface 2	Orientation	U-value W/m^{2}K NPL	U-value W/m^{2}K WIS	Diff. U-value WIS - NPL
Air	8	0,837	0,837	Vertical	3,10	3,10	0,00
				Horizontal	3,15	3,14	-0,01
		0,17	0,837	Vertical	2,32	2,32	0,00
				Horizontal	2,41	2,40	-0,01
90% Argon	8	0,837	0,837	Vertical	2,89	2,89	0,00
				Horizontal	2,96	2,96	0,00
		0,17	0,837	Vertical	1,98	1,98	0,00
				Horizontal	2,10	2,09	-0,01
Air	12	0,837	0,837	Vertical	2,86	2,86	0,00
				Horizontal	3,11	3,10	-0,01
		0,17	0,837	Vertical	1,92	1,92	0,00
				Horizontal	2,34	2,33	-0,01
		0,04	0,837	Vertical	1,63	1,63	0,00
				Horizontal	2,11	2,11	0,00
90% Argon	12	0,837	0,837	Vertical	2,70	2,71	0,01
				Horizontal	2,93	2,92	-0,01
		0,17	0,837	Vertical	1,64	1,64	0,00
				Horizontal	2,04	2,03	-0,01

Gas fill	Gap size (mm)	Cor ε Surface 1	Cor ε Surface 2	Orientation	U-value W/m^{2}K NPL	U-value W/m^{2}K WIS	Diff. U-value WIS - NPL
Air	16	0,837	0,837	Vertical	2,74	2,74	0,00
				Horizontal	3,08	3,07	-0,01
		0,17	0,837	Vertical	1,71	1,70	-0,01
				Horizontal	2,29	2,28	-0,01
90% Argon	16	0,837	0,837	Vertical	2,63	2,63	0,00
				Horizontal	2,90	2,90	0,00
		0,17	0,837	Vertical	1,51	1,50	-0,01
				Horizontal	1,99	1,99	0,00
Air	20	0,837	0,837	Vertical	2,76	2,75	-0,01
				Horizontal	3,05	3,05	0,00
		0,17	0,837	Vertical	1,73	1,73	0,00
				Horizontal	2,25	2,24	-0,01
90% Argon	20	0,837	0,837	Vertical	2,65	2,64	-0,01
				Horizontal	2,88	2,88	0,00
		0,17	0,837	Vertical	1,53	1,52	-0,01
				Horizontal	1,96	1,95	-0,01

The results show close agreement between the two calculation methods.

4. Conclusion

The calculation of U-values of the glazing obtained with WIS complies with EN 673 within the investigated range of variations.