1 Foam Garden Window in THERM 2.1a.

1.1 Foam Garden Window Description and Solution Method

The foam garden window was modeled by THERM with and without radiation enclosure as seen in Figures 1 and 2, respectively.

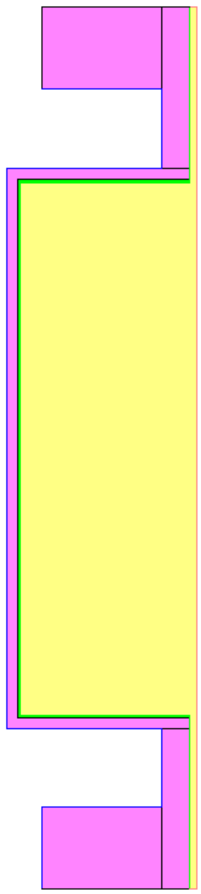


Figure 1: Foam Garden Window with Radiation Enclosure

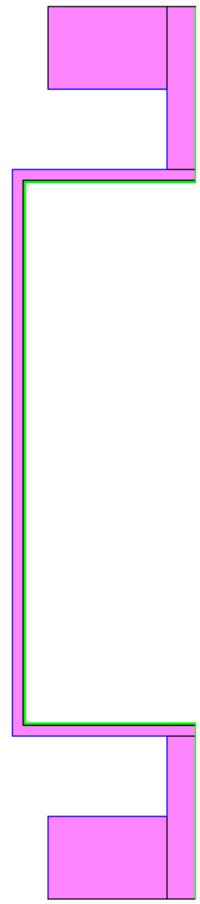


Figure 2: Foam Garden Window with No Radiation Enclosure

The procedure to model the foam garden window by both methods is as follows:

1. A surface wall temperature is initially assumed
2. The heat transfer coefficients are calculated. The convective heat transfer coefficient was calculated for the models with a radiation enclosure while the total heat transfer coefficient was calculated for the models without a radiation enclosure.

3. The heat transfer coefficient values are used by THERM to solve the model

4. Post-processed, new wall temperatures in THERM are determined and heat transfer coefficients are recalculated

5. Steps 3 and 4 are reiterated until wall temperatures converge to a constant value.

Exterior boundary conditions are applied to both cases.

Also, for both models, average and discrete heat transfer coefficients were used. An average heat transfer is the application of a constant heat transfer coefficient on the indoor surface The discrete heat transfer coefficient breaks the indoor boundary into small, "discrete" segments and a constant heat transfer coefficient is applied on each segment based on surface temperature and the location along the surface.

For the average heat transfer coefficient, the Nusselt number formula given by Skok et al. (1991) was used and is:

$$\overline{Nu_L} = 0.087 Ra_L^{1/3} \tag{1}$$

With the determination of average Nusselt number, the heat transfer coefficient was found by:

$$\bar{h} = \frac{\overline{Nu_L} k}{L} \tag{2}$$

For the discrete heat transfer coefficients, the derivative if Equation (1) was taken:

$$Nu_x = 36.7045 \frac{x^3 \Delta T^{1/3}}{x} \tag{3}$$

1.2 Results

The indoor surface temperature at the slot is plotted with the radiation enclosure using average and discrete heat transfer coefficients is shown in Figure 3. These two curves are compared to the LBNL experimental data.

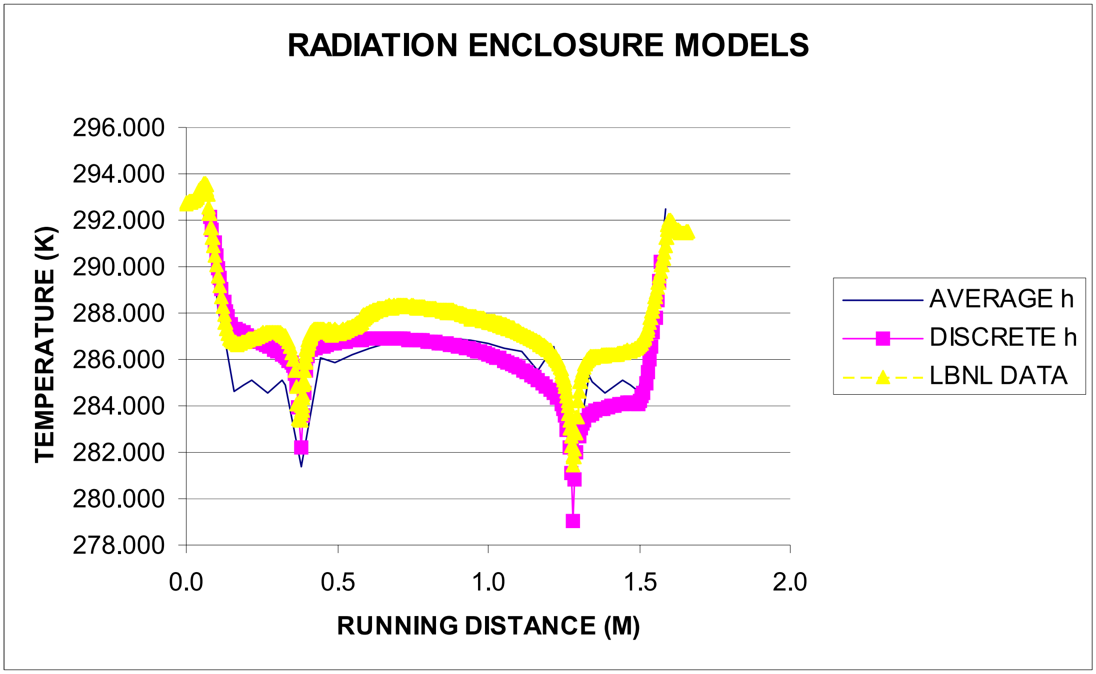


Figure 3: Temperature Plots for Radiation Enclosure Models

The convective heat transfer coefficients of the radiation enclosure models is shown in Figure 4 for both the average and discrete heat transfer coefficients. Again these two curves are compared to the LBNL experimental data.

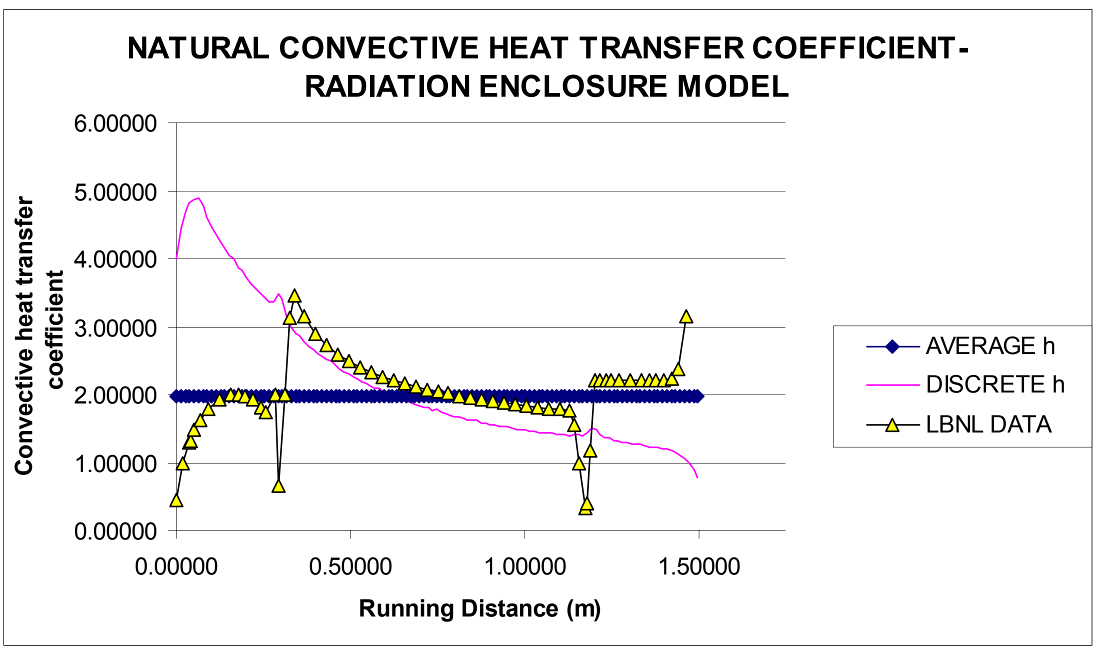


Figure 4: Convective Heat Transfer Coefficient-Radiation Models

The indoor surface temperature at the slot is plotted with NFRC boundary conditions in Figure 5.

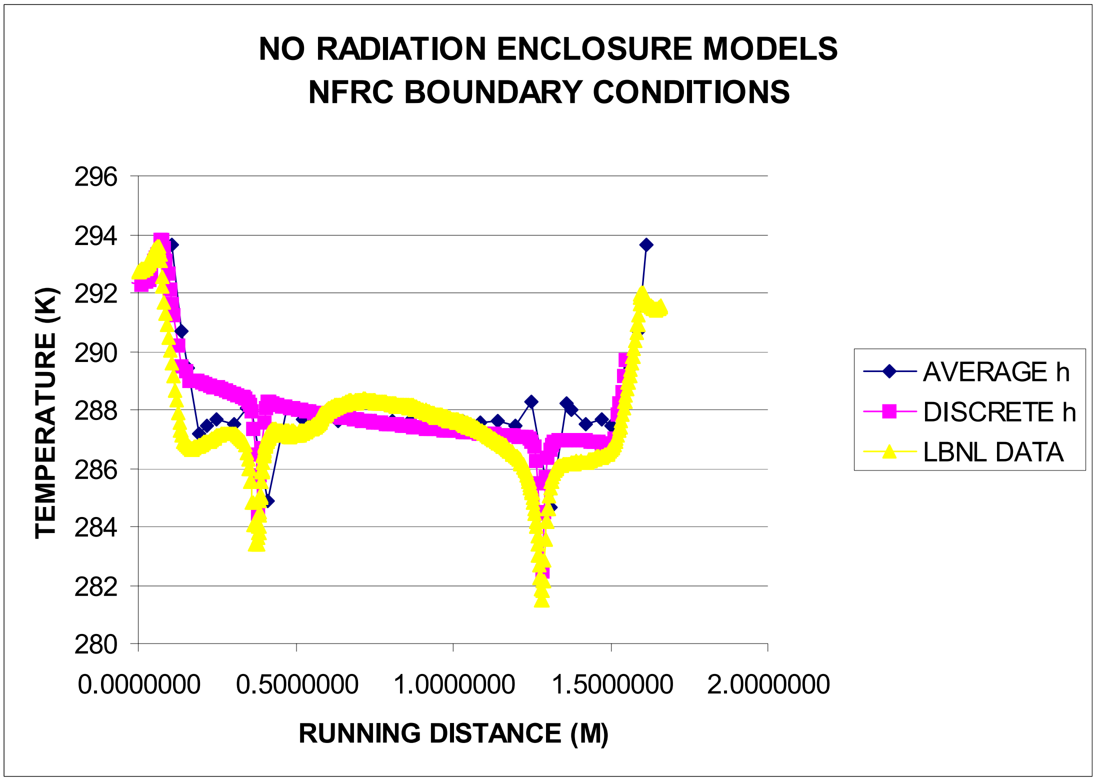


Figure 5: Slot Surface Temperature with NFRC Boundary Conditions

The total (convective and radiative) heat transfer coefficients of the radiation enclosure models are shown in Figure 6 for both the average and discrete heat transfer coefficients. Again these two curves are compared to the LBNL experimental data.

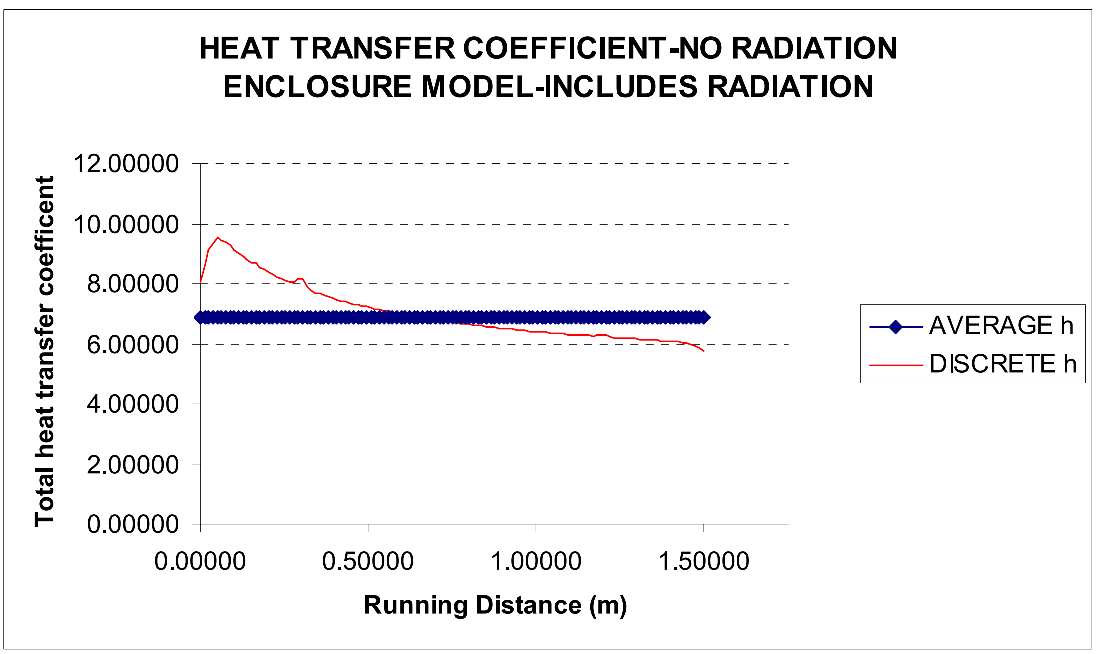


Figure 6: Slot Heat Transfer Coefficients with NFRC Boundary Conditions

Convective flux was calculated by $q = h_c(T_W - T_{ref})$ where T_{ref} is the reference temperature (21.1°C), T_W is the surface wall temperature and h_c is the convective heat transfer coefficient. Total flux was calculated by $q = h_{Total}(T_W - T_{ref})$ where in this case h_{Total} is the total (convective plus radiative heat transfer coefficient).

Total and convective flux results are given in Figures 7-8.

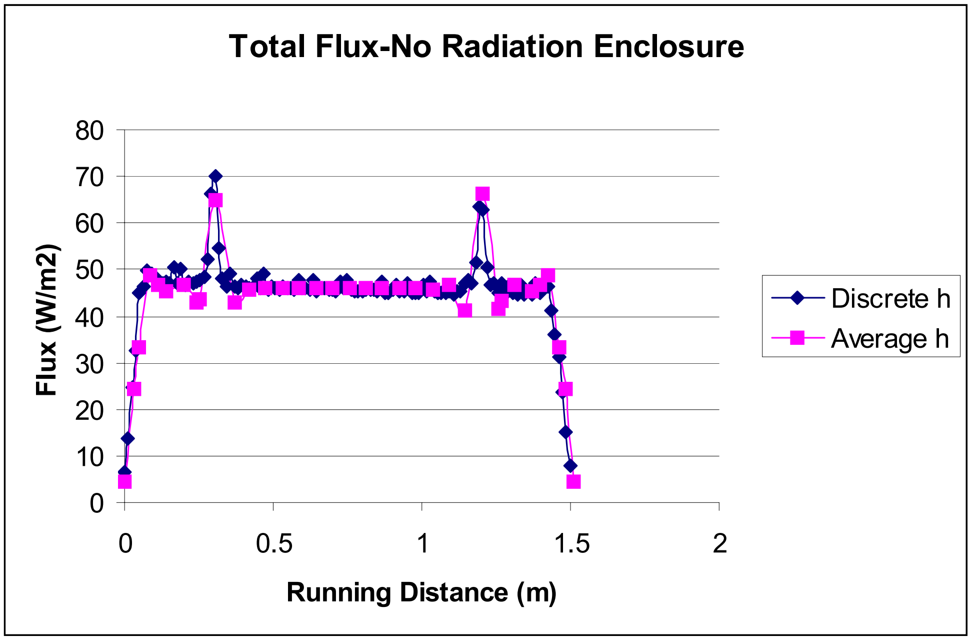


Figure 7: Total Flux-No Radiation Enclosure

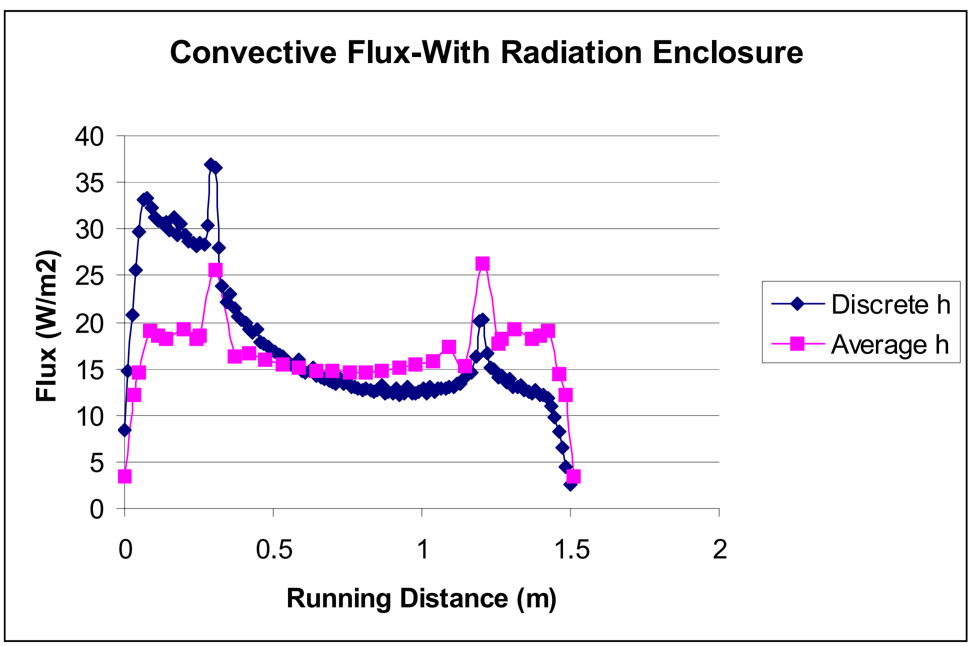


Figure 8: Convective Flux-With Radiation Enclosure

An U-factor, heat flow and flux for the head, sill, edge of glass head, edge of glass sill and center of glass for the foam garden window was calculated to compare to the values obtained by LBNL using THERM. The U-factor tags for both cases were broken up as shown in Figure 9 below:

Figure 9: U-factor tags of Foam Garden Window

The results for the cases where an average h (with and without radiation enclosure) is shown in Table 1.

No Radiation Enclosure	**Q**	**qav**	**U**	PERCENTAGE U-FACTOR ERROR
FRAME SILL	1.201767542	50.46791	1.297375503	19.53951474
FRAME HEAD	1.19554783	50.20684	1.290664228	19.22697797
EDGE OF GLASS SILL	15.26312359	240.36415	6.179027017	9.009078761
CENTER OF GLASS	35.31416084	45.58419	1.17183	2.437885837
EDGE OF GLASS HEAD	15.25129757	240.17791	6.174239449	8.947182055
Radiation Enclosure				
FRAME SILL	1.081507747	45.41763	1.167548306	7.577303271
FRAME HEAD	1.075495834	45.16527	1.161061034	7.254695184
EDGE OF GLASS SILL	13.96380113	219.90238	5.653017479	-0.270669488
CENTER OF GLASS	34.05086358	43.95350	1.12991	-1.226635616
EDGE OF GLASS HEAD	13.95013817	219.68722	5.647486252	-0.347610755

Table 1: Head and Sill Frame, Edge and Center-of-glass Property

The last column, Error, is a percentage error between the results presented to the THERM models done by LBNL. But I do not know what assumptions they used, what heat transfer coefficients they applied to solve the model and this was just to see if the results were within the ballpark. I did use the same lengths and same procedure to calculate the Q, qv, and U above.

Likewise, the results for the cases where a discrete h (with and without radiation enclosure) is shown in Table 2.

No Radiation Enclosure	**Q**	**qav**	**U**	PERCENTAGE U-FACTOR ERROR
FRAME SILL	1.1458	48.11837	1.236976083	13.97434309
FRAME HEAD	1.1506	48.31861	1.24212358	14.74296533
EDGE OF GLASS SILL	15.6426	246.34047	6.33266	11.71943913
CENTER OF GLASS	35.4140	45.71315	1.175145246	2.727694752
EDGE OF GLASS HEAD	14.7819	232.78589	5.984213	5.594081437
Radiation Enclosure				

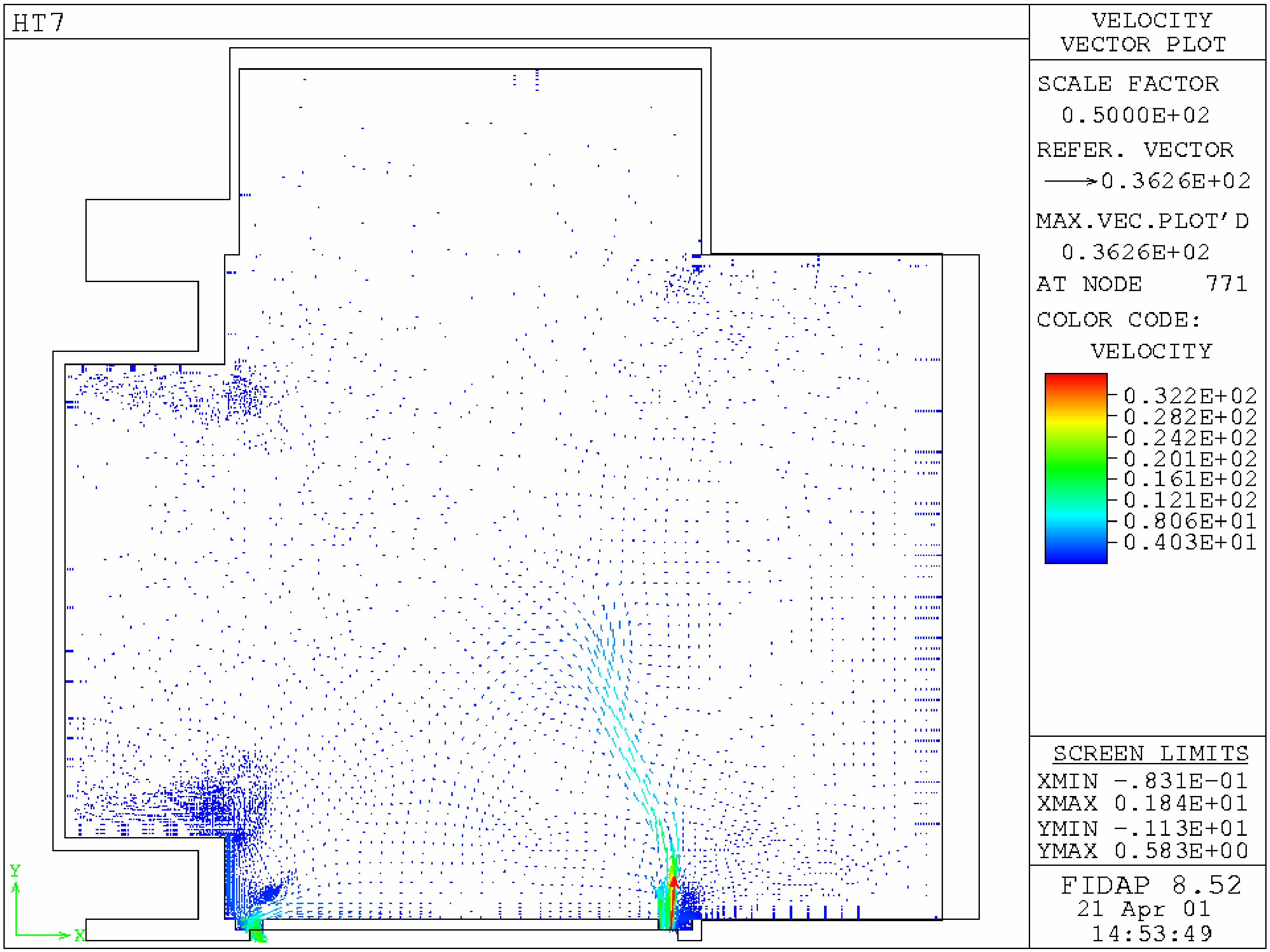
FRAME SILL	1.093208	45.90888	1.18017697	8.740901681
FRAME HEAD	1.038831	43.62556	1.12147967	3.598309442
EDGE OF GLASS SILL	14.67864	231.1597	5.942408	4.834696455
CENTER OF GLASS	34.20123	44.14771	1.13490246	-0.790209729
EDGE OF GLASS HEAD	13.34685	210.1867	5.403256	-4.65716142

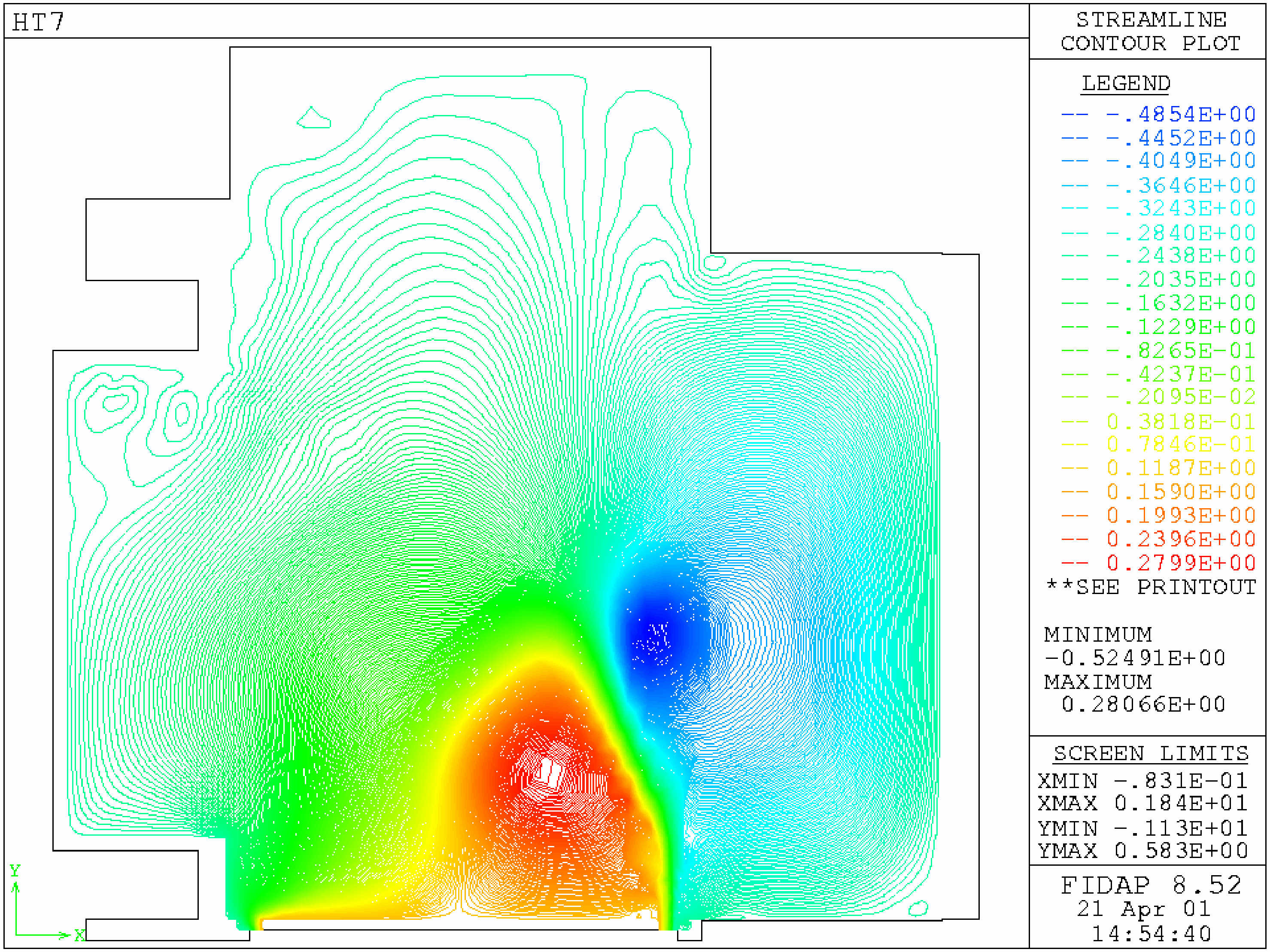
Table 2: Head and Sill Frame, Edge and Center-of-glass Property

2 FIDAP MODEL OF FOAM GARDEN WINDOW

Below is the temperature, velocity vectors and streamlines of the foam garden window.


HT7
TEMPERATURE
CONTOUR PLOT
LEGEND
-- 0.2573E+03
-- 0.2592E+03
-- 0.2612E+03
-- 0.2631E+03
-- 0.2650E+03
-- 0.2670E+03
-- 0.2689E+03
-- 0.2709E+03
-- 0.2728E+03
-- 0.2748E+03
-- 0.2767E+03
-- 0.2787E+03
-- 0.2806E+03
-- 0.2826E+03
-- 0.2845E+03
-- 0.2865E+03
-- 0.2884E+03
-- 0.2904E+03
-- 0.2923E+03
-- 0.2943E+03
**SEE PRINTOUT
MINIMUM
0.25535E+03
MAXIMUM
0.29429E+03
SCREEN LIMITS
XMIN -.831E-01
XMAX 0.184E+01
YMIN -.113E+01
YMAX 0.583E+00
FIDAP 8.52
21 Apr 01
14:54:33
Centerline
Velocity 1
Y
X


HT7
VELOCITY
VECTOR PLOT
SCALE FACTOR
0.5000E+02
REFER. VECTOR
0.3626E+02
MAX.VEC.PLOT'D
0.3626E+02
AT NODE 771
COLOR CODE:
VELOCITY
0.322E+02
0.282E+02
0.242E+02
0.201E+02
0.161E+02
0.121E+02
0.806E+01
0.403E+01
SCREEN LIMITS
XMIN -.831E-01
XMAX 0.184E+01
YMIN -.113E+01
YMAX 0.583E+00
FIDAP 8.52
21 Apr 01
14:53:49
Y
X


HT7
STREAMLINE
CONTOUR PLOT
LEGEND
-- -.4854E+00
-- -.4452E+00
-- -.4049E+00
-- -.3646E+00
-- -.3243E+00
-- -.2840E+00
-- -.2438E+00
-- -.2035E+00
-- -.1632E+00
-- -.1229E+00
-- -.8265E-01
-- -.4237E-01
-- -.2095E-02
-- 0.3818E-01
-- 0.7846E-01
-- 0.1187E+00
-- 0.1590E+00
-- 0.1993E+00
-- 0.2396E+00
-- 0.2799E+00
**SEE PRINTOUT
MINIMUM
-0.52491E+00
MAXIMUM
0.28066E+00
SCREEN LIMITS
XMIN -.831E-01
XMAX 0.184E+01
YMIN -.113E+01
YMAX 0.583E+00
FIDAP 8.52
21 Apr 01
14:54:40
Y
X

The centerline speed was plotted (refer to the temperature contour plot of the foam garden window) and is shown in Figure 10.

Figure 10: Centerline Velocity

The FIDAP slot velocity was compared to the LBNL slot velocity and is shown in Figure 11:

Figure 11: Slot Centerline Velocity

Also, the line labeled Velocity 1 (refer to the temperature contour plot of the foam garden window) was plotted from both FIDAP and LBNL data and is shown in Figure 12.

Figure 12: Slot Vertical Velocity

The surface temperature of the foam garden window on the indoor side is shown in Figure 13:

Figure 13: Surface temperature of foam garden window

The flux from FIDAP is:

Figure 14: FIDAP Total Flux