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Technical Report:

**Computer Modeling Results for NFRC Simulation
Round Robin 1999 (SRR99) Window Using
THERM and WINDOW Software**

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NFRC Simulation Round Robin

The NFRC Simulation Round Robin 1999, which consisted of a double-glazed, residential, thermally unbroken, aluminum horizontal slider, was modeled. Using Therm 2.0 and Window 4.1 software programs, the horizontal slider was modeled by applying standard NFRC conditions as well as including a radiation enclosure to account for the radiative heat transfer effects.

Both cases consisted of modeling the window at a 90° tilt with the following material thermal-physical properties:

Table 1: Material thermal-physical properties of aluminum horizontal slider

Material	k (Btu/h-ft-F)	e
Aluminum	92.448	0.2
Vinyl(flexible)	0.069	0.9
Polysulphide	0.11	0.9
Mohair sweep	0.081	0.9
Glass-clear	0.52	0.84
Silica Gel	0.017	0.9
Butyl Rubber	0.139	0.9

The location of the material properties in a typical cross-section is shown in Figure 1:

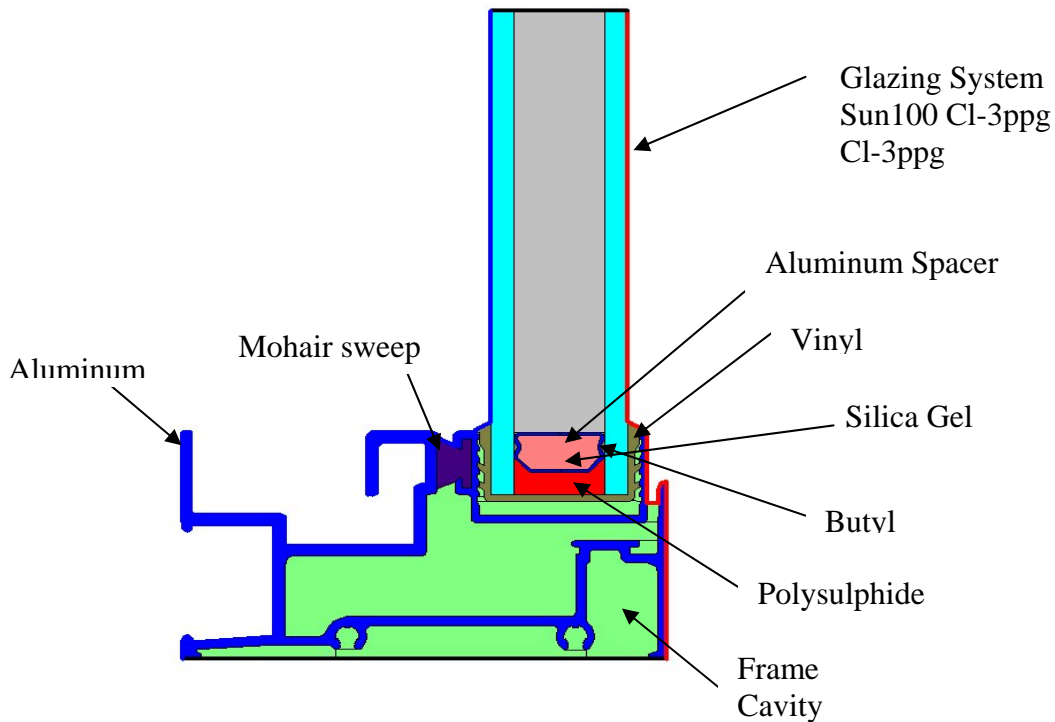


Figure 1: Window Construction

Window 4.1 was used to create the IG unit. A two layer IG unit was used, which consisted of S100CL 3.PPG (nominal thickness - 0.129 inches), Clear 3.PPG (nominal thickness - 0.129 inches) and a gas mixture composed of 10% Air and 90% Argon. The overall thickness of this IG unit was 0.75 inches.

The double glazed, aluminum horizontal slider was modeled according to the THERM NFRC Simulation Training Manual for the case using standard NFRC conditions as well as for the case which included a radiation enclosure to account for the radiative heat transfer effects. The frame and edge cross-sections U-factors and total U-factors (with and without dividers) for the two cases were obtained and is shown in Table 2:

Table 2: Frame, Edge and Total U-factors for NFRC and detailed radiation model cases

Cross Section	NFRC U-factors (<i>Btu/hr-ft² - °F</i>)		Detailed Radiation Model U-factors (<i>Btu/hr-ft² - °F</i>)	
	<i>Frame</i>	<i>Edge</i>	<i>Frame</i>	<i>Edge</i>
Fixed Sill	3.6333	0.3845	2.6567	0.3652
Vented Sill	1.5693	0.4478	1.3539	0.4406
Fixed Head	2.4436	0.3637	2.0214	0.3511
Vented Head	1.4804	0.4383	1.3147	0.4336
Fixed Jamb	2.7003	0.3630	2.2872	0.3413
Vented Jamb	1.8158	0.4370	1.4567	0.4346
Meeting Rail	1.9760	0.4120	1.7308	0.3984
Divider	0.6219	0.3449	0.6219	0.3449
<i>Total U-factor with dividers</i>	<i>0.64</i>		<i>0.59</i>	
<i>Total U-factor without dividers</i>	<i>0.58</i>		<i>0.52</i>	

Modeling Results using NFRC Standard Conditions

The Simulation Round Robin 1999 of the aluminum slider was modeled using the Therm 2.0 and Window 4.1 software under NFRC standard conditions. Additionally, eight laboratories participated in the Round Robin test and the total U-factor values ranged between 0.56 Btu/hr-ft²-°F to 0.58 Btu/hr-ft²-°F, with an average U-factor value of 0.57 Btu/hr-ft²-°F. This was comparable to the U-factor value of 0.58 Btu/hr-ft²-°F (without dividers) obtained computationally by Therm 2.0 and Window 4.1. With two horizontal and two vertical dividers on each glazing system, the U-factor increased to 0.643 Btu/hr-ft²-°F.

In order to model the horizontal slider, the following boundary conditions for the IG unit were used: The convective, radiative and overall surface heat transfer coefficients for the outdoor glazing boundary were calculated in Window 4.1, while the overall value for the frame is prescribed by NFRC 100 standard (NFRC 1997).

On indoor side, for glazing, convective and radiative parts of surface heat transfer coefficient were calculated in WINDOW 4.1 and transferred to THERM as overall surface heat transfer coefficient. Overall frame surface heat transfer coefficient is prescribed by THERM NFRC Simulation manual (NFRC 1999).

Table 3: Boundary conditions with standard NFRC conditions

<i>Boundary Conditions</i>		<i>Environmental Temperature (°F)</i>	<i>h_c</i>	<i>h_r</i>	<i>Overall h</i>	<i>ε</i>
			<i>(Btu/h-ft²-F)</i>			
Outdoor Side	Glazing	0	4.485	0.567	5.052	0.84
	Frame		N/A	N/A		
Indoor Side	Glazing	70	2.157	0.611	1.134	0.84
	Frame		2.157	0.572		

The Window 4.1 results of this case model with dividers is below:

ID:2
 Name:DHS_NO_RAD_DV
 Mode:Design
 EnvCond:1

Type:Horz Slider
 Tilt: 90
 Size:Horz Slid AA
 Width: 60.00"
 Height: 36.00"
 Area: 15.00 ft2

FrID: 8

GlzSysID: 11	GlzSysID: 11
Wid:28.71"	Wid:27.41"
Div ID: 7	Div ID: 7
#H: 2 #V: 2	#H: 2 #V: 2
FrID: 10	

FrID: 9

FrID: 11

FrID: 12

U-value: 0.644 Btu/h-ft2-F
 SC: 0.535
 SHGC: 0.460
 Vt: 0.551

Data for Glazing Systems

ID	Name	COG Area ft2	#Lay	Tilt	Uc Btu/h-ft2	SCc	SHGCc	Vtc	RHG
11	dhs-gl	1.265	2	90	0.272	0.62	0.53	0.75	128
11	dhs-gl	1.125	2	90	0.272	0.62	0.53	0.75	128

Glass and Gas Data for Glazing System '11 dhs-gl'

ID	Name	D(in)	Tsol	1 Rsol	2 Tsol	1 Rvis	2 Tvis	Tir	1 Emis	2 Keff	
Outside											
5142FS100CL_3.PPG	#	0.129	.566	.210	.270	.827	.061	.046	.000	.843	.520
8	Air/Argon/Kryp	0.492	Air:	10%	Ar:	90%	Kr:	0%		.015	
5009	CLEAR_3.PPG	0.129	.827	.076	.076	.898	.086	.086	.000	.840	.520
Inside											

Frame Data

Location	ID	Name	Source	Frame Area ft2	Edge Area ft2	Uframe Btu/h-ft2-F	Uedge
Left Jamb	8	JF_NR.T2W	FRAME Jamb	0.205	0.492	2.7003	0.3630
Left Header	6	HF_NR.T2W	FRAME Head	0.308	0.417	2.4436	0.3637
Mullion	10	MR_NR.T2W	FRAME Rail	0.369	0.985	1.9760	0.4120
Left Sill	11	SF_NR.T2W	FRAME Sill	0.308	0.417	3.6333	0.3845
Right Header	7	HV_NR.T2W	FRAME Head	0.298	0.394	1.4804	0.4383
Right Jamb	9	JV_NR.T2W	FRAME Jamb	0.342	0.493	1.8158	0.4370
Right Sill	12	SV_NR.T2W	FRAME Sill	0.289	0.394	1.5693	0.4478

ID	Name	Source	Divider Area ft2	Edge Area ft2	Udiv Btu/h-ft2-F	Udivedge Btu/h-ft2-F
7	DV_NR.T2W	FRAME Divide	0.910	2.593	0.6219	0.3449
7	DV_NR.T2W	FRAME Divide	0.890	2.506	0.6219	0.3449

Gas Data

ID	Name	Cond Btu/h-ft-F	dCond Btu/h-ft-F2	Visc lb-s/ft2	dVisc lb-s/ft2-F	Dens lb/ft3	dDens lb/ft3-F	Pran	dPran
			x e-5	x e-5	x e-8				
8	Air/Argon/Kryp	Air: .0101	10% 1.7324	Argon: 0.0442	90% 0.0756	Kryp: 0.1081	0% -0.0002	.6840	.00043

No gas data for Single Glazing

Environmental Conditions: 1 NFRC/ASHRAE

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky (F)
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
8	JF_NR.T2W	FRAME Jamb	2.70	0.36	N/A	0.7500	0.272	0.853	0.50
6	HF_NR.T2W	FRAME Head	2.44	0.36	N/A	0.7500	0.272	1.481	0.50
10	MR_NR.T2W	FRAME Rail	1.98	0.41	N/A	0.7500	0.272	1.607	0.50
11	SF_NR.T2W	FRAME Sill	3.63	0.38	N/A	0.7500	0.272	1.481	0.50
7	HV_NR.T2W	FRAME Head	1.48	0.44	N/A	0.7500	0.272	1.484	0.50
9	JV_NR.T2W	FRAME Jamb	1.82	0.44	N/A	0.7500	0.272	1.426	0.50
12	SV_NR.T2W	FRAME Sill	1.57	0.45	N/A	0.7500	0.272	1.441	0.50

ID	Name	Source	U-value		Edge Corr	GlzSys Width in	GlzSys Uc Btu/h- ft2-F	Width (PFD) in	Abs
			Div Btu/h- ft2-F	Edge Btu/h- ft2-F					
7	DV_NR.T2W	FRAME Divide	0.62	0.34	N/A	0.7500	0.272	1.100	0.50

Optical Properties for Glazing System '11 dhs-gl'

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

Vtc : 0.746
 Rf : 0.120
 Rb : 0.124

Tsol : 0.474
 Rf : 0.239
 Rb : 0.269

Abs 1: 0.231
 Abs 2: 0.056
 Abs 3:
 Abs 4:
 Abs 5:
 Abs 6:
 SHGCc: 0.534

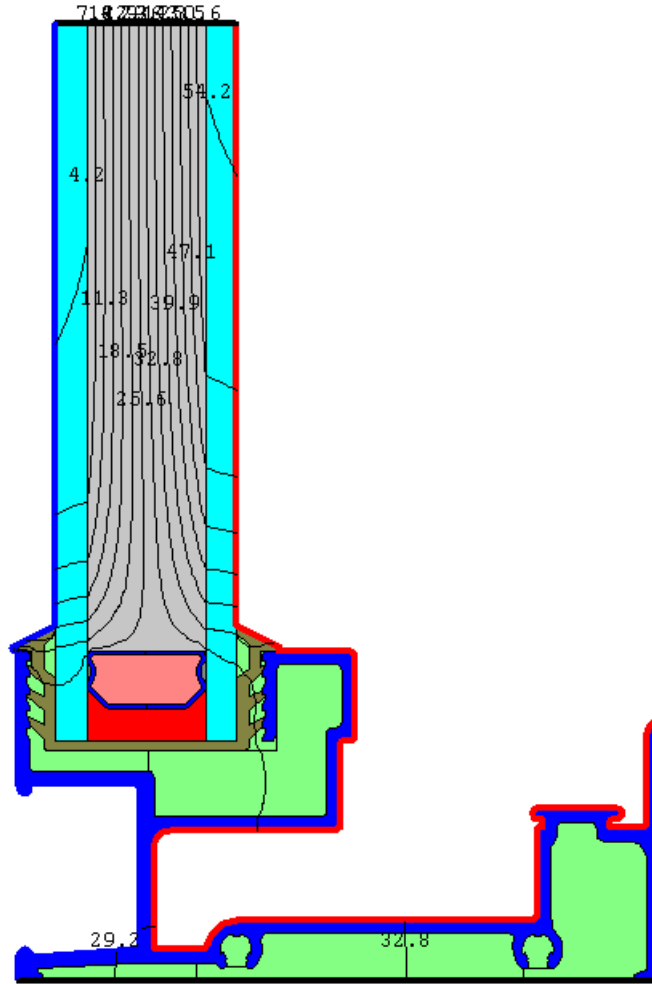
SCc: 0.62 Color Properties DomWL Purity L* a* b*
 Tdw: N/A Transmittance um %
 Tuv: N/A Reflectance um %

Temperature Distribution (degrees F) for '11 dhs-gl'

Env. Conditions:	1 NFRC/ASHRAE	U-value	Condensation RH	Solar
	Outside Air	0.0		89.0
	Outer Surface	3.8	N/A	102.2
Layer 1	Center	4.0		102.7
	Inner Surface	4.2		102.7
	Outer Surface	55.7		88.7
Layer 2	Center	55.9		88.6
	Inner Surface	56.1	61.3%	88.4
	Inside Air	70.0		75.0

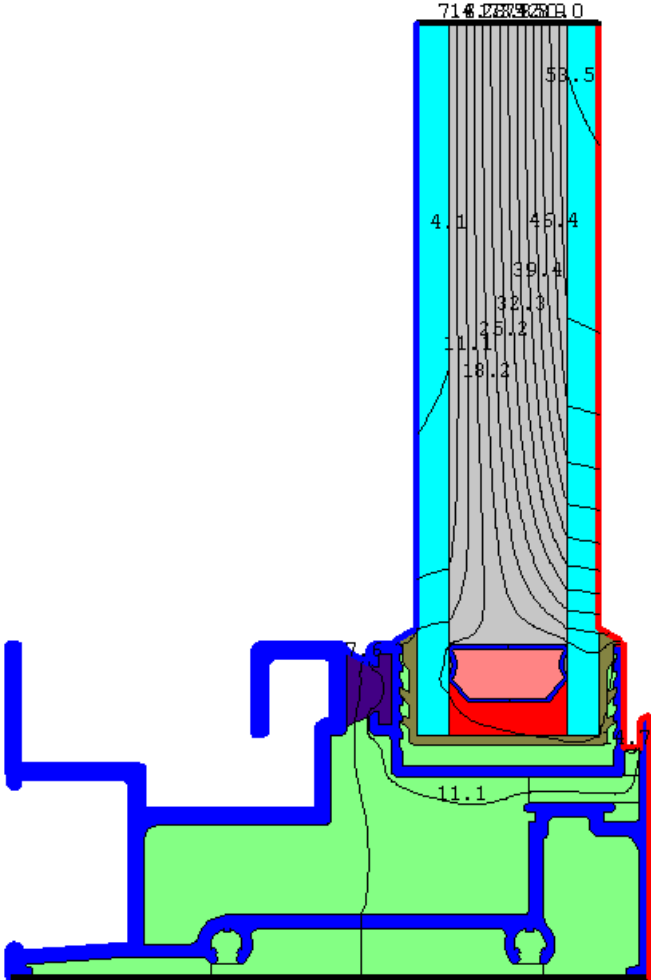
Below are the isotherm models of the various cross-sections with frame and edge U-factors.

Aluminum Horizontal Slider – Fixed Sill Cross Section



	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	3.6333	70.0	1.48071	Projected Y
Edge	0.3845	70.0	2.5	Projected Y
% Error Energy Norm				8.66%
			Export	OK

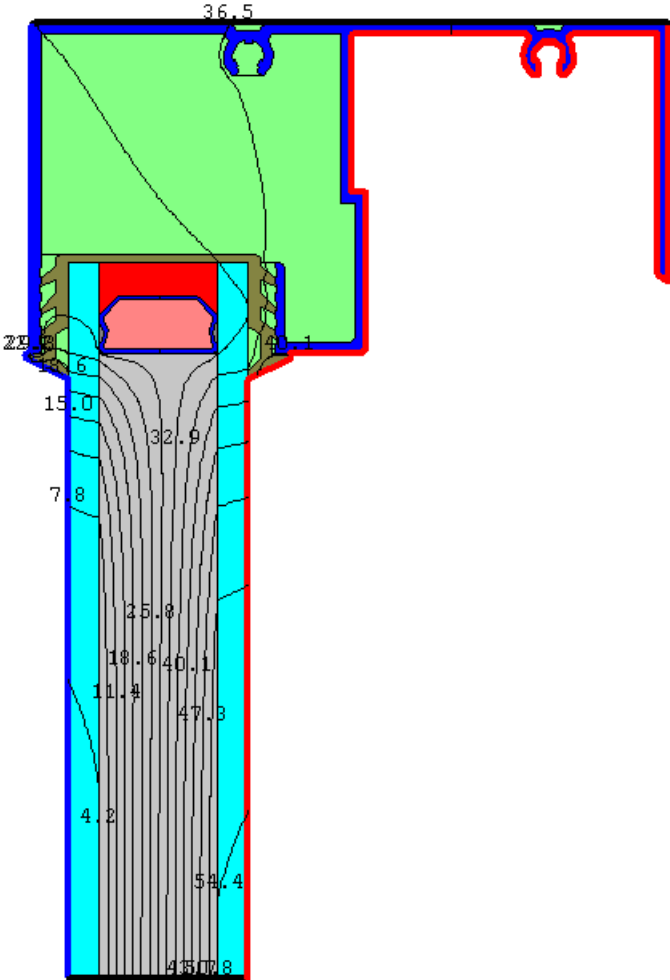
Aluminum Horizontal Slider – Vented Sill Cross Section



	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	1.5693	70.0	1.4407	Projected Y
Edge	0.4478	70.0	2.49992	Projected Y
% Error Energy Norm		6.03%		

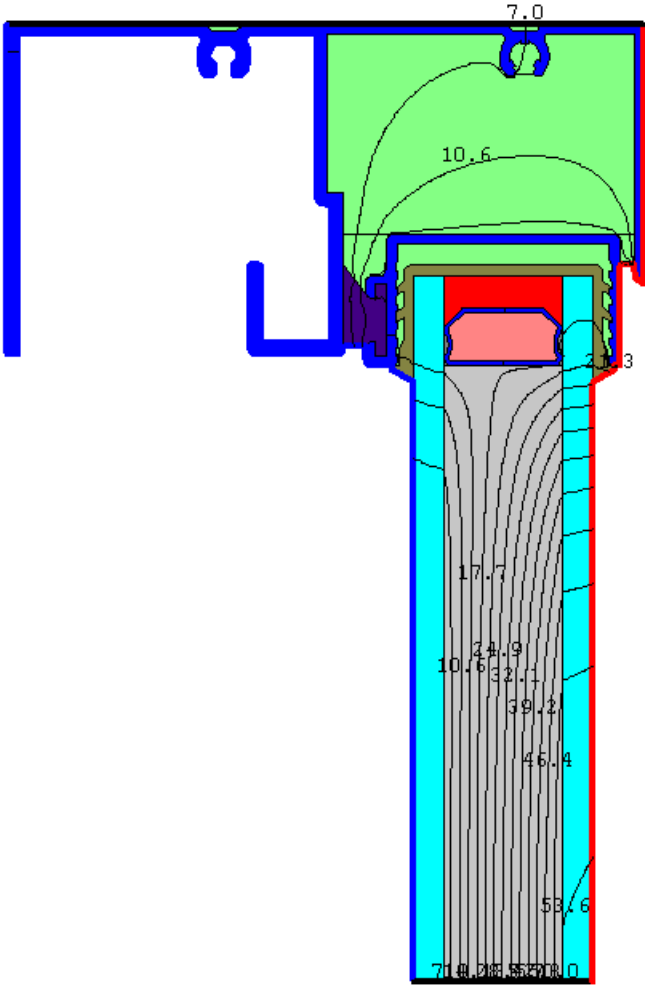
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Aluminum Horizontal Slider – Fixed Head Cross Section



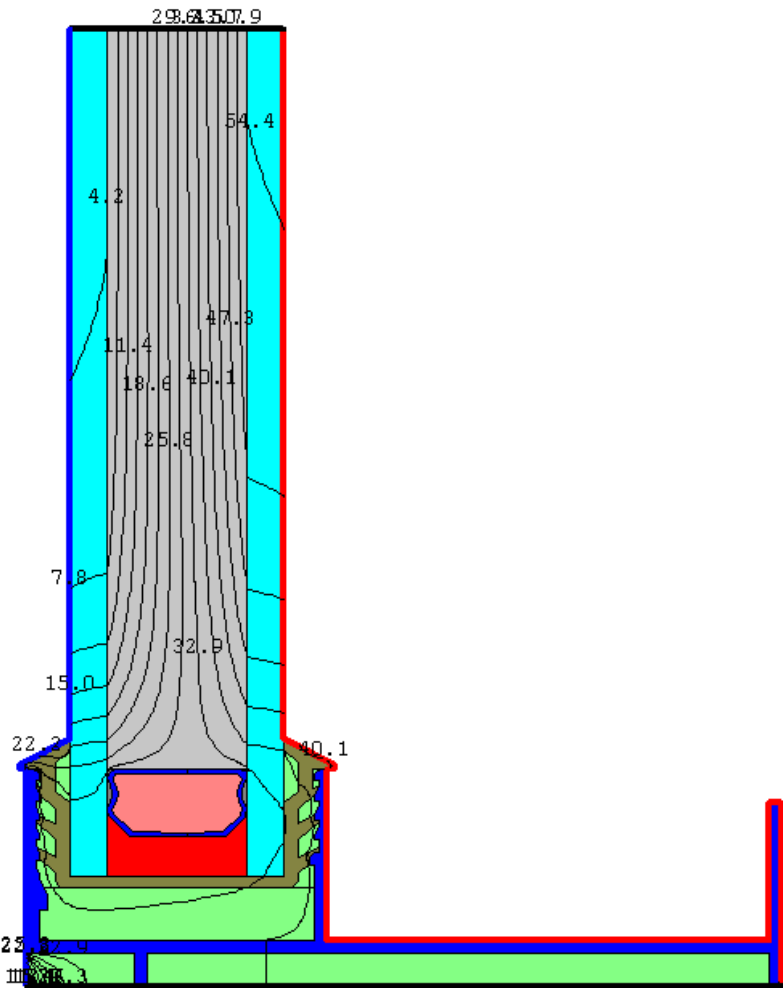
U-Factors				
	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	2.4436	70.0	1.48101	Projected Y
Edge	0.3637	70.0	2.5	Projected Y
% Error Energy Norm				6.32%
			Export	OK

Aluminum Horizontal Slider – Vented Head Cross Section



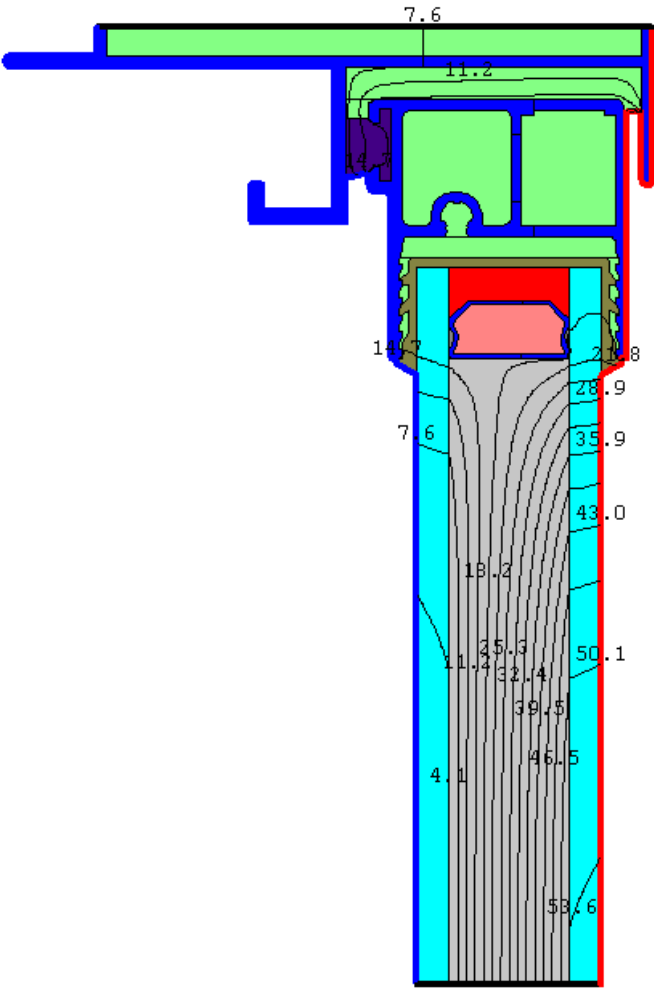
U-Factors				
	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	1.4804	70.0	1.48439	Projected Y
Edge	0.4383	70.0	2.50002	Projected Y
% Error Energy Norm		7.48%		
			Export	OK

Aluminum Horizontal Slider – Fixed Jamb Cross Section



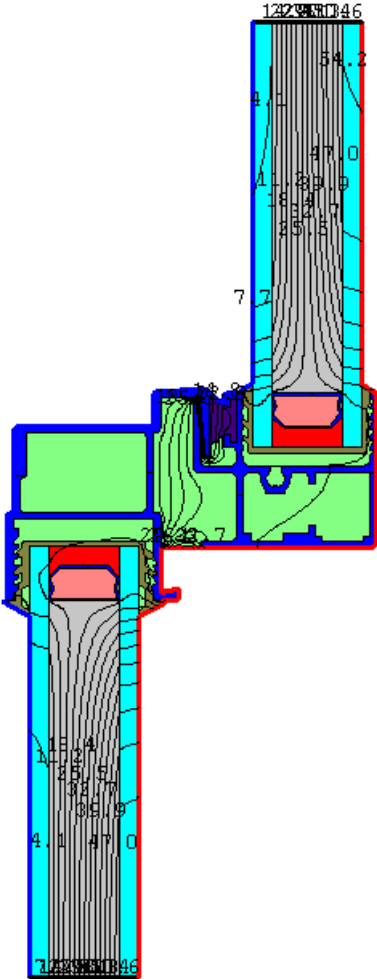
	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	2.7003	70.0	0.853282	Projected Y
Edge	0.3630	70.0	2.50002	Projected Y
% Error Energy Norm				8.04%
			Export	OK

Aluminum Horizontal Slider – Vented Jamb Cross Section



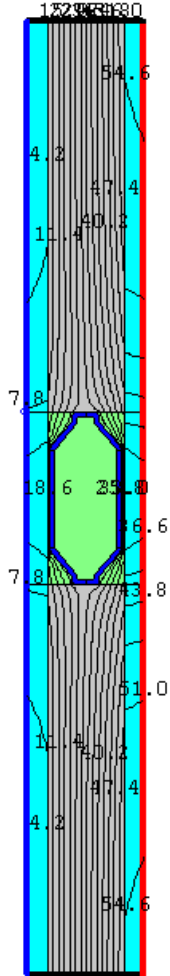
U-Factors				
	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	1.8158	70.0	1.42588	Projected Y
Edge	0.4370	70.0	2.50003	Projected Y
% Error Energy Norm		6.93%		
			Export	OK

Aluminum Horizontal Slider – Meeting Rail Cross Section



U-Factors				
	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	1.9760	70.0	1.60742	Projected Y
Edge	0.4120	70.0	5.00028	Projected Y
% Error Energy Norm		7.93%		
			Export	OK

Aluminum Horizontal Slider – Divider



U-Factors				
	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Edge	0.3449	70.0	5	Projected Y
Frame	0.6219	70.0	1.1	Projected Y
% Error Energy Norm		6.56%		
			Export	OK

Modeling Results Using Detailed Radiation Model

The Simulation Round Robin 1999 of the aluminum slider was also modeled with a radiation enclosure by the Therm 2.0 and Window 4.1 software in order to more accurately account for the radiative heat transfer effects. The boundary conditions used for the radiation enclosure model for the IG unit and frame are shown in Table 4.

The convective, radiative and overall surface heat transfer coefficients for the outdoor glazing boundary were calculated in Window 4.1, while the overall value for frame is prescribed by NFRC 100 standard (NFRC 1997).

On indoor side, convective surface heat transfer coefficient was calculated based on recommendations given in THERM NFRC Simulation manual (NFRC 1999). Radiative component for the center of glass was calculated in WINDOW 4.1, while for edge of glass and frame sections, the radiative component was explicitly calculated by the THERM program, as a part of the overall solution (NFRC 1999).

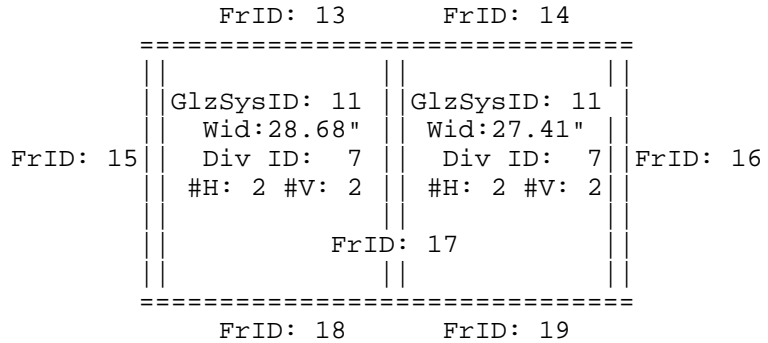
Table 4: Boundary conditions for radiation enclosure model

<i>Boundary Conditions</i>		<i>Environmental Temperature (°F)</i>	<i>h_c</i>	<i>h_r</i>	<i>Overall h</i>	<i>ε</i>
			<i>(Btu/h-ft²-F)</i>			
Outdoor Side	Glazing	0	4.485	0.567	5.052	0.84
	Frame		N/A	N/A	5.112	0.90
Indoor Side	Edge of Glass	70	0.521	Calc.	N/A	0.84
	Center of Glass		2.157	0.611	1.341	0.84
	Frame		0.61	Calc.	N/A	0.90

The Window 4.1 results of this case model with dividers is below:

ID:4
 Name:DHS_RAD_DV
 Mode:Design
 EnvCond:1

 Type:Horz Slider
 Tilt: 90
 Size:Horz Slid AA
 Width: 60.00"
 Height: 36.00"
 Area: 15.00 ft2



U-value: 0.586 Btu/h-ft2-F
 SC: 0.524
 SHGC: 0.451
 Vt: 0.551

Data for Glazing Systems

ID	Name	COG Area ft2	#Lay	Tilt	Uc Btu/h-ft2	SCc	SHGCc	Vtc	RHG
11	dhs-gl	1.263	2	90	0.272	0.62	0.53	0.75	128
11	dhs-gl	1.125	2	90	0.272	0.62	0.53	0.75	128

Glass and Gas Data for Glazing System '11 dhs-gl'

ID	Name	D(in)	Tsol	1 Rsol	2 Tsol	1 Rvis	2 Tvis	Tir	1 Emis	2 Keff	
Outside											
5142FS100CL_3.PPG	#	0.129	.566	.210	.270	.827	.061	.046	.000	.843	.520
8	Air/Argon/Kryp	0.492	Air:	10%	Ar:	90%	Kr:	0%		.015	
5009	CLEAR_3.PPG	0.129	.827	.076	.076	.898	.086	.086	.000	.840	.520
Inside											

Frame Data

Location	ID	Name	Source	Frame Area ft2	Edge Area ft2	Uframe Btu/h-ft2-F	Uedge
Left Jamb	15	JF_R.T2W	FRAME Sill	0.210	0.492	2.2872	0.3413
Left Header	13	HF_R.T2W	FRAME Head	0.308	0.416	2.0214	0.3511
Mullion	17	MR_R.T2W	FRAME Rail	0.369	0.985	1.7308	0.3984
Left Sill	18	SF_R.T2W	FRAME Sill	0.308	0.416	2.6567	0.3652
Right Header	14	HV_R.T2W	FRAME Head	0.298	0.394	1.3147	0.4336
Right Jamb	16	JV_R.T2W	FRAME Jamb	0.342	0.493	1.4567	0.4346
Right Sill	19	SV_R.T2W	FRAME Sill	0.289	0.394	1.3539	0.4406

ID	Name	Source	Divider Area ft2	Edge Area ft2	Udiv Btu/h-ft2-F	Udivedge Btu/h-ft2-F
7	DV_NR.T2W	FRAME Divide	0.909	2.592	0.6219	0.3449
7	DV_NR.T2W	FRAME Divide	0.890	2.506	0.6219	0.3449

Gas Data

ID	Name	Cond Btu/h-ft-F	dCond Btu/h-ft-F2	Visc lb-s/ft2	dVisc lb-s/ft2-F	Dens lb/ft3	dDens lb/ft3-F	Pran	dPran
			x e-5	x e-5	x e-8				
8	Air/Argon/Kryp	Air: .0101	10% 1.7324	Argon: 0.0442	90% 0.0756	Kryp: 0.1081	0% -0.0002	.6840	.00043

No gas data for Single Glazing

Environmental Conditions: 1 NFRC/ASHRAE

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky (F)
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
15	JF_R.T2W	FRAME Sill	2.29	0.34	N/A	0.7500	0.272	0.875	0.50
13	HF_R.T2W	FRAME Head	2.02	0.35	N/A	0.7500	0.272	1.481	0.50
17	MR_R.T2W	FRAME Rail	1.73	0.40	N/A	0.7500	0.272	1.607	0.50
18	SF_R.T2W	FRAME Sill	2.66	0.37	N/A	0.7500	0.272	1.481	0.50
14	HV_R.T2W	FRAME Head	1.31	0.43	N/A	0.7500	0.272	1.484	0.50
16	JV_R.T2W	FRAME Jamb	1.46	0.43	N/A	0.7500	0.272	1.426	0.50
19	SV_R.T2W	FRAME Sill	1.35	0.44	N/A	0.7500	0.272	1.441	0.50

ID	Name	Source	U-value		Edge Corr	GlzSys Width in	GlzSys Uc Btu/h- ft2-F	Width (PFD) in	Abs
			Div Btu/h- ft2-F	Edge Btu/h- ft2-F					
7	DV_NR.T2W	FRAME Divide	0.62	0.34	N/A	0.7500	0.272	1.100	0.50

Optical Properties for Glazing System '11 dhs-gl'

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

Vtc : 0.746
 Rf : 0.120
 Rb : 0.124

Tsol : 0.474
 Rf : 0.239
 Rb : 0.269

Abs 1: 0.231
 Abs 2: 0.056
 Abs 3:
 Abs 4:
 Abs 5:
 Abs 6:
 SHGCc: 0.534

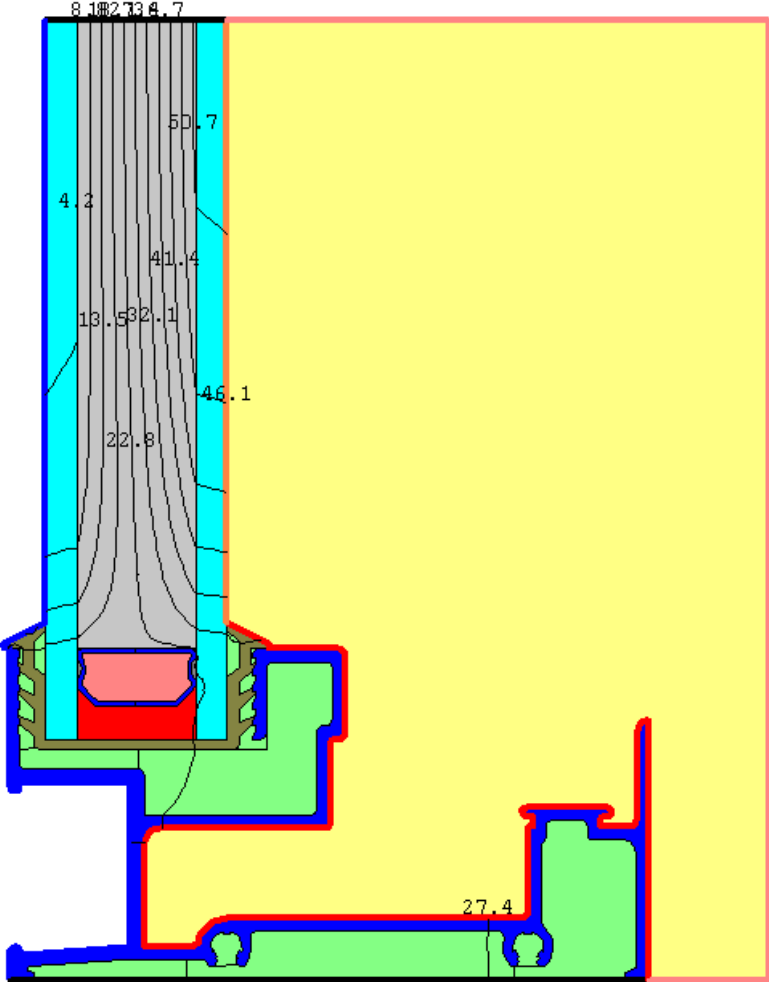
SCc: 0.62 Color Properties DomWL Purity L* a* b*
 Tdw: N/A Transmittance um %
 Tuv: N/A Reflectance um %

Temperature Distribution (degrees F) for '11 dhs-gl'

Env. Conditions:	1 NFRC/ASHRAE	U-value	Condensation RH	Solar
	Outside Air	0.0		89.0
	Outer Surface	3.8	N/A	102.2
Layer 1	Center	4.0		102.7
	Inner Surface	4.2		102.7
	Outer Surface	55.7		88.7
Layer 2	Center	55.9		88.6
	Inner Surface	56.1	61.3%	88.4
	Inside Air	70.0		75.0

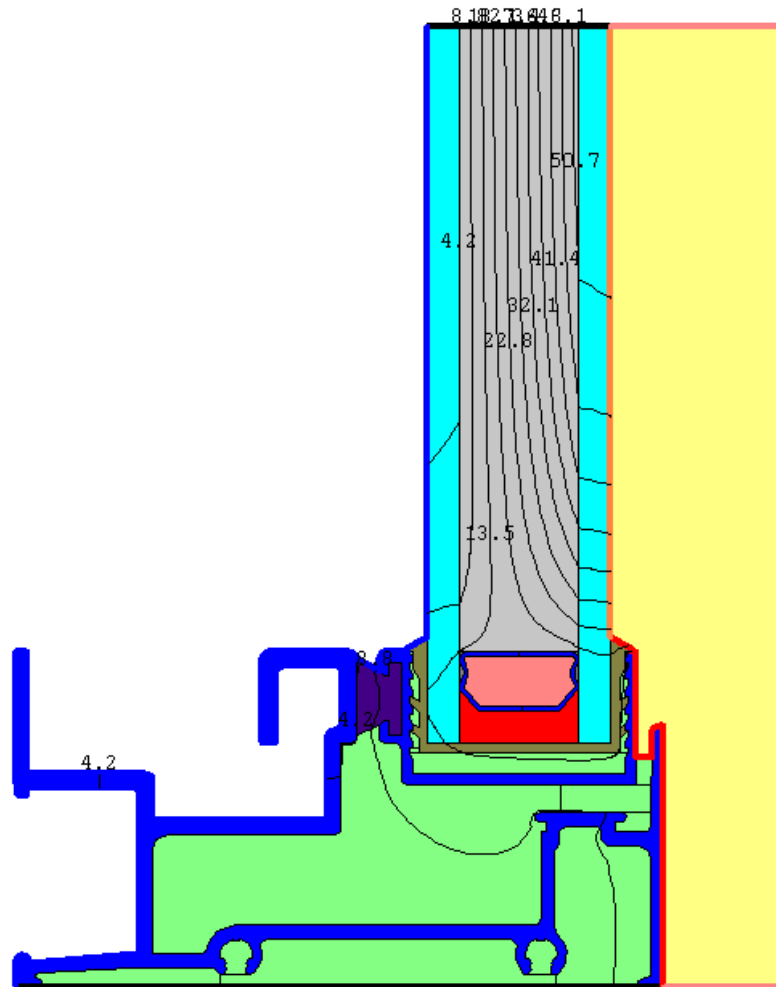
Below are the isotherm models of the various cross-sections with frame and edge U-factors.

Double Glazed Aluminum Horizontal Slider with Radiation Enclosure – Fixed Sill



	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	2.6567	70.0	1.48071	Projected Y
Edge	0.3652	70.0	2.5	Projected Y
% Error Energy Norm		9.46%		

Double Glazed Aluminum Horizontal Slider with Radiation Enclosure – Vented Sill

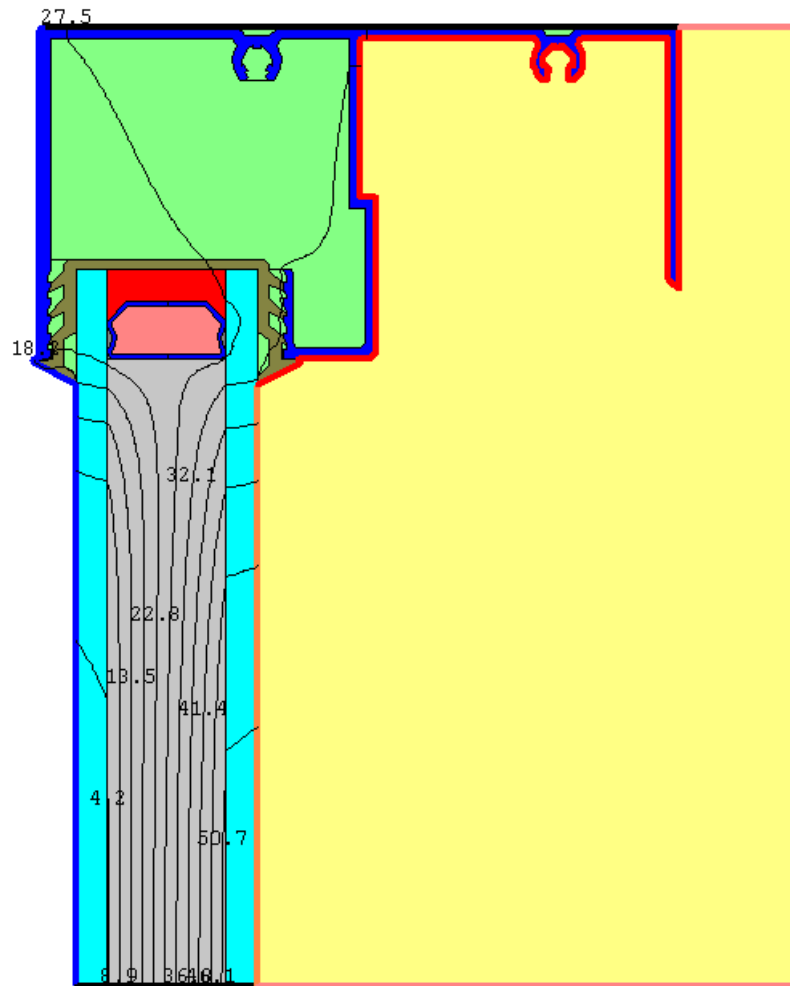


	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	1.3539	70.0	1.4407	Projected Y
Edge	0.4406	70.0	2.49992	Projected Y

% Error Energy Norm 9.96%

Export OK

Double Glazed Aluminum Horizontal Slider with Radiation Enclosure – Fixed Head

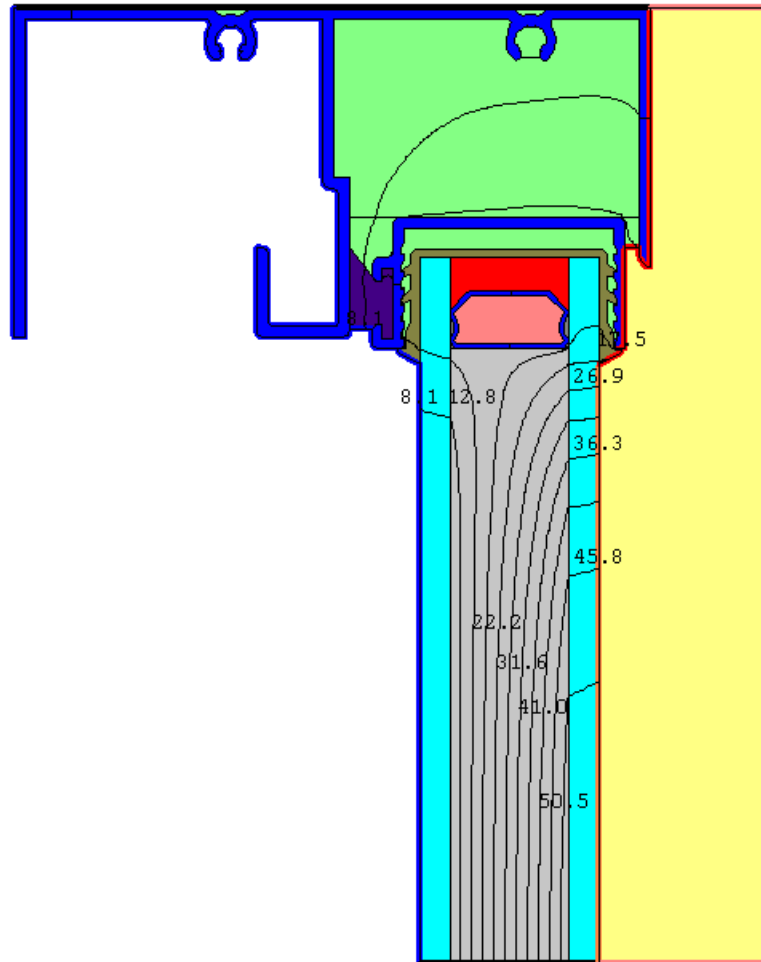


U-Factors			
	U-factor Btu/h-ft ² -F	delta T F	Length inches
Frame	2.0214	70.0	1.48101
Edge	0.3511	70.0	2.5

% Error Energy Norm 9.79%

Export OK

Double Glazed Aluminum Horizontal Slider with Radiation Enclosure – Vented Head

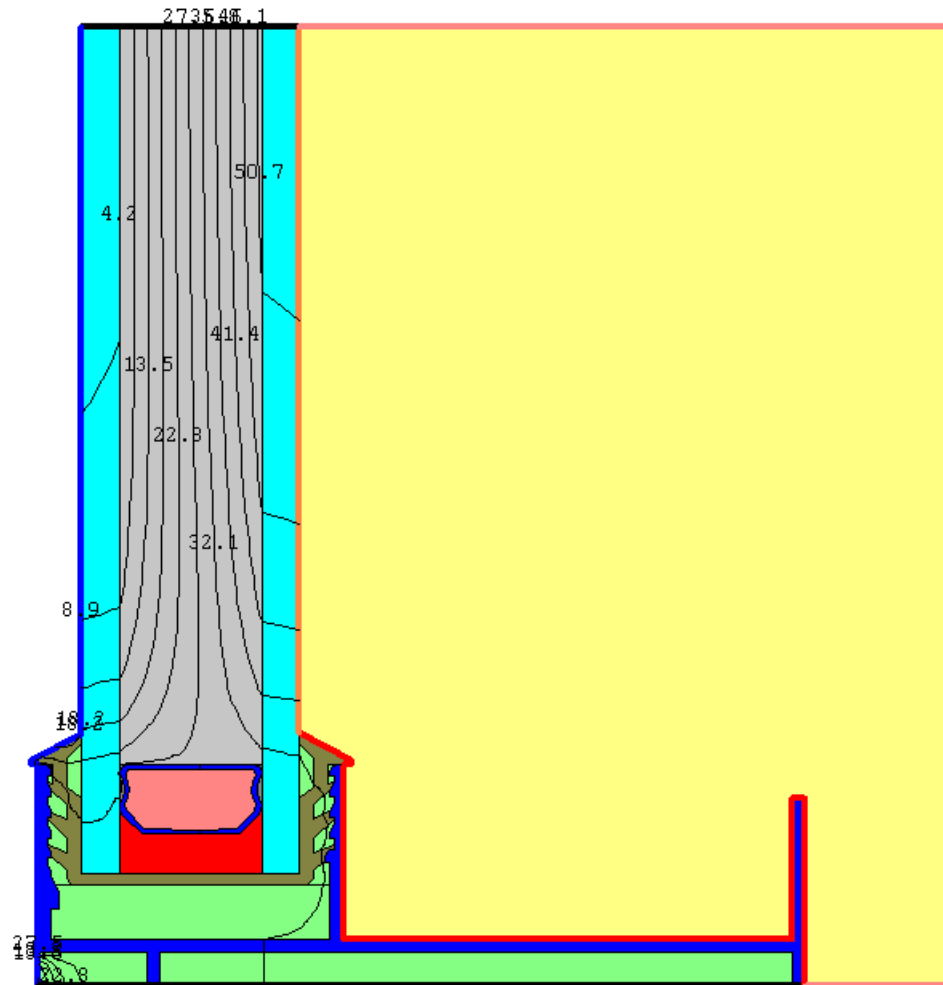


	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	1.3147	70.0	1.48439	Projected Y
Edge	0.4336	70.0	2.50002	Projected Y

% Error Energy Norm 5.80%

Export OK

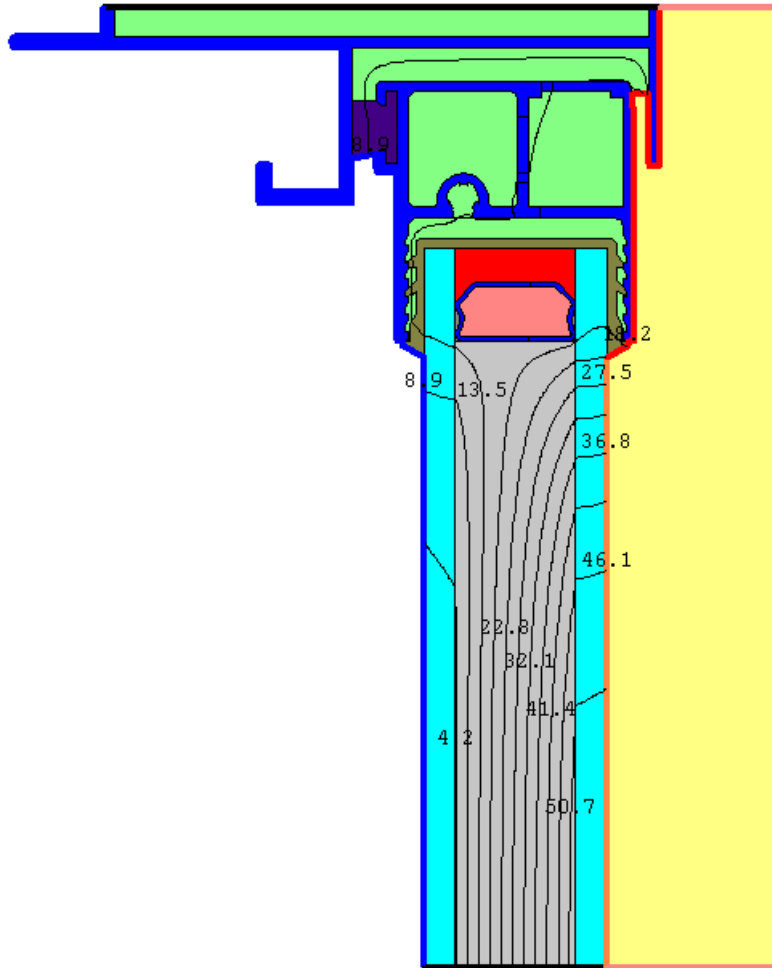
Double Glazed Aluminum Horizontal Slider with Radiation Enclosure – Fixed Jamb



	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	2.2872	70.0	0.875441	Projected Y
Edge	0.3413	70.0	2.43122	Projected Y
% Error Energy Norm		9.44%		

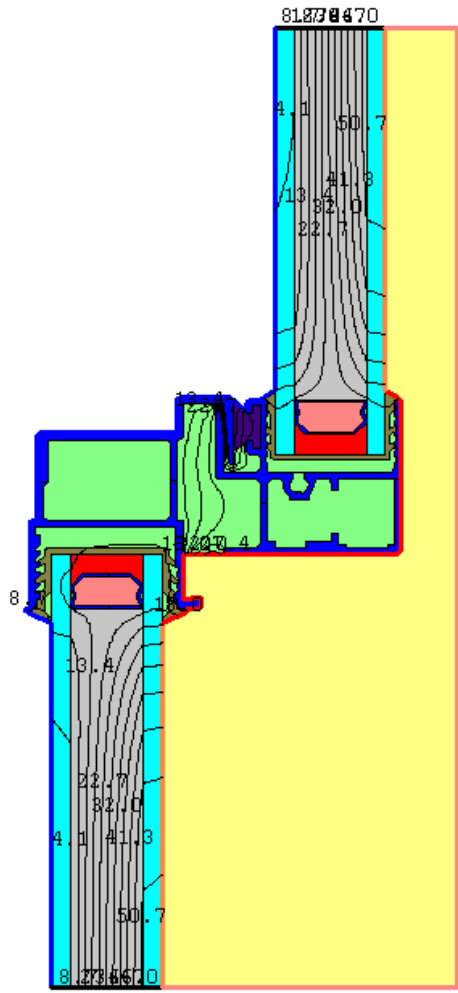
Export OK

Double Glazed Aluminum Horizontal Slider with Radiation Enclosure – Vented Jamb



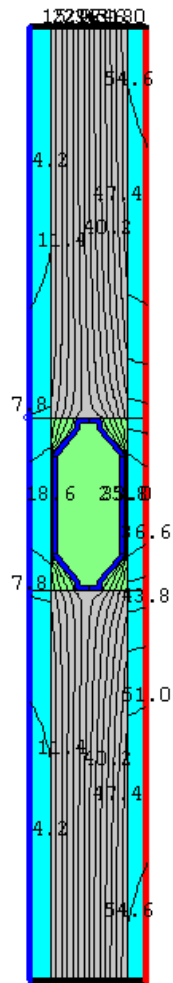
	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	1.4567	70.0	1.42588	Projected Y
Edge	0.4346	70.0	2.50003	Projected Y
% Error Energy Norm		6.38%		
			Export	OK

Double Glazed Aluminum Horizontal Slider with Radiation Enclosure – Meeting Rail



	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Frame	1.7308	70.0	1.60742	Projected Y
Edge	0.3984	70.0	5.00028	Projected Y
% Error Energy Norm				9.56%
			Export	OK

Double Glazed Aluminum Horizontal Slider with Radiation Enclosure – Divider



	U-factor Btu/h-ft ² -F	delta T F	Length inches	
Edge	0.3449	70.0	5	Projected Y
Frame	0.6219	70.0	1.1	Projected Y
% Error Energy Norm				6.56%
			Export	OK