Center for Energy Efficiency and Renewable Energy

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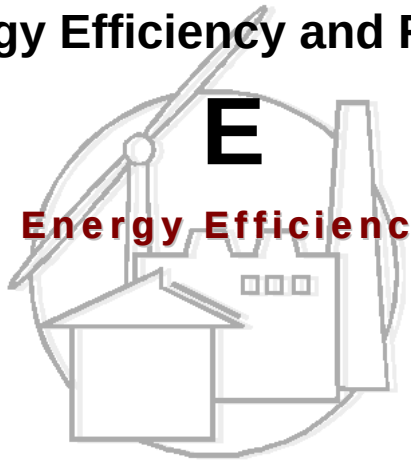

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TECHNICAL REPORT

Computer Modeling of Heat Transfer For NFRC 1999-2000 Testing Round Robin Window – U-Factor and CR Simulations Using WINDOW 5 and THERM 5

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DESCRIPTION OF THE SPECIMEN

The product selected for testing is a nominal 60’’x36” horizontal slider window with Aluminum frame. Thermo physical properties of different frame material are given in Table 1 and schematic representation of the material locations for a sill section is shown in Fig. 1. The geometry and cross sections as drawn in THERM and their distribution is given in Fig. 2.

Table 1: Material Thermo Physical Properties

Material	***Conductivity***		***ε***
	Btu/h-ft-F	***W/mK***	
Aluminum	92.448	160.01	0.2
Mohair (Poly) Sweep	0.0809	0.14	0.9
Butyl Rubber	0.1387	0.24	0.9
Silica Gel (desiccant)	0.0173	0.03	0.9
Polysulphide	0.1098	0.19	0.9
Vinyl (Flexible)	0.0693	0.12	0.9
Steel-ANSI 1040 Mild	27.7344	48.00	0.2

Window 5 has been used to create the glazing system. The glazing unit consists of two panes of 0.129" PPG glass separated by a 0.003” thick heat mirror with coating on the inner side (ε=0.088) and two air spaces each of 0.244”. The outer surface of inner glass has spectrally selective coating (ε=0.088). The detailed report generated by Window5 is given in Appendix A.

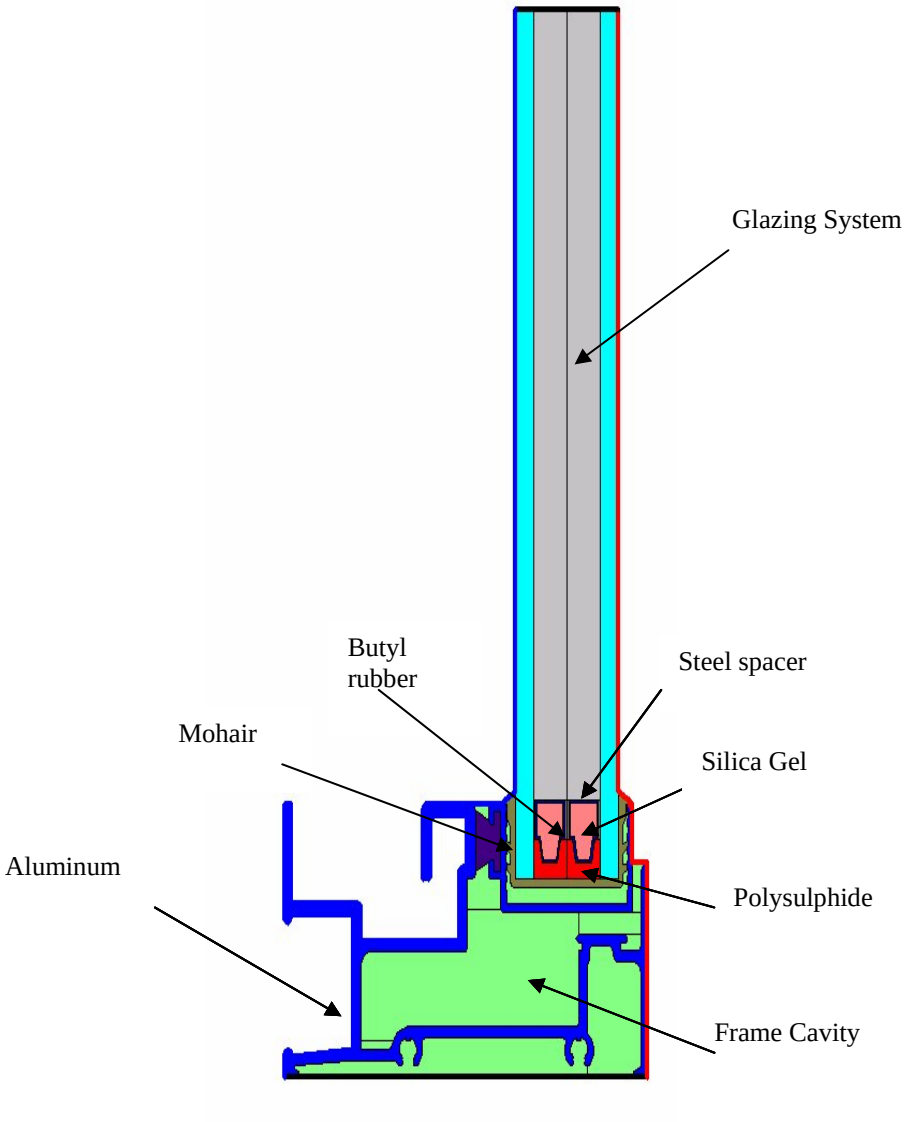
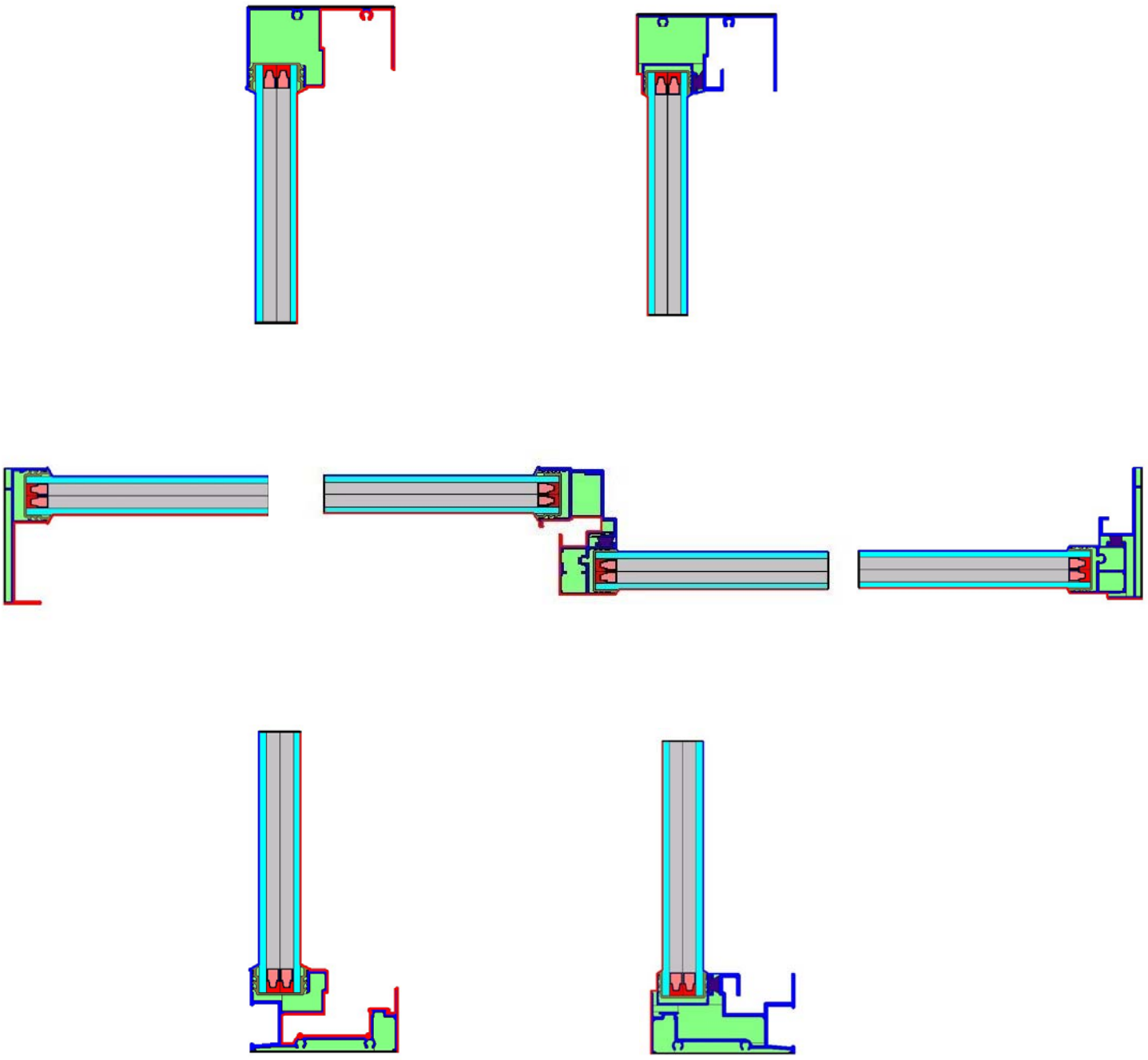


Fig. 1: Schematic Representations of Frame Materials in a Sill Cross-Section of Frame (Fixed)



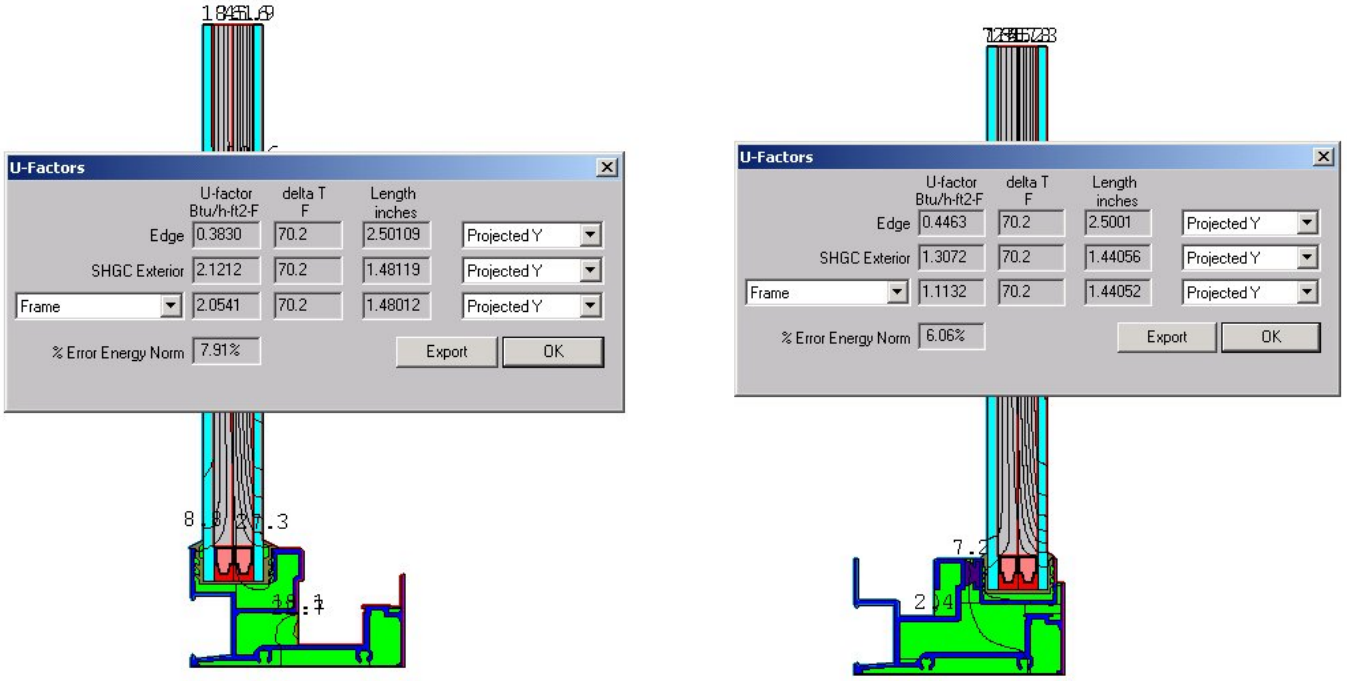
Fixed **Vented**

Fig. 2: Schematic Representation of TRR99 window drawn in THERM5

The U factor and isotherms for different cross sections of the window are shown in Fig. 3-6. U-factor as well as CR calculations have been performed using the boundary conditions given in Table 2. Radiation heat transfer has been modeled on the warm side using detailed view factor based radiation calculations (grey body), and on the cold side using black body radiation. For the sake of comparison an additional set of calculations has also been performed by not considering the exposed grooves with small cross sections or cavities connected to the external or internal environments by a slit greater than 2mm but not exceeding 10 mm as slightly ventilated air cavities

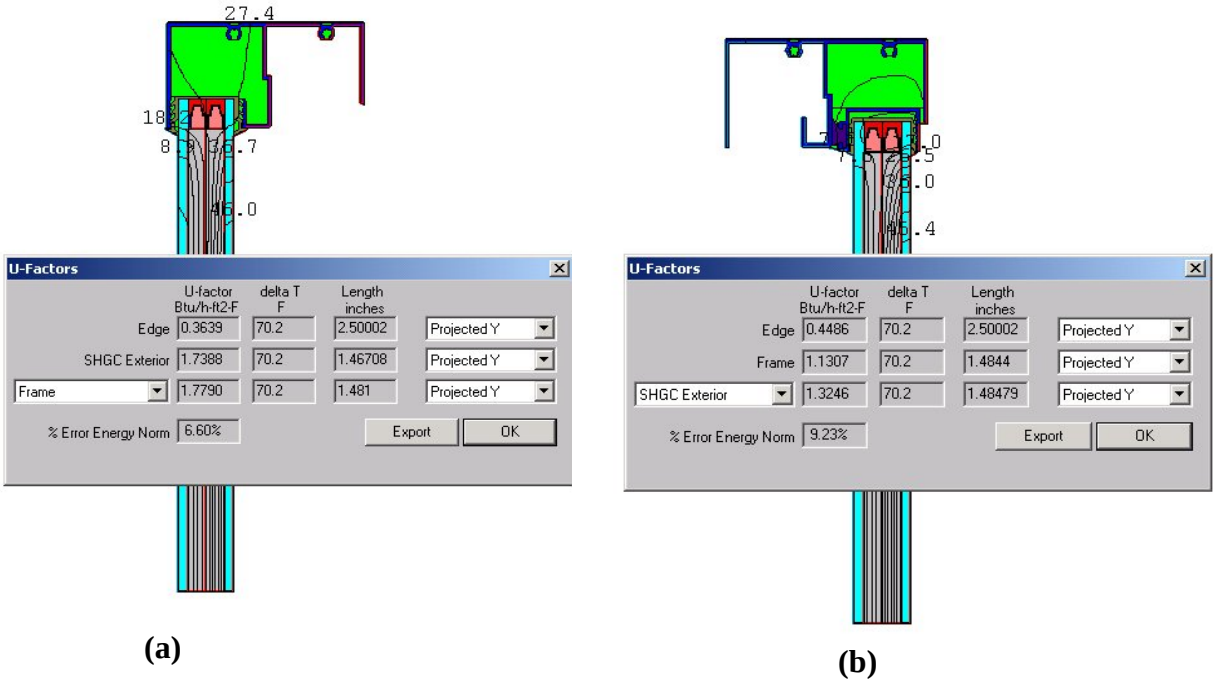
Table 2: Boundary Conditions For Indoor and Outdoor Side of Window System for U- factor Calculation without radiation enclosure

Boundary Conditions		*Environmental Temperature*		h_c		*Overall h*		ε
		F	C	$Btu/hr{\cdot}ft^2{\cdot}F$	$W/m^2{\cdot}K$	$Btu/h{\cdot}ft^2{\cdot}F$	$W/m^2{\cdot}K$	
Outdoor Side	Glazing	0	-18	4.58	26	N/A	N/A	0.84
	Frame			4.58	26	N/A	N/A	0.90
Indoor Side	Glazing	70	21	0.45	2.55	N/A	N/A	0.84
	Frame			0.45	2.55	N/A	N/A	0.90



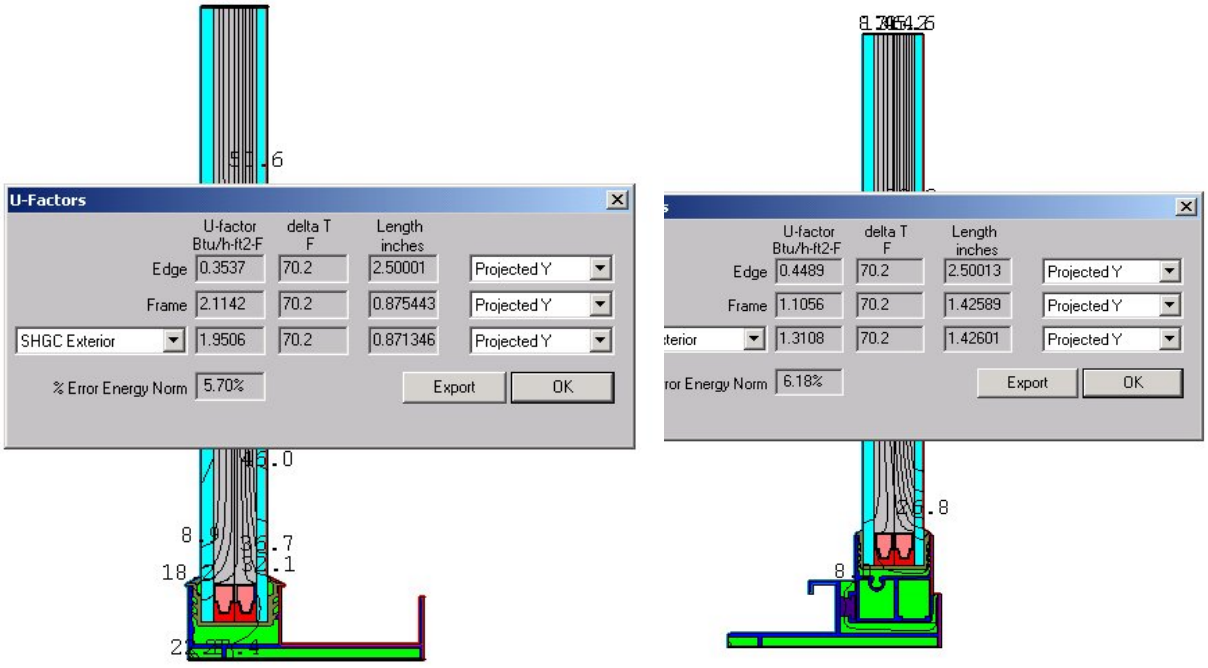
(a) **(b)**

Fig. 3: Isotherms and U factors For Sill Cross Section: (a) Fixed (b) Vented



(a) **(b)**

Fig. 4: Isotherms and U factors For Head Cross Section: (a) Fixed (b) Vented



(a) **(b)**

Fig. 5: Isotherms and U factors For Jamb Cross Section: (a) Fixed (b) Vented

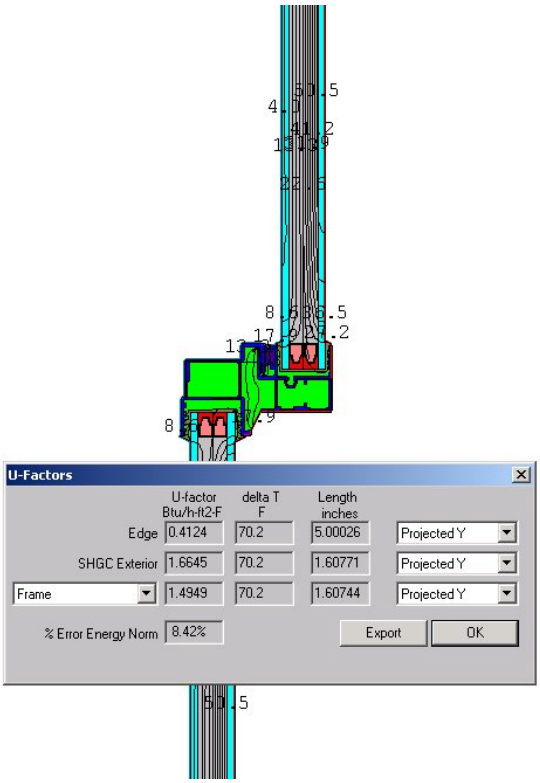


Fig. 6: Isotherms and U factors For Meeting rail Cross Section

The U-factors, SHGC, VT and CR values for TRR99 are given in Table 3. Table 4 shows the respective values for the case when the cavities are not considered as slightly ventilated

Table 3: Frame, Edge And Overall U-Factors and CR value – Ventilated cavities

Cross Section	*Name of THERM data file (ext .THM)*	*Projected frame width*		*Frame*		*Edge-of-Glass*		
		in.	*mm*	*Btu/h·ft²·F*	*W/m²·K*	*Btu/h·ft²·F*	*W/m²-K*	*U-*
Head Fixed	W5_trr99_hf_et.	1.4810	37.6174	1.779	10.102	0.364	2.067	*F*
Head Vented	W5_trr99_hv_et	1.4848	37.7139	1.131	6.422	0.4486	2.547	*a*
Sill Fixed	W5_trr99_sf_et	1.4801	37.5945	2.054	11.663	0.383	2.175	*c*
Sill Vented	W5_trr99_sv_et	1.4405	36.5887	1.113	6.320	0.446	2.533	*t*
Jamb Fixed	W5_trr99_jf_et	0.8713	22.1310	2.114	12.019	0.354	2.010	*o*
Jamb Vented	W5_trr99_jv_et	1.4259	36.2179	1.106	6.280	0.4489	2.549	*r*
Meeting Rail	W5_trr99_mr_et	1.6074	40.8280	1.495	8.489	0.412	2.340	*s*
Overall				15.08		45.37		*CR*

	U-Factor		*SHGC*	*VT*	*CR*
	Btu/hr·ft²·F	*W/m²·K*			
Center of glass	0.309	1.753	0.346	0.581	65.09
Window Assembly	**0.505**	**2.868**	**0.312 (0.313)***	**0.499**	**15**

Note: *SHGC calculated using exterior tag

Table 4: Frame, Edge And Overall U-Factors and CR value – no ventilated cavities

Cross Section	*Name of THERM data file (ext .THM)*	*Projected frame width*		*Frame*		*Edge-of-Glass*		
		in.	*mm*	*Btu/h·ft²·F*	*W/m²·K*	*Btu/h·ft²·F*	*W/m²-K*	*U-*
Head Fixed	W5_trr99_hf_et.	1.4810	37.6174	1.805	10.249	0.3314	1.882	*F*
Head Vented	W5_trr99_hv_et	1.4848	37.7139	1.130	6.416	0.4471	2.539	*a*
Sill Fixed	W5_trr99_sf_et	1.4801	37.5945	2.383	13.531	0.3787	1.923	*c*
Sill Vented	W5_trr99_sv_et	1.4405	36.5887	1.119	6.354	0.4471	2.539	*t*
Jamb Fixed	W5_trr99_jf_et	0.8713	22.1310	2.114	12.019	0.354	2.010	*o*
Jamb Vented	W5_trr99_jv_et	1.4259	36.2179	1.106	6.280	0.4489	2.549	*r*
Meeting Rail	W5_trr99_mr_et	1.6074	40.8280	1.983	11.260	0.4025	2.285	*s*
Overall				15.48		47.16		*CR*

	U-Factor		*SHGC*	*VT*	*CR*
	Btu/hr·ft²·F	*W/m²·K*			
Center of glass	0.309	1.753	0.346	0.581	65.09
Window Assembly	**0.522**	**2.964**	**0.314***	**0.499**	**15**

Note: *SHGC calculated using exterior tag

Temperature Distribution along the Inner Surface of the Window

Figs 7 and 8 show the temperature distribution along the fixed and vented parts respectively. The middle point in the graph corresponds to the center of glass temperature. The peaks on the frame sections (say Fig 7) are due to fact that as per ISO15099 exposed grooves with small cross sections or cavities connected to the external or internal environments by a slit greater than 2mm but not exceeding 10 mm have been considered as slightly ventilated air cavities. Distance at X-axis corresponds to either the bottom of sill section to the top of the head section or from fixed jamb section to meeting rail and then to the vented jamb section. Fig. 9 shows the distribution horizontally, starting from the fixed jamb through the meeting rail upto the vented jamb section. Temperature distribution when these cavities have not been considered as slightly ventilated is given in . Figs10-12.

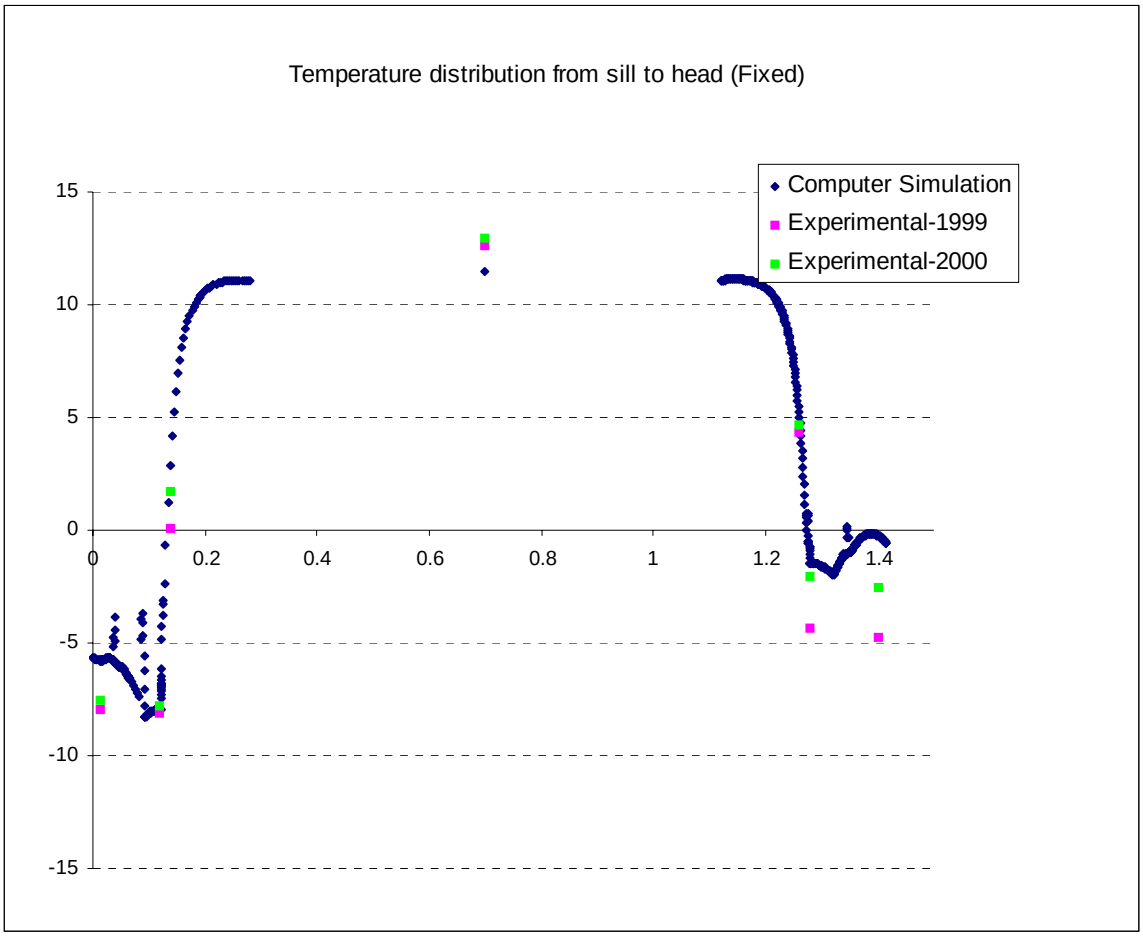


Figure 7: Temperature Distribution From Sill To Head (Fixed Section) –

Figs 7 through 9 also show some average value taken from Round Robin inter-laboratory test results for the same window. As Round Robin 2000 is inter-laboratory test results for the same window, the average values from these test results have also been plotted in these figures.

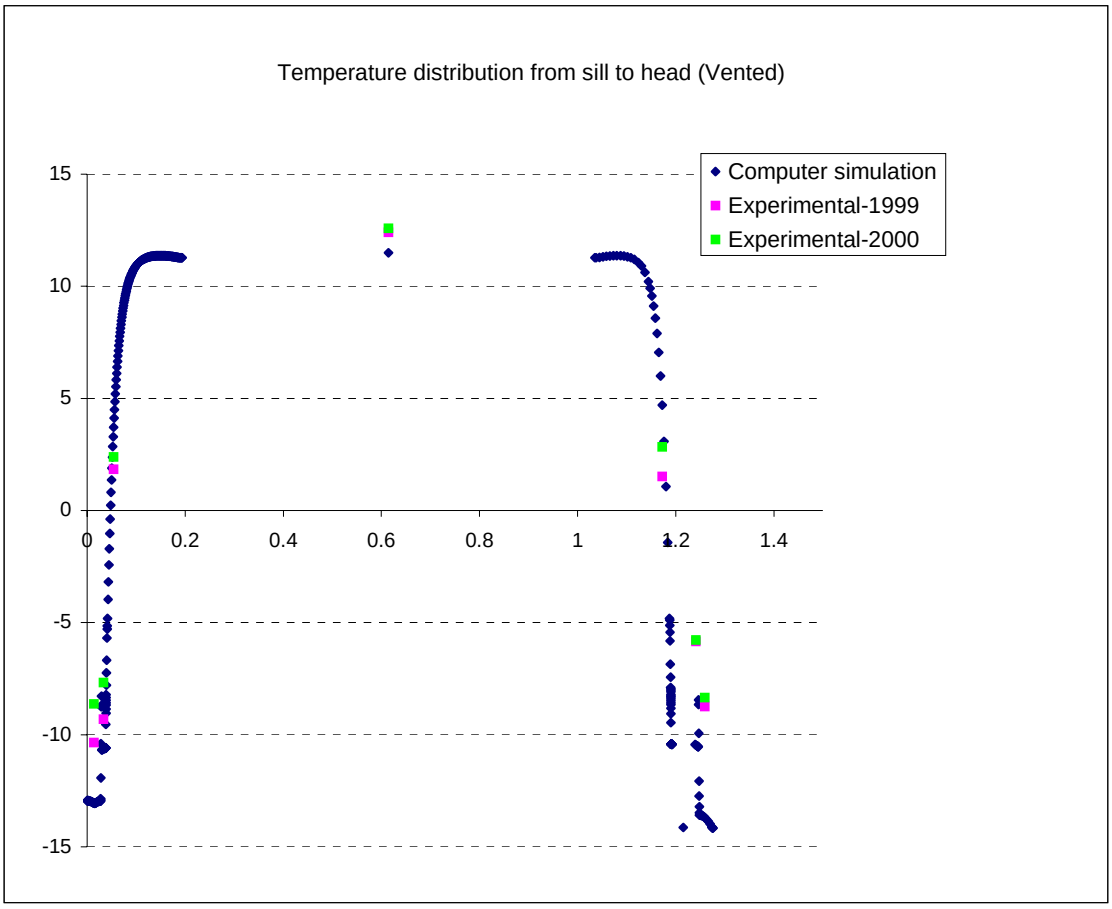


Figure 8: Temperature Distribution From Sill To Head (Vented Section)

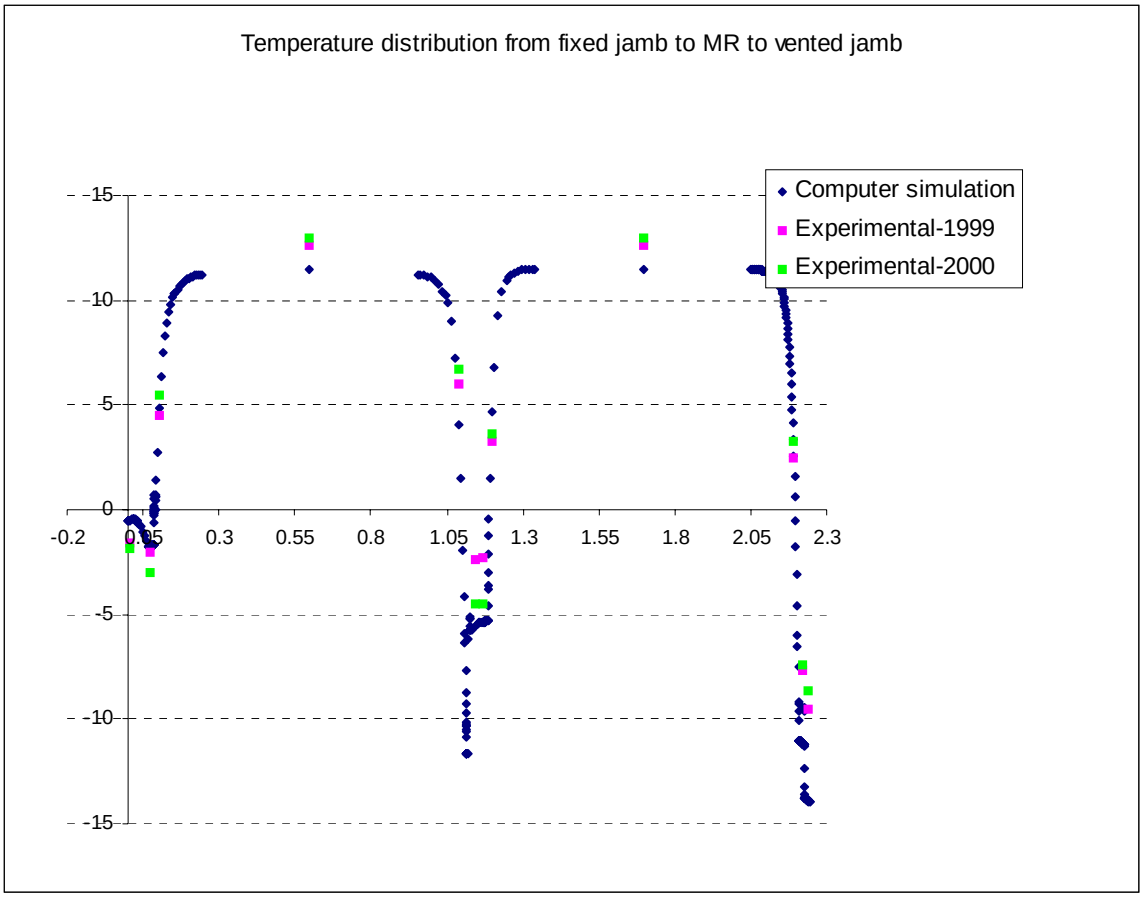


Figure 9: Temperature Distribution From Fixed Jamb to MR To Vented Jamb

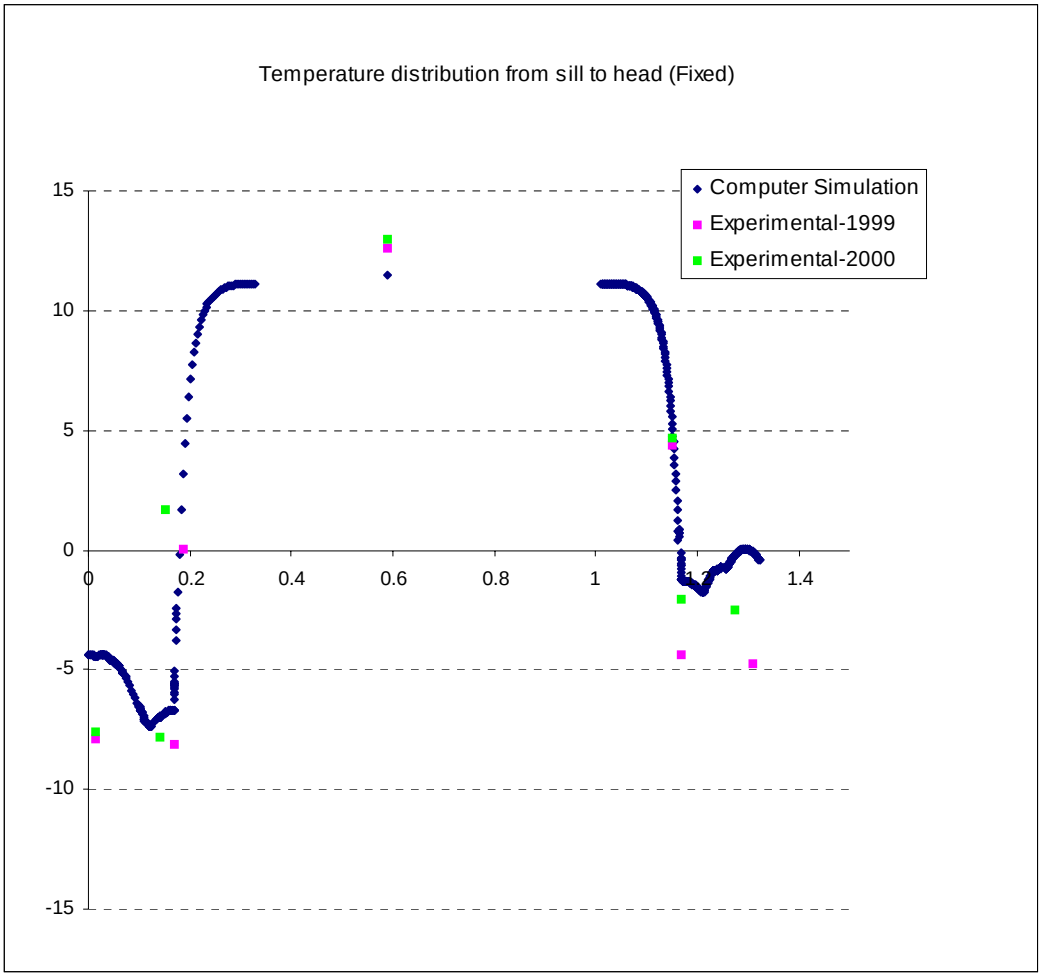


Figure 10: Temperature Distribution From Sill To Head (Fixed Section) –no ventilated cavities

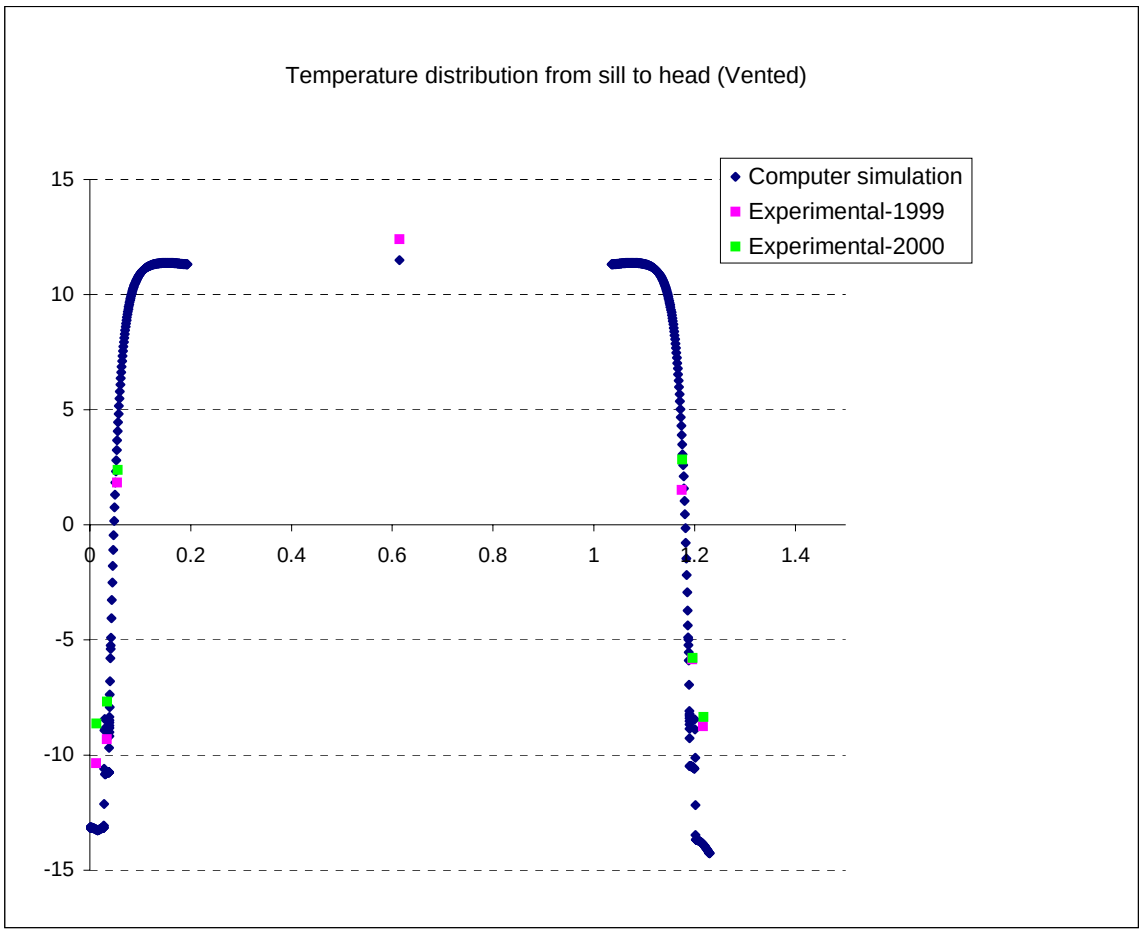


Figure 11: Temperature Distribution From Sill To Head (Vented Section) - no ventilated cavities

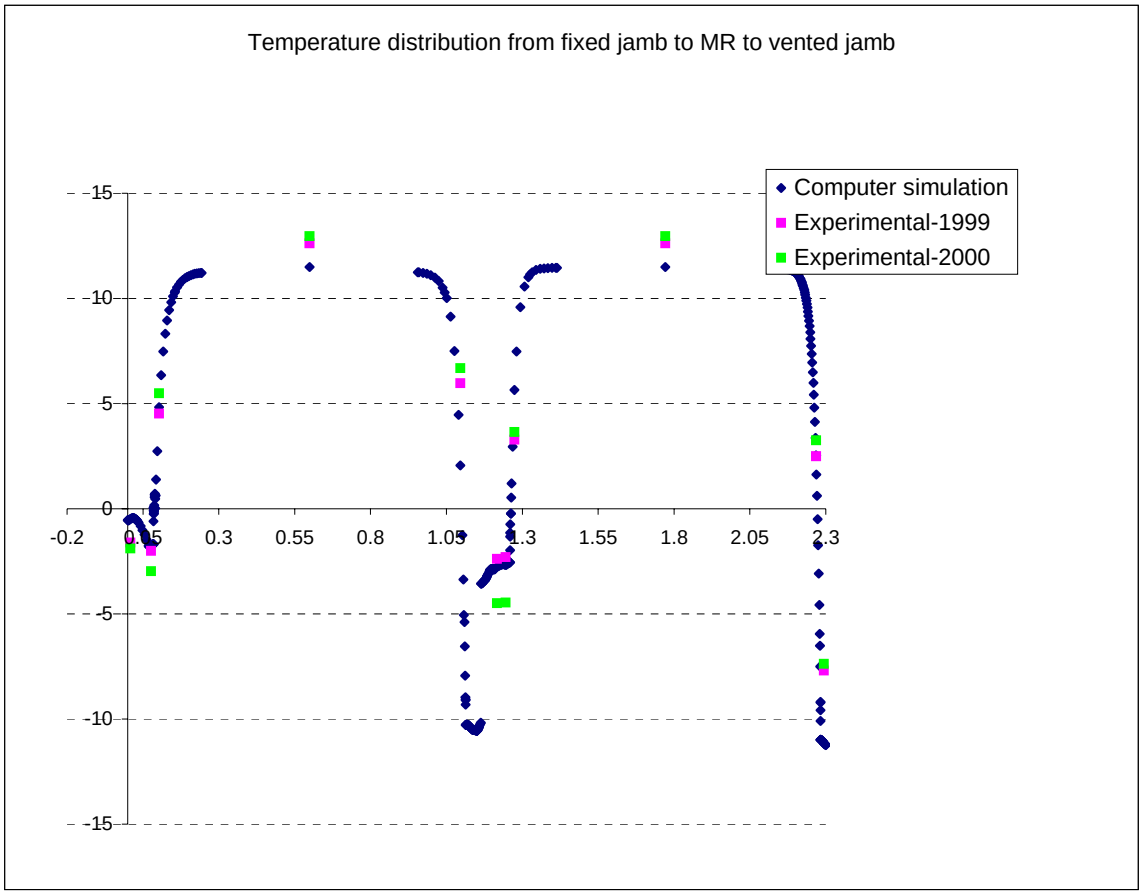


Figure 12: Temperature Distribution From Fixed Jamb to MR To Vented Jamb- no ventilated cavities

APPENDIX A: GLAZING SYSTEM


```
       ID: 2
     Name: TRR99
  EnvCond: 1 NFRC 100-2002
     Type: Horizontal Slider, custom
     Tilt:  90
     Size: 0
    Width: 1524.0 mm
   Height: 914.4 mm
     Area:  1.39 m2

  U-value: 2.867 W/m2-K
     SHGC: 0.313
       Vt: 0.499
       CI:  15.1
```

Data for Glazing Systems

ID	Name	COG Area m2	#Lay	Tilt	Uc W/m2	SCc	SHGCc	Vtc	RHG
1	TRR99	0.422	3	90	1.753	0.40	0.35	0.58	266
1	TRR99	0.412	3	90	1.753	0.40	0.35	0.58	266

Glass and Gas Data for Glazing System '1 TRR99'

ID	Name	D(mm)	Tsol	1 Rsol	2 Rsol	Tvis	1 Rvis	2 Rvis	Tir	1 Emis	2 Emis	Keff
Outside												
5009	CLEAR_3.PPG *	3.3	.827	.076	.077	.898	.086	.086	.000	.840	.840	.900
1	Air	6.2										.041
9942	HMSC75.cust	0.1	.375	.460	.467	.754	.128	.105	.000	.772	.088	.140
1	Air	6.2										.026
9944	S500CL_3.cust	3.3	.705	.126	.108	.833	.113	.109	.000	.230	.840	.900
Inside												

Frame Data

Location	ID	Name	Source	Frame Area m2	Edge Area m2	Uframe W/m2-K	Uedge W/m2-K
Left Header	22	TRR99_HF	Therm	0.028	0.044	10.1022	2.0670
Left Jamb	23	TRR99_JF	Therm	0.019	0.049	12.0045	2.0102
Right Header	26	TRR99_HV	Therm	0.028	0.043	6.4225	2.5497
Mullion	24	TRR99_MR	Therm	0.034	0.091	8.4895	2.3396
Right Jamb	27	TRR99_JV	Therm	0.032	0.049	6.2805	2.5497
Left Sill	21	TRR99_SF	Therm	0.028	0.044	11.6638	2.1749
Right Sill	25	TRR99_SV	Therm	0.027	0.043	6.3203	2.5327

Gas Data

ID	Name	Type	Cond W/m-K	Visc kg/m-s	Cp J/kg-K	Dens kg/m3	Pran
1	Air	Pure	0.0241	0.0000	1006.1033	1.2883	0.7197

Environmental Conditions: 1 NFRC 100-2002

	Tout (C)	Tin (C)	WndSpd (m/s)	Wnd Dir	Solar (W/m2)	Tsky (C)	Esky
Uvalue	-18.0	21.0	5.50	Windward	0.0	-18.0	1.00
Solar	32.0	24.0	2.80	Windward	783.0	32.0	1.00

Frame Library Data

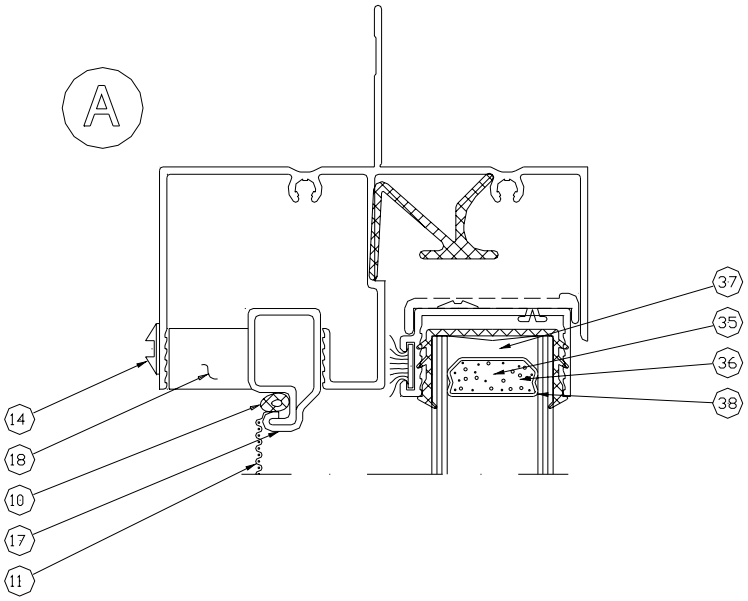
ID	Name	Source	U-value Frame W/m2-K	U-value Edge W/m2-K	Edge Corr	GlzSys Width mm	GlzSys Uc W/m2-K	Width (PFD) mm	Abs
22	TRR99 HF	Therm	10.1022	2.0670	N/A	19.050	1.755	37.62	0.50
23	TRR99_JF	Therm	12.0045	2.0102	N/A	19.050	1.755	22.22	0.50
21	TRR99 SF	Therm	11.6638	2.1749	N/A	19.050	1.755	37.59	0.50
24	TRR99 MR	Therm	8.4895	2.3396	N/A	19.050	1.755	40.82	0.50
27	TRR99_JV	Therm	6.2805	2.5497	N/A	19.050	1.755	36.22	0.50
26	TRR99 HV	Therm	6.4225	2.5497	N/A	19.050	1.755	37.69	0.50
25	TRR99_SV	Therm	6.3203	2.5327	N/A	19.050	1.755	36.60	0.50

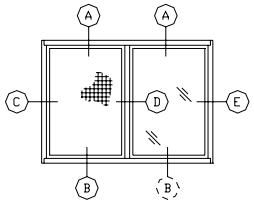
No Dividers for this Glazing System

Temperature Distribution (degrees C)

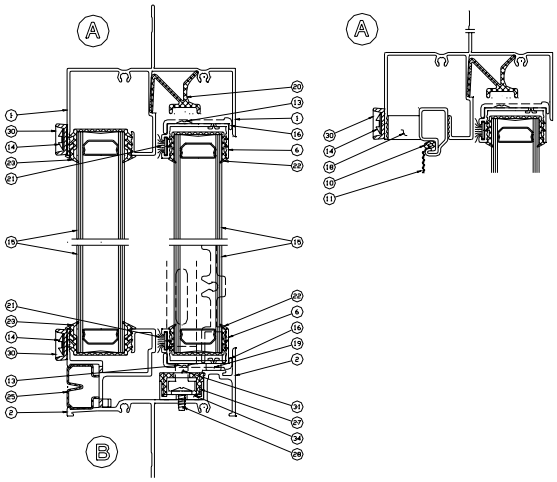
	Winter Out	Winter In	Summer Out	Summer In
Lay1	-15.7	-15.4	40.1	40.5
Lay2	-4.9	-4.9	47.3	47.3
Lay3	11.2	11.5	36.5	36.2

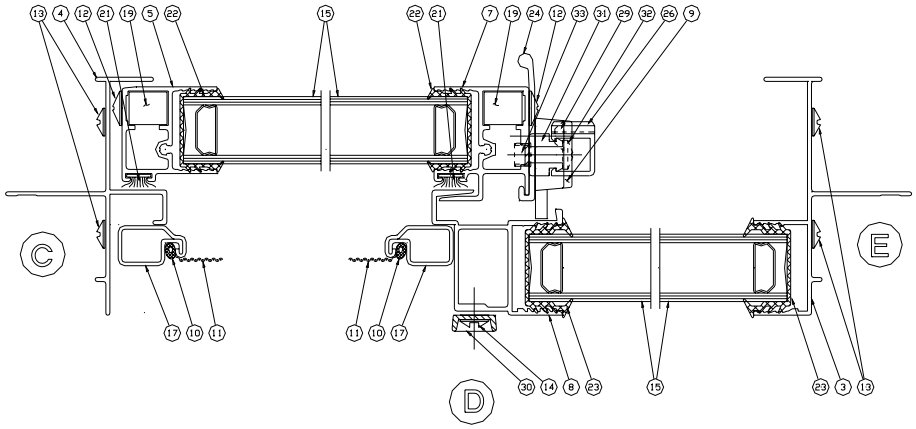
APPENDIX B: Autocad drawings





ELEVATION


A
A
B


C
D
E