Building Energy Efficiency Program

C E E R E

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TITLE

Anaysis of PFM02 window Using Computer Modeling According to NFRC 500

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PFM02

PFm02, which consists of a double-glazed window, has been modeled.

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 detailed cross sections of the window system (case 3) are shown in Fig. 2.

Following 4 cases have been considered:

Case 1: Without foam and no radiation enclosure
Case 2: Without foam and with radiation enclosure
Case 3: With foam and no radiation enclosure
Case 4: With foam and with radiation enclosure

Table 1: Material Thermo physical Properties

Material	***k* (W/m-K)**	ε
Aluminum Alloys	160.0	0.2
Polystyrene-Expanded (EPS)	0.035	0.9
Pine or Douglas Fir	0.14	0.9
Polyfoam tape	0.24	0.9
Silicone tape	0.36	0.9
Silica Gel (Desiccant)	0.03	0.9
Butyl Rubber	0.24	0.9
Urethane Sealant	0.31	0.9
Clear Glass	0.90	0.84

Window 4.1 has been used to create the glazing unit. The glazing unit is a 2 layered unit with CIG clear glass (ID 2003 in W4.1 glass library) as the outer layer and CIG SUN145 (ID 2018 in W4.1 glass library) as the inner layer . The filled gas is air, 0.65 inches for the gap. The detailed reports from Window4.1 are given in Appendix.

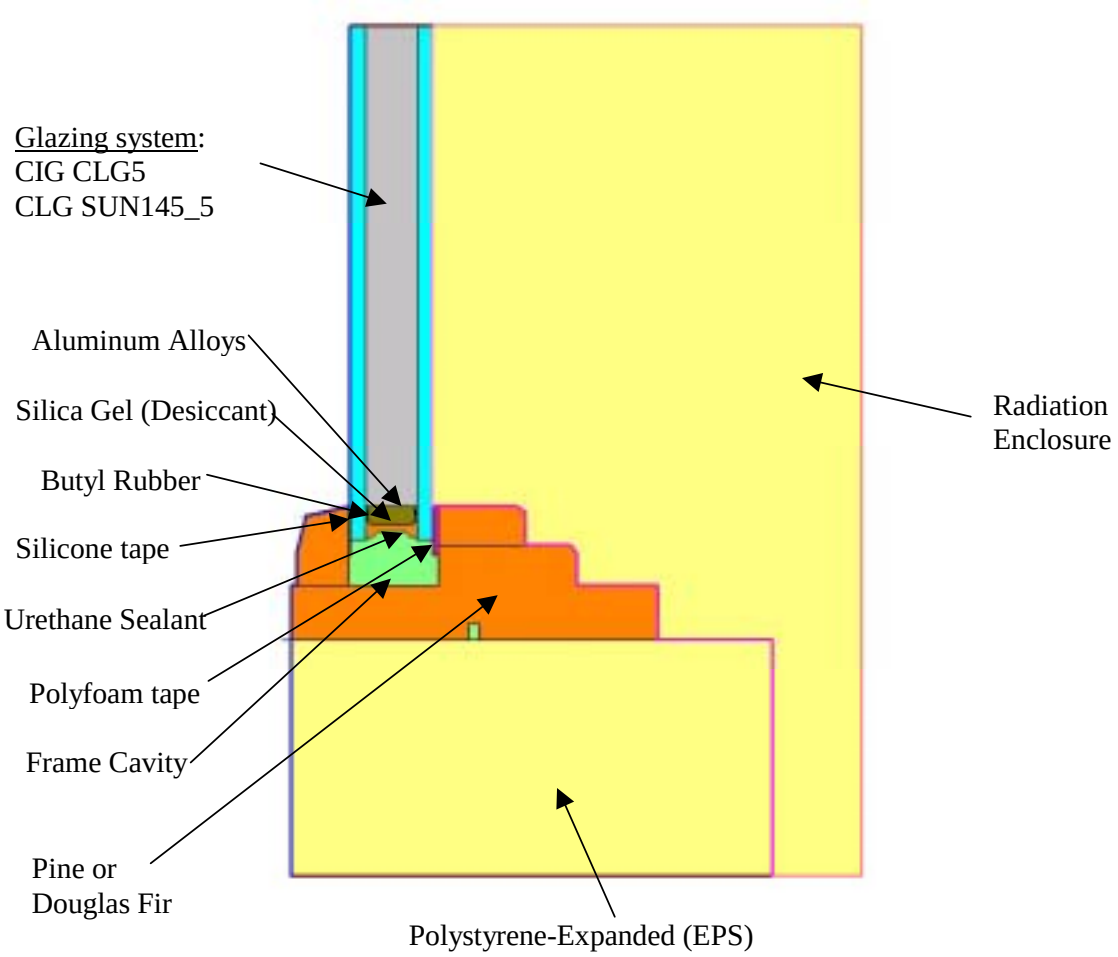

Fig. 1: Schematic representations of frame materials in a sill cross-section of frame (case 4)

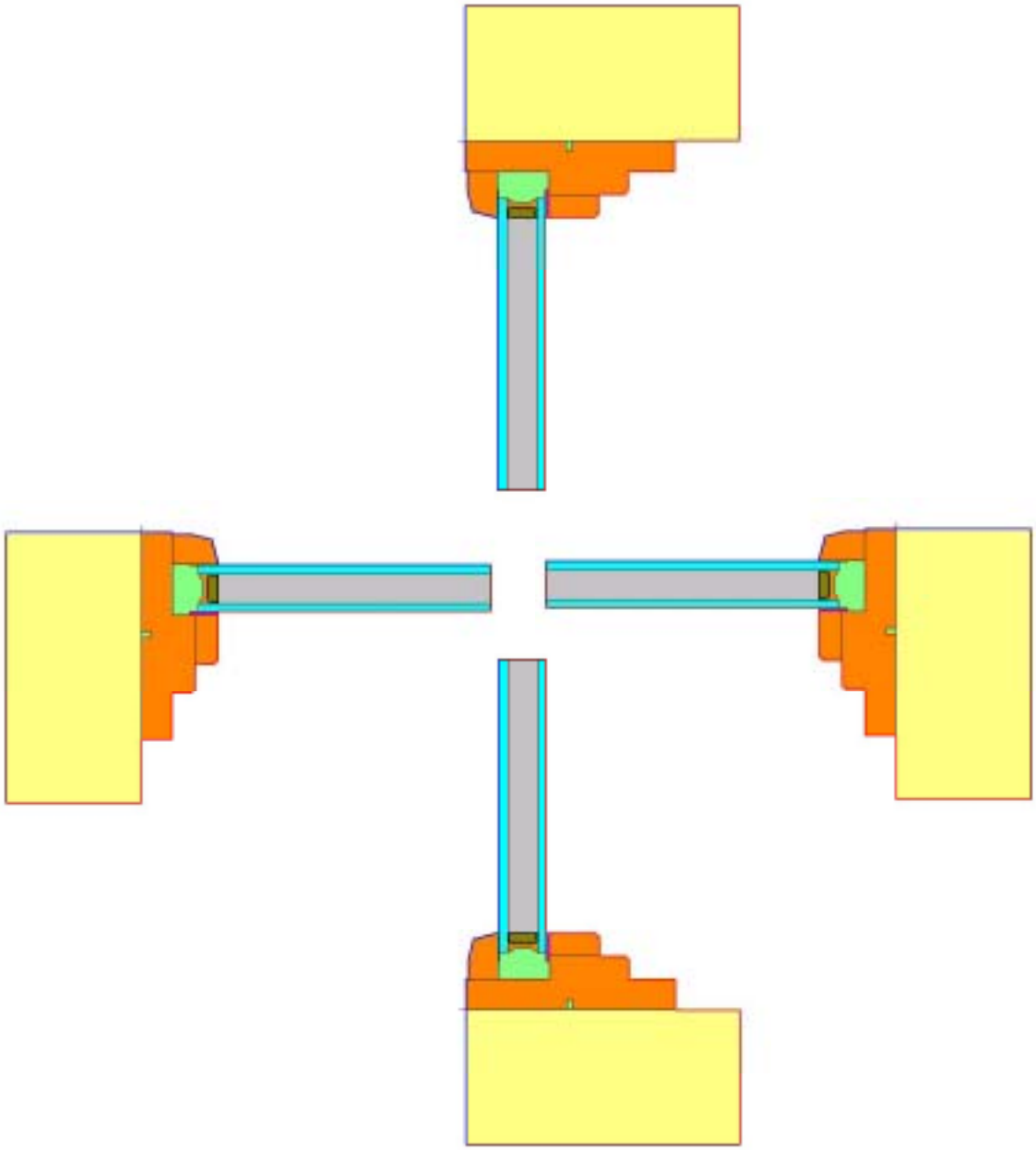

Fig. 2: Head, Jambs and sill cross sections of the window assembly (case3)

The isotherms for different cross sections of the window assembly (case 3) are shown in Fig. 3. Similar isotherms have been obtained for other cases. Calculations for case 1 and case 3 which are without radiation enclosure have been performed using the boundary conditions given in Table 2, while the other two cases using the boundary conditions given in Table 5.

Table 2: Boundary Conditions for Indoor and Outdoor Side of Window System case 1 , 3

Boundary Conditions		*Environmental Temperature (F)*	*Overall h* *(Btu/h-ft^2-F)*
Outdoor Side	Edge-of-glass	0	5.112
	Frame		5.112
Indoor Side	Edge-of-glass	70	1.355
	Frame		1.340

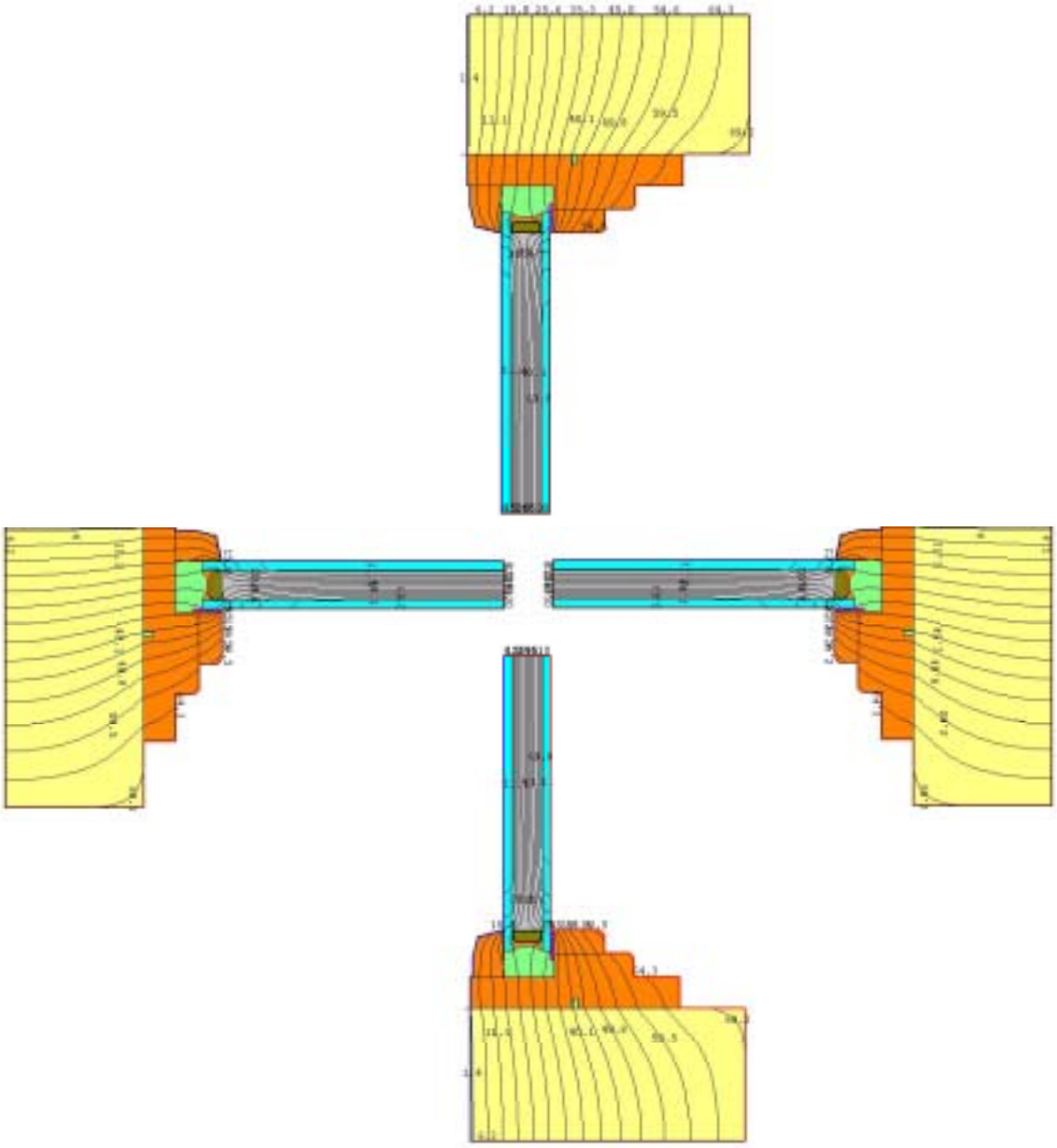

Fig. 3: Isotherms for head, jambs and sill Cross sections of the window system (case 3)

The frame and edge cross-sections U-factors and overall U-factors are given in Tables 3-6 respectively for all cases.

Table 3: Frame, Edge and Overall U-factors for Case 1 Window

Cross Section	*Name of THERM data file*	*Project Y of frame(inches)*	*U-factor of frame(Btu/h-ft^2-F)*	*U-factor of edge-of-glass(Btu/h-ft^2-F)*
Head	Pfm02_h_nRnf.thm	1.688	0.428	0.447
Sill	Pfm02_s_nRnf.thm	1.688	0.429	0.448
Jamb L	Pfm02_j_nRnf.thm	1.688	0.429	0.448
Jamb R	Pfm02_j_nRnf.thm	1.688	0.429	0.448
		U-Factor (Btu/h-ft^2-F)	*SHGC*	*VT*
Center of glass		0.320	0.33	0.44
Window assembly		0.380	0.28	0.34

Table 4: Frame, Edge and Overall U-factors for Case 2 Window

Cross Section	*Name of THERM data file*	*Project Y of frame(inches)*	*U-factor of frame(Btu/h-ft^2-F)*	*U-factor of edge-of-glass(Btu/h-ft^2-F)*
Head	Pfm02_h_rnf.thm	1.688	0.441	0.436
Sill	Pfm02_s_rnf.thm	1.688	0.498	0.448
Jamb L	Pfm02_j_rnf.thm	1.688	0.498	0.448
Jamb R	Pfm02j_rnf.thm	1.688	0.498	0.448
		U-Factor (Btu/h-ft^2-F)	*SHGC*	*VT*
Center of glass		0.320	0.33	0.44
Window assembly		0.392	0.28	0.34

Table 4: Frame, Edge and Overall U-factors for Case 3 Window

Cross Section	*Name of THERM data file*	*Project Y of frame(inches)*	*U-factor of frame(Btu/h-ft^2-F)*	*U-factor of edge-of-glass(Btu/h-ft^2-F)*
Head	Pfm02h_rnf.thm	1.688	0.461	0.450
Sill	Pfm02s_rnf.thm	1.688	0.465	0.452
Jamb L	Pfm02j_rnf.thm	1.688	0.465	0.452
Jamb R	Pfm02j_rnf.thm	1.688	0.465	0.452
		U-Factor (Btu/h-ft^2-F)	*SHGC*	*VT*
Center of glass		0.320	0.33	0.44
Window assembly		0.389	0.28	0.34

Table 5: Frame, Edge and Overall U-factors for Case 4 Window

Cross Section	*Name of THERM data file*	*Project Y of frame(inches)*	*U-factor of frame(Btu/h-ft^2-F)*	*U-factor of edge-of-glass(Btu/h-ft^2-F)*
Head	Pfm02_h_rf.thm	1.688	0.424	0.429
Sill	Pfm02_j_rf.thm	1.688	0.428	0.430
Jamb L	Pfm02_j_rf.thm	1.688	0.428	0.431
Jamb R	Pfm02_j_rf.thm	1.688	0.428	0.431
		U-Factor (Btu/h-ft^2-F)	*SHGC*	*VT*
Center of glass		0.320	0.33	0.44
Window assembly		0.375	0.28	0.34

Condensation Index:

Condensation Index (CI) has been calculated for case 4 with the boundary are shown in Fig. 4.

Table 5: Boundary Conditions for Indoor and Outdoor Side of Window System case 2, 4 and CI model for case 4

Boundary Conditions		*Environmental Temperature (F)*	h_c	*Overall h*	ε
			(Btu/h-ft^2-F)		
Outdoor Side	Glazing	0	N/A	5.112	0.84
	Frame		N/A	5.112	0.90
Indoor Side	Glazing	70	0.543	N/A	0.84
	Frame		0.444	N/A	0.90

Fig. 4 shows the schematic representation of head, jambs and sill cross sections (case 4). The jamb sections are modeled without radiation enclosure. The radiation enclosure has been used for the detailed radiation heat transfer calculations. Besides the method outlined in NFRC 500, CI calculations have been performed by the following three different methods:

Method 1 doesn't take area weighting for CI_g.

Method 2 takes area weighting of edge-of-glass area and center of glass area separately i.e. eqn (2) of NFRC 500 is divided into the following two parts:

$$CI_{cg} = \left\{1 - \left(SS_{cog}\right)^{1/3}\right\} * 100$$

$$CI_{eog} = \left\{1 - \left(\frac{\sum_k SS_{eog_k} * A_{eog_k}}{A_{eog}}\right)^{1/3}\right\} * 100$$

CI_g is the minimum of the two, i.e. CI_g =Min (CI_{cg}, CI_{eog})

Method 3 is to take the CI value as the minimum value of CI_f and average of CI_{cog} and CI_{eog} , which are calculated using equations of Method 2.

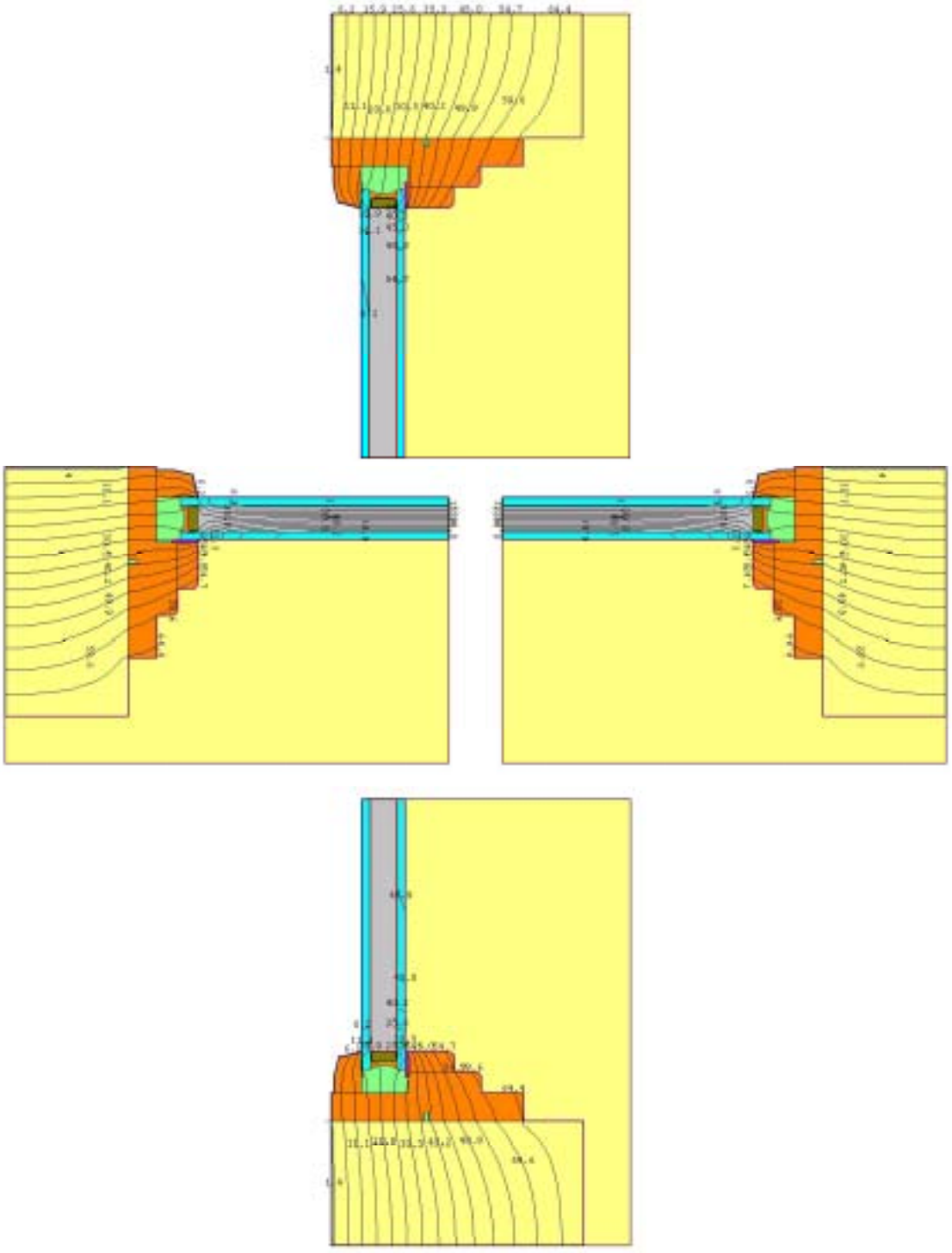

Fig. 4: Isotherms for head, jambs and sill Cross sections of CI for case 4

Table 6 shows the results calculated by using different methods.

Table 6: CI of windows using three different methods

	Method 1	*Method 2*	*Method 3*	*Current NFRC 500*
CI_f	68.30	68.30	68.30	68.30
CI_{cog}	-	66.07	-	-
CI_{eog}	-	48.95	-	-
CI_g	51.49	-	57.51	58.22
CI	**51.49**	**48.95**	**57.51**	**58.22**

Fig. 5 shows the temperature variation in the window assembly for both cases. The middle point in the graph corresponds to the center of glass temperature. Distance at X-axis corresponds to the bottom of sill section to the top of the head section.

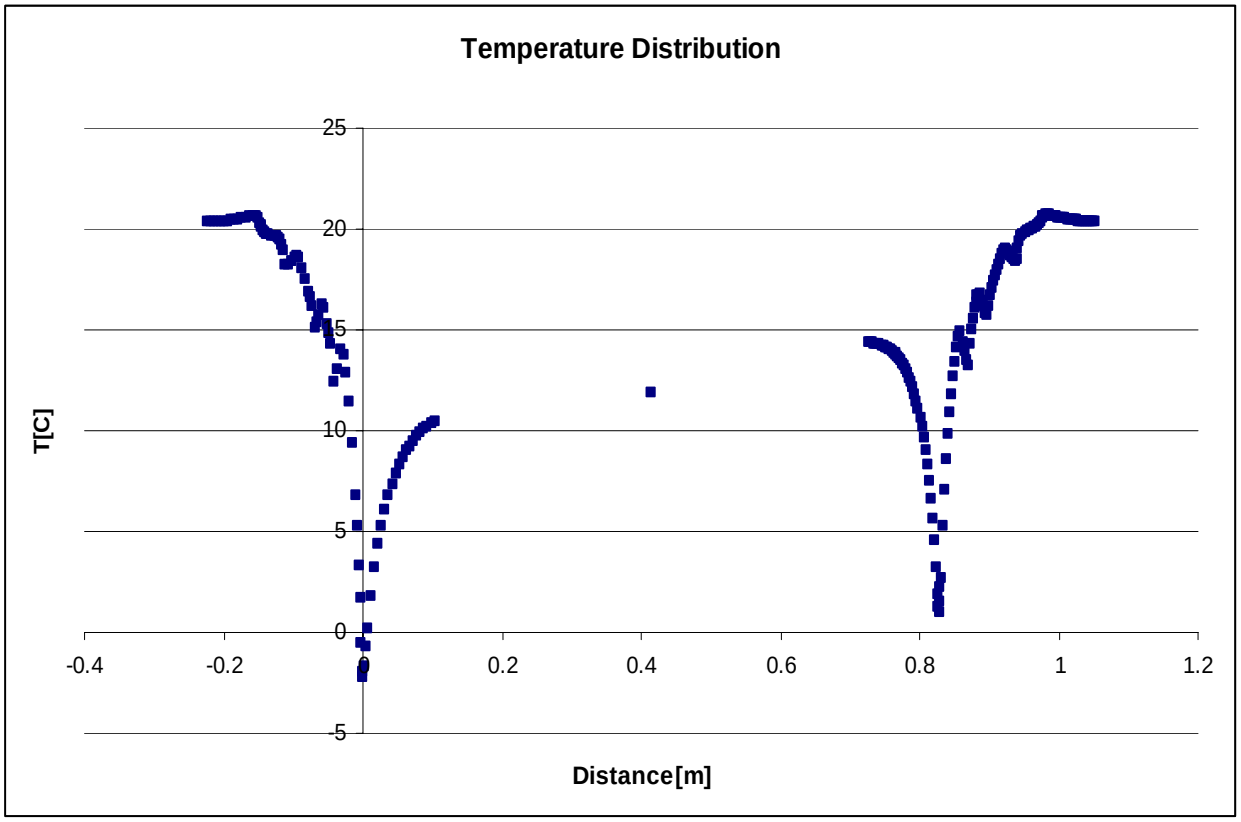

Figure 5. Temperature variation in the window assembly

APPENDIX—Window4.1 report for case 4 window

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WINDOW 4.1  Report                    Page 1                    01/26/01 13:38:40
      ID:7                                        FrID: 16
    Name:Pfm02                                 ==================
    Mode:Design                                ||                ||
 EnvCond:1                                     ||                ||
                                               || GlzSysID:  2   ||
    Type:Casement                  FrID: 17||   Div ID:  0   ||FrID: 17
    Tilt: 90                                   ||                ||
    Size:Custom                                ||                ||
   Width:  24.00"                              ||                ||
  Height:  36.00"                              ||                ||
    Area:  6.00 ft2                            ==================
                                                     FrID: 18
 U-value: 0.375 Btu/h-ft2-F
      SC: 0.321
    SHGC: 0.276
      Vt: 0.345


Data for Glazing Systems

                     COG
ID  Name             Area #Lay  Tilt      Uc     SCc   SHGCc  Vtc    RHG
                     ft2             Btu/h-ft2
--- ---------------- ----- ----  ----   -------   ----  -----  ----  -----
  2 PFM02           2.997   2    90      0.320   0.39   0.33  0.44     82

Glass and Gas Data for Glazing System '2 PFM02'

ID   Name            D(in) Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2 Keff
---- --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
Outside
2018 SUN145-5.CIG    0.187 .325 .218 .266 .491 .133 .071 .000 .836 .100 .520
   1 Air             0.650                                               .025
2003 CLR-5.CIG       0.187 .807 .072 .072 .896 .080 .080 .000 .836 .836 .520
Inside

Frame Data
                                                    Frame   Edge
Location         ID   Name          Source         Area    Area    Uframe   Uedge
                                                     ft2      ft2   Btu/h-ft2-F
---------------- ---  ------------ ------------- -----   -----  -------  ------
Left Jamb        17   2_JAMB.T2W    FRAME Sill    0.402   0.523   0.4278  0.4307
Header           16   2_HEAD.T2W    FRAME Sill    0.262   0.315   0.4235  0.4287
Right Jamb       17   2_JAMB.T2W    FRAME Sill    0.402   0.523   0.4278  0.4307
Sill             18   2_SILL.T2W    FRAME Sill    0.262   0.315   0.4279  0.4302
```

Gas Data

ID	Name	Cond Btu/h-ft-F	dCond Btu/h-ft-F2 x e-5	Visc lb-s/ft2 x e-5	dVisc lb-s/ft2-F x e-8	Dens lb/ft3	dDens lb/ft3-F	Pran	dPran
1	Air	.0139	2.4395	0.0361	0.1161	0.0805	-0.0002	.7200	.00100

Environmental Conditions: 1 NFRC/ASHRAE

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky
Uvalue	0.0	70.0	15.00	Windward	0.0	0.0	1.00
Solar	89.0	75.0	7.50	Windward	248.2	89.0	1.00

Frame Library Data

ID	Name	Source	U-value Frame Btu/h-ft2-F	U-value Edge Btu/h-ft2-F	Edge Corr	GlzSys Width in	GlzSys Uc Btu/h-ft2-F	Width (PFD) in	Abs
17	2_JAMB.T2W	FRAME Sill	0.43	0.43	N/A	1.0240	0.320	1.688	0.50
16	2_HEAD.T2W	FRAME Sill	0.42	0.43	N/A	1.0240	0.320	1.688	0.50
18	2_SILL.T2W	FRAME Sill	0.43	0.43	N/A	1.0240	0.320	1.688	0.50

Divider Library Data

ID	Name	Source	U-value Div Btu/h-ft2-F	U-value Edge Btu/h-ft2-F	Edge Corr	GlzSys Width in	GlzSys Uc Btu/h-ft2-F	Width (PFD) in	Abs

No Dividers for this Glazing System

Optical Properties for Glazing System '2 PFM02'

Angle	0	10	20	30	40	50	60	70	80	90	Hemis

Vtc : 0.443
Rf : 0.153
Rb : 0.137

Tsol : 0.267
Rf : 0.226
Rb : 0.248

Abs 1: 0.467
Abs 2: 0.040
Abs 3:
Abs 4:
Abs 5:
Abs 6:
SHGCc: 0.334

SCc: 0.39	Color Properties	DomWL	Purity	L*	a*	b*
Tdw: N/A	Transmittance	um	%			
Tuv: N/A	Reflectance	um	%			

Temperature Distribution (degrees F) for '2 PFM02'

Env. Conditions:	1 NFRC/ASHRAE	U-value	Condensation RH	Solar
	Outside Air	0.0		89.0
	Outer Surface	4.5	N/A	115.3
Layer 1	Center	4.8		116.9
	Inner Surface	5.1		116.7
	Outer Surface	52.8		90.5
Layer 2	Center	53.1		90.4
	Inner Surface	53.5	55.7%	90.0
	Inside Air	70.0		75.0