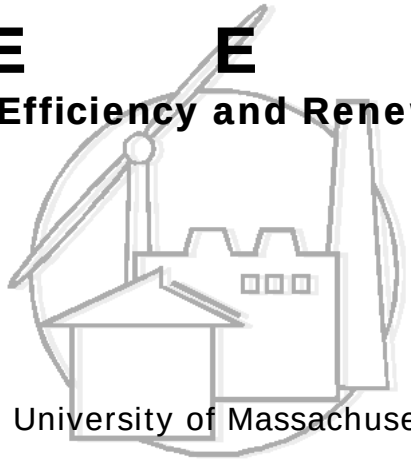
Building Energy Efficiency Program

C E E R E

Center for Energy Efficiency and Renewable Energy



University of Massachusetts

Department of Mechanical and Industrial Engineering

219 Engineering Lab.

Amherst, MA 01003-2210

TECHICAL REPORT:

Computer Modeling of CI According to NFRC 500 Of A Wood Fixed Window With Varying Spacers and Glazing Options

January, 2001

Condensation Index (CI) mainly depends on the type of spacers and glazing. The CI for different spacer types and glazing types (double, triple and with low-e coatings) has been calculated using NFRC500 procedure. As the CI is determined for a single set of environmental conditions and it is a comparative rating that indicates a product's ability to resist the formation of condensation, therefore, different types of spacers and glazing units have been analyzed using this procedure.

Analysis 1: Spacers

For analysis the spacers have been characterized by their K_{eff} values. K_{eff} has been defined so that the comparison can be made. K_{eff} for different spacers has been calculated as follows:

Overall U factor of individual spacer was calculated using THERM. By the electrical analogy of heat transfer mechanism

$$R_{Tot} = \frac{1}{h_o} + \frac{L}{k_{eff}} + \frac{1}{h_i} \qquad (1)$$

Where L is the length of the spacer, hi and ho are inside and outside heat transfer coefficients respectively and R_{tot} (=1/U) is overall resistance.

From eqn (1):

$$\frac{L}{k_{eff}} = R_{Tot} - \frac{1}{h_o} - \frac{1}{h_i} \qquad (2)$$

or

$$K_{eff} = \frac{L}{R_{Tot} - \frac{1}{h_o} - \frac{1}{h_i}} \qquad (3)$$

The analysis has been carried out for the window shown in Fig. 1.1. Fig. 1.2 shows the type of spacers analyzed. For the sake of completeness two extreme values of K_{eff} have been assumed at the lower and upper ends. As there was large gap in the values of K_{eff} between stainless and Aluminum spacers, an assumed value of 10 has been considered for the calculations. Figs. 1.3 to 1.5 show the heat transfer values for the cross sections of the window. No primary sealant has been considered for this analysis.

The CI values have been calculated by NFRC 500 method. Details of window are given in Appendix 1 (Window 4.1 report).

NFRC TRRB97:

Geometry:

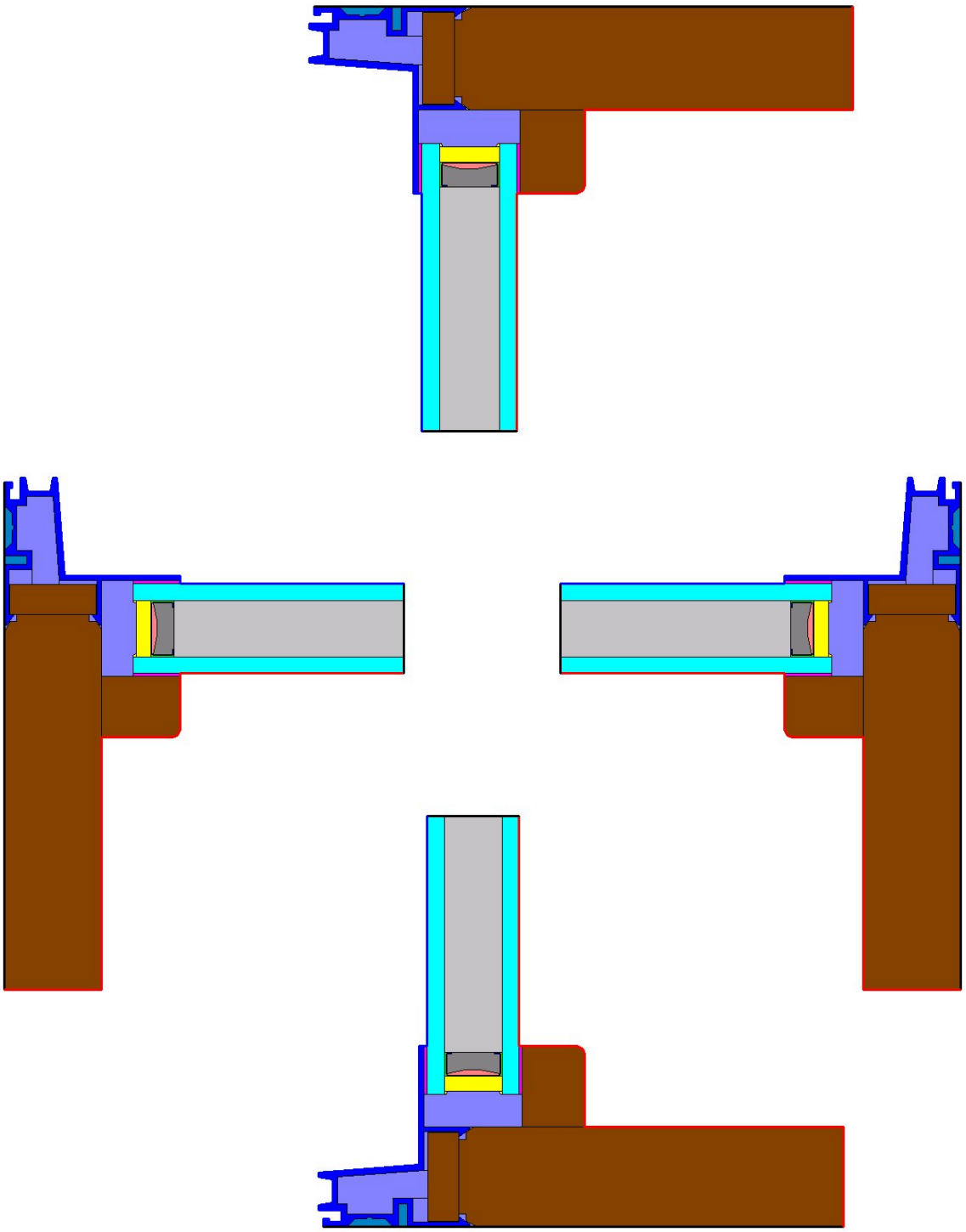
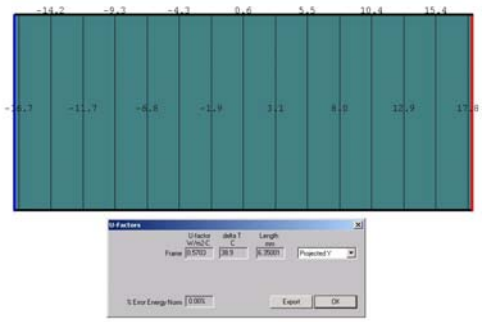
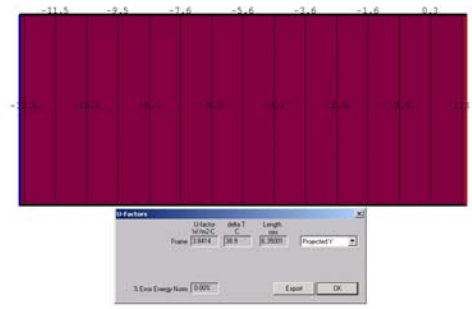


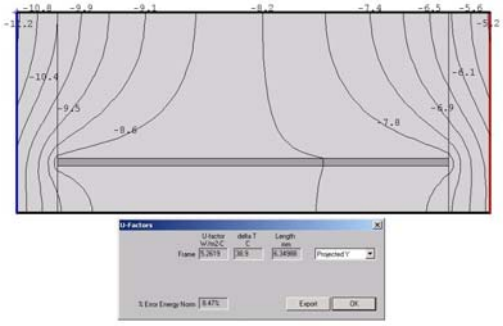
Figure 1.1. Geometry of the window analyzed



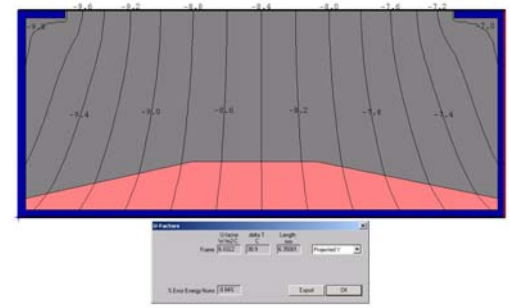
Lower extreme (K_{eff}=0.01)



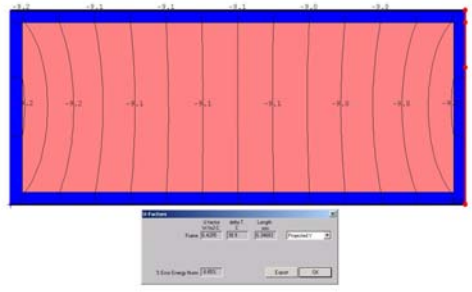
Super spacer (K_{eff}=0.168)



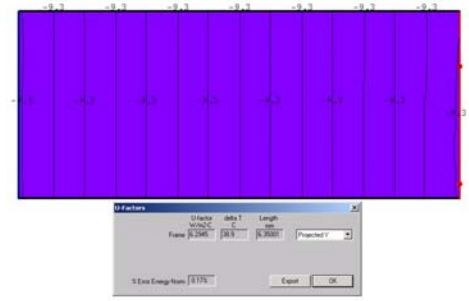
Swiggle (K_{eff}=0.656)



Stainless Steel (K_{eff}=1.61)



Aluminum (K_{eff}=19.31)



Upper Extreme (K_{eff}=200)

Figure 1.2. Spacer types

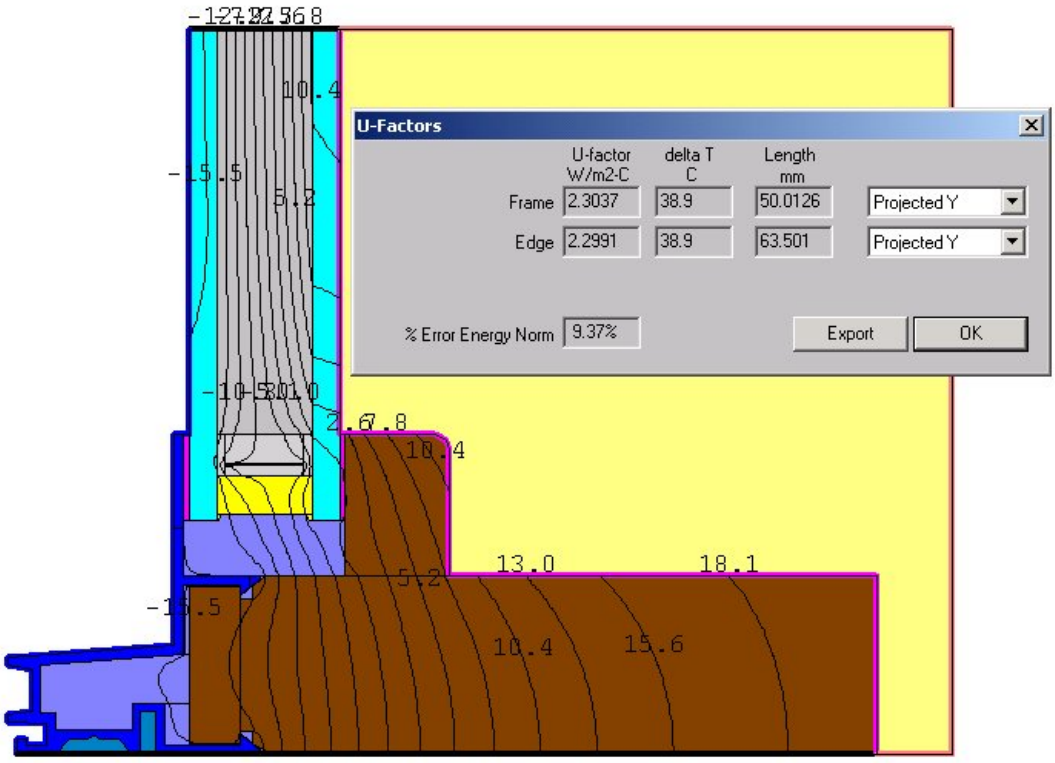


Figure 1.3. Heat Transfer Results for TRRB97 Jamb Cross-section Using Condensation Index Model

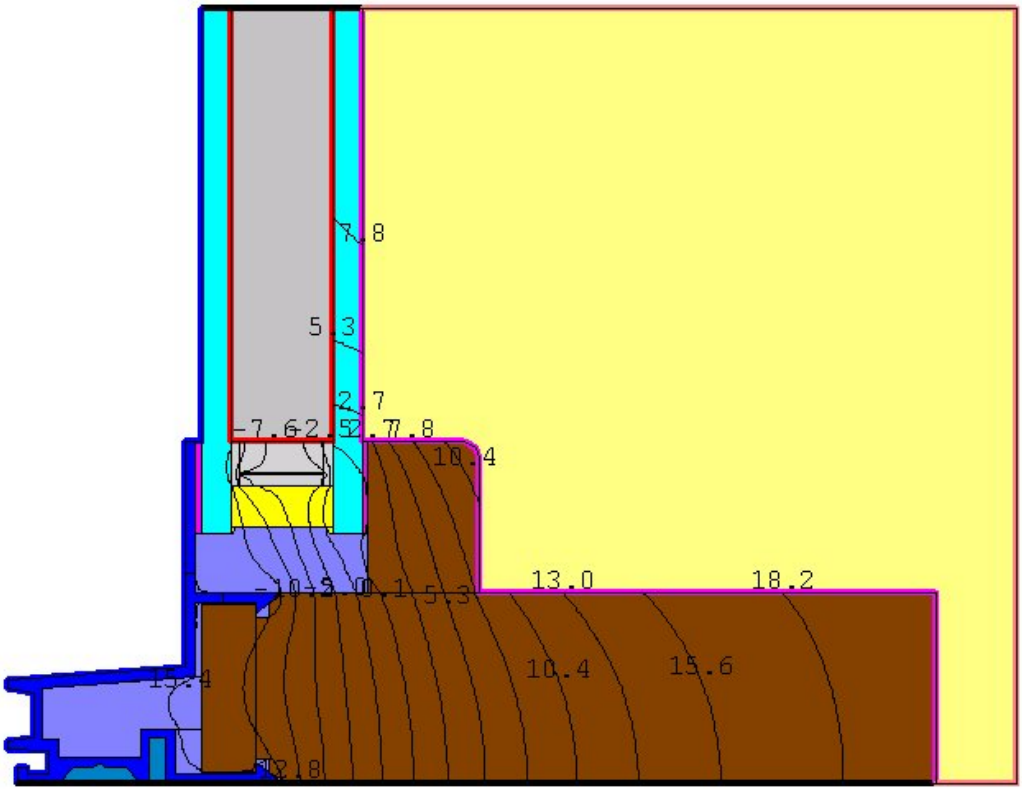


Figure 1.4. Heat Transfer Results for TRRB97 Sill Cross-section Using Condensation Index Model

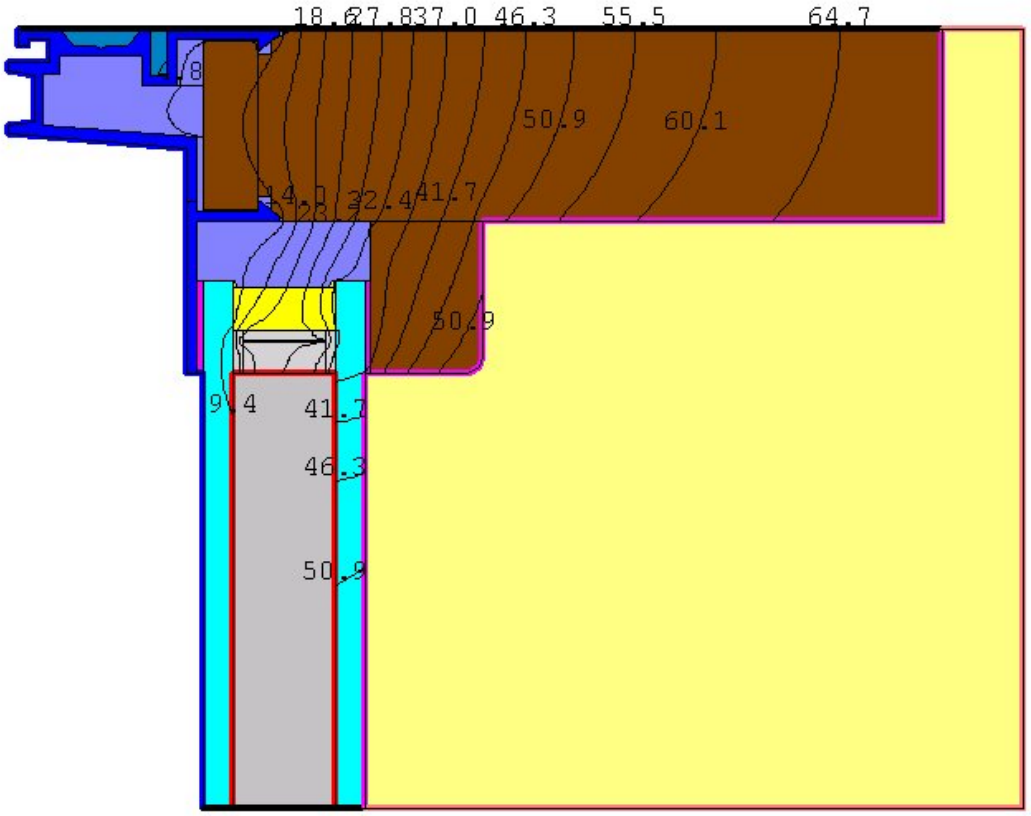


Figure 1.5. Heat Transfer Results for TRRB97 Head Cross-section Using Condensation Index Model

The K_{eff} values for different spacers along with the corresponding CI values have been given in Table 1.1.

Table 1.1. K_{eff} for different spacers and corresponding Condensation Index (NFRC Testing Round Robin 1997)

SPACER	L (m)	K_{EFF}	CI Current	CI Alternate 1	CI Alternate 2	CI Alternate 3
Lower Extreme	0.0159	0.01	65.09	57.78	59.42	69.30
Super	0.0159	0.168	64.82	56.97	58.72	69.17
Swiggle	0.0159	0.656	63.47	53.20	55.41	66.01
Stainless steel	0.0159	1.61	61.50	48.18	50.95	63.78
Middle Point	0.0159	10.00	59.36	43.21	46.48	60.89
Aluminum	0.0159	19.31	59.2	42.86	46.16	60.31
Upper Extreme1	0.0159	50.00	58.93	42.26	45.62	60.31
Upper Extreme2	0.0159	200.0	58.85	42.07	45.45	60.20

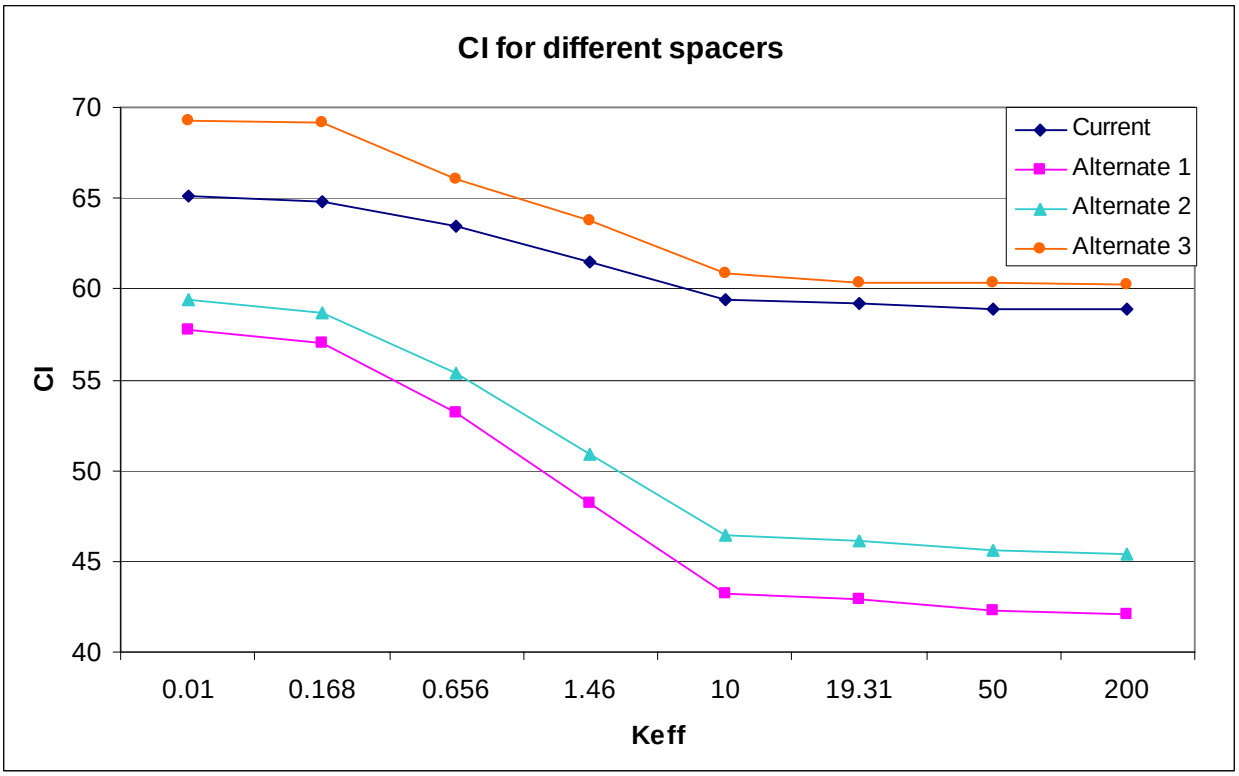


Figure 1.6. Variation of CI with k_{eff}

Fig 1.6 shows the temperature variation in a window assembly. 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.

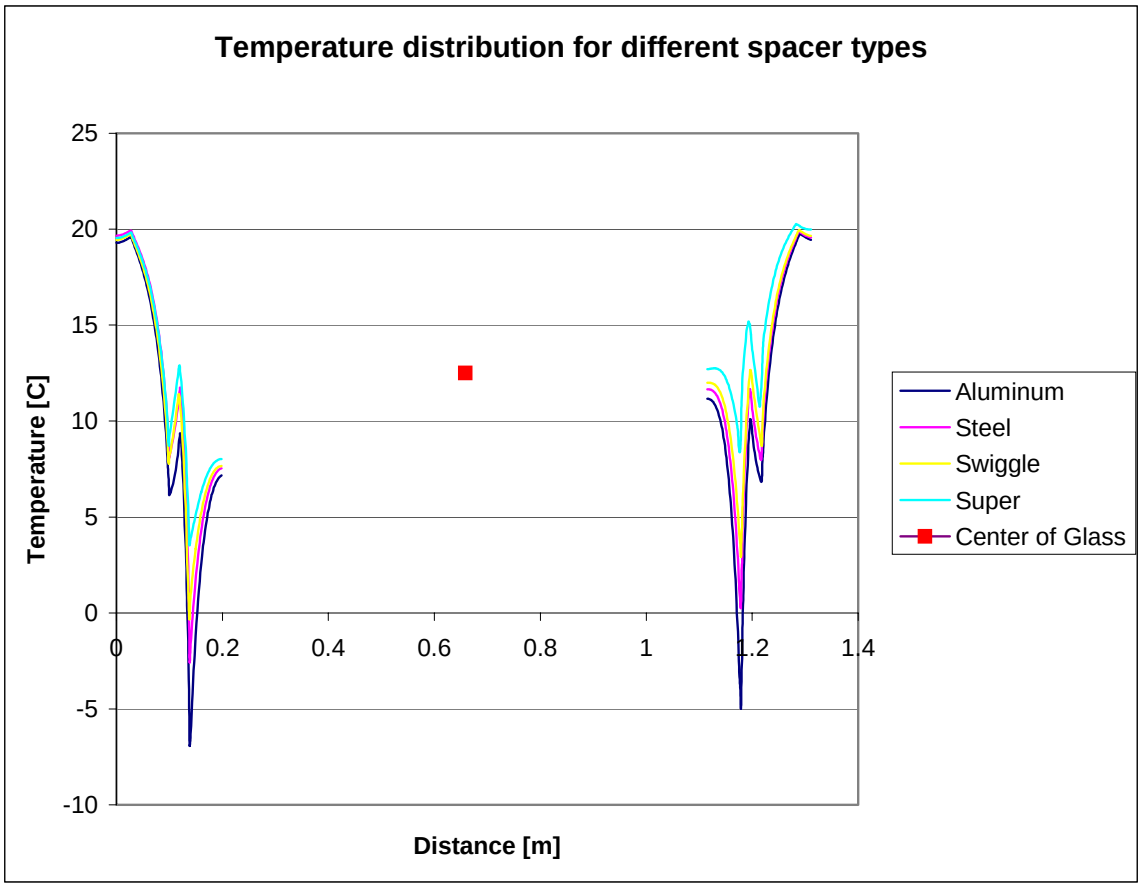


Figure 1.7. Temperature distribution for different spacer types

Analysis 2: Glazing

The following three glazing types with Aluminum and super spacers have been analyzed:

1. Double glazing unit **(Clear-clear)**
2. Double glazing unit with low-e coating (e=0.04) on surface 3 **(Clear-lowE)**
3. Triple glazing unit with low-e (e=0.04) coating on surface 3 and 5 **(Triple-lowE)**

Details of window systems for all the combinations are given in appendix 2.

CI values for all the three glazing units (for window geometry shown in Fig. 1.1), with Aluminum and Super spacer have been given in Table 1.2 and graphically presented in Figs 1.8 and 1.9.

Table 1.2. Condensation Index (CI) for different glazing units

Glazing Type	CI							
	Aluminum Spacer				Super Spacer			
	Current	Alternate 1	Alternate 2	Alternate 3	Current	Alternate 1	Alternate 2	Alternate 3
Clear-clear	46.91	36.47	38.83	53.83	51.12	50.91	51.66	60.33
Clear-lowE	59.57	43.66	46.90	60.54	65.32	58.47	60.02	69.19
Triple-lowE	62.85	51.44	54.59	65.33	74.79	67.15	68.83	74.98

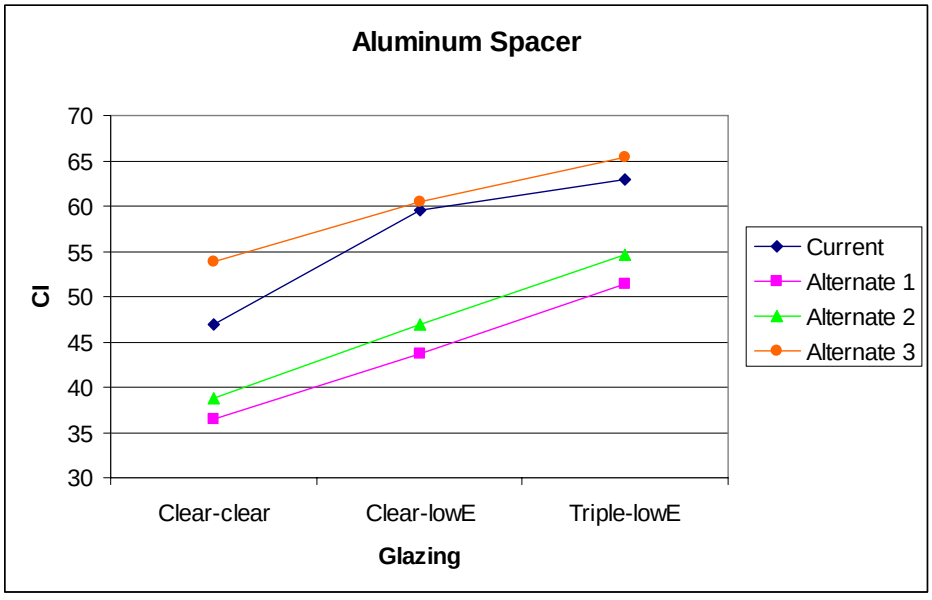


Figure 1.8. CI for different glazing units with Aluminum spacer

Figure 1.9. CI for different glazing units with Aluminum spacer

Figs. 1.10 and 1.11 show the temperature distribution along the glazing unit for different glazing unit option with Aluminum and Super spacers respectively.

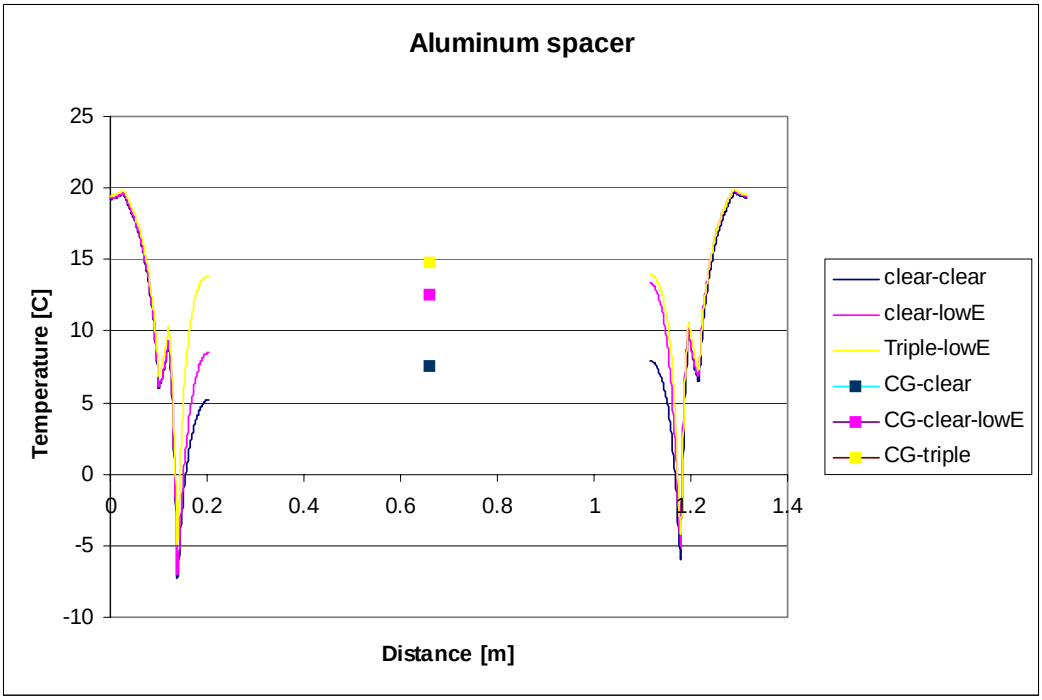


Figure 1.10. Temperature distribution for different glazing units with Aluminum spacer

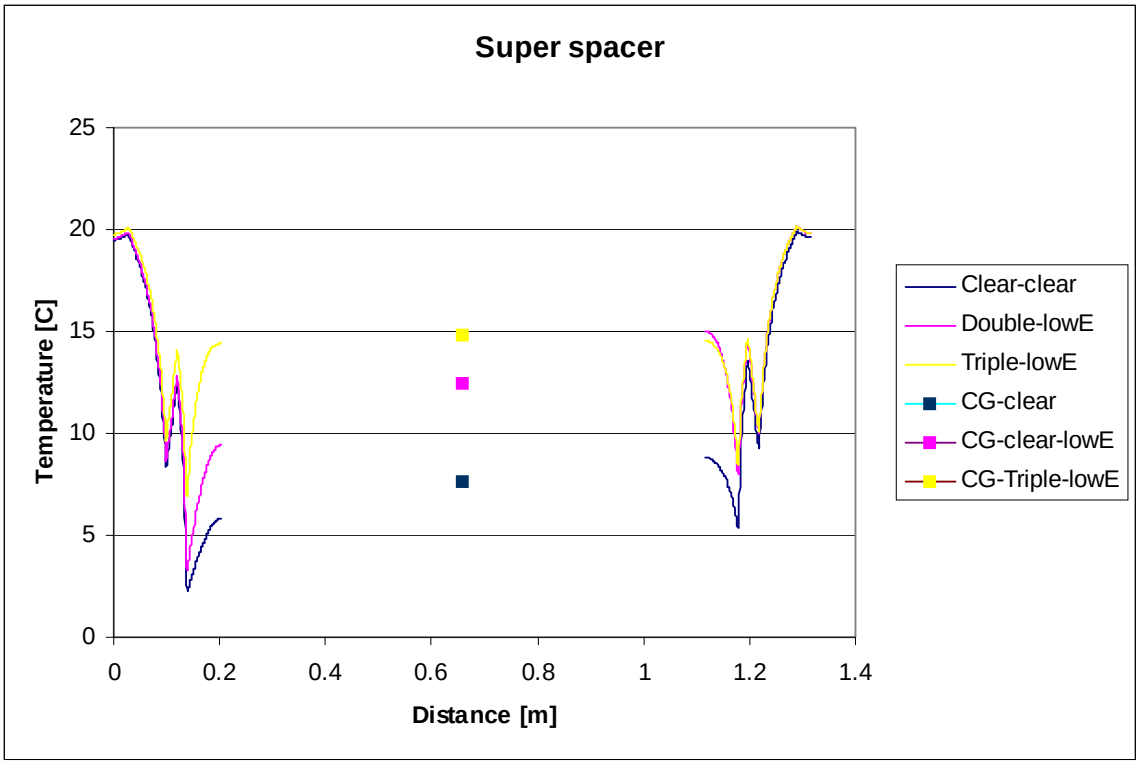


Figure 1.11. Temperature distribution for different glazing units with Super spacer

Appendix 1

Test Round Robin Double glazing unit (TTRB97)

WINDOW 4.1 Report 11/27/00 12:59:56

Name:TRRB97
Mode:Design
Type:Picture
Tilt: 90
Size:Fixed AA
Width: 48.00"
Height: 48.00"
Area: 16.00 ft2
U-value: 0.317 Btu/h-ft2-F
SC: 0.406
SHGC: 0.349
Vt: 0.596

Data for Glazing Systems

ID	Name	COG Area ft2	#Lay	Tilt	Uc Btu/h-ft2	SCc	SHGCc	Vtc	RHG
12	trrb-971	10.596	2	90	0.299	0.47	0.40	0.71	97

Glass and Gas Data for Glazing System '12 trrb-971'

ID	Name	D(in)	Tsol	1 Rsol	2 Rsol	Tvis	1 Rvis	2 Rvis	Tir	1 Emis	2 Emis	Keff
Outside												
2013	EE172-5.CIG	0.187	.411	.297	.425	.787	.056	.043	.000	.836	.041	.520
1	Air	0.625										.022
2003	CLR-5.CIG	0.187	.807	.072	.072	.896	.080	.080	.000	.836	.836	.520
Inside												

Frame Data

Location	ID	Name	Source	Frame Area ft2	Edge Area ft2	Uframe Btu/h-ft2-F	Uedge
Left Jamb	11	TRBEST.T2W	FRAME Jamb	0.629	0.722	0.3574	.3499
Header	11	TRBEST.T2W	FRAME Head	0.629	0.722	0.3574	.3499
Right Jamb	11	TRBEST.T2W	FRAME jamb	0.629	0.722	0.3574	.3499
Sill	11	TRBEST.T2W	FRAME Sill	0.629	0.722	0.3574	.3499

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

Optical Properties for Glazing System '12 trrb-971'

Angle	0	10	20	30	40	50	60	70	80	90	Hemis
Vtc	0.708										
Rf	0.105										
Rb	0.114										
Tsol	0.342										
Rf	0.309										
Rb	0.357										
Abs 1	0.297										
Abs 2	0.052										
SHGCc	0.403										
SCc	0.47										

Temperature Distribution (degrees F) for '12 trrb-971'

Env. Conditions:	1 NFRC/ASHRAE	U-value	Condensation RH	Solar
	Outside Air	0.0		89.0
	Outer Surface	4.2	N/A	106.1
Layer 1	Center	4.5		107.1
	Inner Surface	4.8		107.0
	Outer Surface	53.9		88.9
Layer 2	Center	54.2		88.8
	Inner Surface	54.5	57.8%	88.5
	Inside Air	70.0		75.0

Appendix 2

A. Clear Double glazing unit

```
WINDOW 4.1  Report                                        11/29/00 10:53:42
    Name:Al_clr_db
    Mode:Design
    Type:Casement
    Tilt: 90
    Size:Fixed AA
   Width:  48.00"
  Height:  48.00"
    Area: 16.00 ft2
   U-value: 0.504 Btu/h-ft2-F
      SC: 0.731
    SHGC: 0.629
      Vt: 0.681

Data for Glazing Systems
                    COG
ID  Name            Area #Lay  Tilt      Uc     SCc   SHGCc  Vtc    RHG
                    ft2             Btu/h-ft2
--- --------------- ----- ----  ----   -------   ----  -----  ----  -----
  6 clr,clr         10.596   2    90      0.484   0.85   0.73  0.81    178

Glass and Gas Data for Glazing System '6 clr,clr'

ID   Name            D(in) Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2 Keff
---- --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
Outside
2003 CLR-5.CIG       0.187 .807 .072 .072 .896 .080 .080 .000 .836 .836 .520
   1 Air             0.625                                               .048
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      13   SACLRD.T2W    FRAME Sill    0.629   0.722   0.4824  0.5986
Header         7    HACLRD.T2W    FRAME Head    0.629   0.722   0.4824  0.5978
Right Jamb     13   SACLRD.T2W    FRAME Sill    0.629   0.722   0.4824  0.5986
Sill           13   SACLRD.T2W    FRAME Sill    0.629   0.722   0.4824  0.5986


Environmental Conditions: 1 NFRC/ASHRAE

          Tout   Tin  WndSpd   Wnd Dir   Solar  Tsky  Esky
          (F)    (F)   (mph)            (Btu/h-ft2)  (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
```

Temperature Distribution (degrees F) for '6 clr,clr'

Env. Conditions:	1 NFRC/ASHRAE	U-value	Condensation RH	Solar
	Outside Air	0.0		89.0
	Outer Surface	6.7	N/A	96.4
Layer 1	Center	7.2		96.8
	Inner Surface	7.7		96.8
	Outer Surface	44.6		94.1
Layer 2	Center	45.2		94.0
	Inner Surface	45.7	41.6%	93.6
	Inside Air	70.0		75.0

B. Double glazing unit with low_E coating on surface 3

```
 WINDOW 4.1  Report                                    11/29/00 10:53:43
    Name:Al_lowE_db
    Mode:Design
    Type:Casement
    Tilt: 90
    Size:Fixed AA
   Width:  48.00"
  Height:  48.00"
    Area: 16.00 ft2
U-value: 0.362 Btu/h-ft2-F
      SC: 0.469
    SHGC: 0.404
      Vt: 0.596


Data for Glazing Systems

                     COG
ID  Name             Area #Lay  Tilt      Uc     SCc   SHGCc  Vtc    RHG
                     ft2             Btu/h-ft2
--- ---------------- ----- ----  ----   -------   ----  -----  ----  -----
  7 clr,low-e       10.596   2    90      0.299   0.54   0.46  0.71    111

Glass and Gas Data for Glazing System '7 clr,low-e'

ID   Name             D(in) Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2 Keff
---- ---------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
Outside
2003 CLR-5.CIG        0.187 .807 .072 .072 .896 .080 .080 .000 .836 .836 .520
   1 Air              0.625                                                .022
2013FEE172-5.CIG      0.187 .411 .425 .297 .787 .043 .056 .000 .041 .836 .520
Inside

Frame Data
                                                      Frame   Edge
Location     ID   Name          Source         Area    Area    Uframe   Uedge
                                                      ft2      ft2   Btu/h-ft2-F
---------------- ---  ------------ ------------ -----   -----  -------  ----
--
Left Jamb     14   SALOWED.T2W   FRAME Sill    0.629   0.722   0.4806  0.4869
Header         8    HALOWED.T2W   FRAME Head    0.629   0.722   0.4816  0.4886
Right Jamb    14   SALOWED.T2W   FRAME Sill    0.629   0.722   0.4806  0.4869
Sill          14   SALOWED.T2W   FRAME Sill    0.629   0.722   0.4806  0.4869


Environmental Conditions: 1 NFRC/ASHRAE

          Tout   Tin  WndSpd   Wnd Dir   Solar  Tsky  Esky
          (F)    (F)   (mph)            (Btu/h-ft2)  (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
```

Temperature Distribution (degrees F) for '7 clr,low-e'

Env. Conditions:	1 NFRC/ASHRAE	U-value	Condensation RH	Solar
	Outside Air	0.0		89.0
	Outer Surface	4.2	N/A	99.3
Layer 1	Center	4.5		99.9
	Inner Surface	4.8		99.9
	Outer Surface	53.9		98.1
Layer 2	Center	54.2		98.2
	Inner Surface	54.5	57.8%	97.6
	Inside Air	70.0		75.0

C. Triple glazing unit with low_E coating on surface 3 and 5

```
    Name:Al_lowE_trp
    Mode:Design
    Type:Casement
    Tilt: 90
    Size:Fixed AA
   Width:  48.00"
  Height:  48.00"
    Area: 16.00 ft2
 U-value: 0.289 Btu/h-ft2-F
      SC: 0.332
    SHGC: 0.285
      Vt: 0.485

Data for Glazing Systems
               COG
ID  Name             Area #Lay  Tilt      Uc     SCc   SHGCc  Vtc    RHG
                     ft2             Btu/h-ft2
--- -------------- ----- ----  ----   -------   ----  -----  ----  -----
  8 clr,lowe,lowe   10.596   3    90      0.214   0.38   0.32  0.58     79

Glass and Gas Data for Glazing System '8 clr,lowe,lowe'

ID   Name            D(in) Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2 Keff
---- -------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
Outside
2001 CLR-3.CIG       0.117 .844 .075 .075 .904 .082 .082 .000 .837 .837 .520
   1 Air             0.324                                               .014
2011FEE172-3.CIG     0.117 .423 .426 .339 .795 .043 .056 .000 .041 .837 .520
   1 Air             0.324                                               .015
2011FEE172-3.CIG     0.117 .423 .426 .339 .795 .043 .056 .000 .041 .837 .520
Inside
Frame Data
                                                    Frame   Edge
Location         ID   Name          Source         Area    Area    Uframe
Uedge
                                                     ft2      ft2   Btu/h-ft2-F
---------------- ---  ------------ ------------ -----   -----  -------  ----
--
Left Jamb        15   SALOWET.T2W   FRAME Sill    0.629   0.722   0.4751
0.3991
Header           9    HALOWET.T2W   FRAME Head    0.629   0.722   0.4749
0.3993
Right Jamb       15   SALOWET.T2W   FRAME Sill    0.629   0.722   0.4751
0.3991
Sill             15   SALOWET.T2W   FRAME Sill    0.629   0.722   0.4751
0.3991
```

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

Temperature Distribution (degrees F) for '8 clr,lowe,lowe'

Env. Conditions:	1 NFRC/ASHRAE	U-value	Condensation RH	Solar
	Outside Air	0.0		89.0
	Outer Surface	3.0	N/A	101.9
Layer 1	Center	3.1		102.3
	Inner Surface	3.3		102.5
	Outer Surface	31.4		135.5
Layer 2	Center	31.6		135.7
	Inner Surface	31.7		135.5
	Outer Surface	58.3		100.8
Layer 3	Center	58.5		100.6
	Inner Surface	58.6	67.1%	100.2
	Inside Air	70.0		75.0