SRI-MME-90-1030-7079

SRB THERMAL CURTAIN DESIGN SUPPORT

OCTOBER 1990 INTERIM REPORT TO

U.S. POLYMERIC
B.P. CHEMICALS
SANTA ANA, CALIFORNIA 92705

PURCHASE ORDER NUMBER 62550

PRIME CONTRACT NUMBER NAS8-38261

Southern Research Institute

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October 1990 Interim Report

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U.S. POLYMERIC
B.P. CHEMICALS
Advanced Materials Division
Fibers and Materials
700 East Dyer Road
Santa Ana, California 92705

Purchase Order Number 62550

Prime Contract Number NAS8-38261

by

SOUTHERN RESEARCH INSTITUTE
2000 9th Avenue South
P.O. Box 35255
Birmingham, Alabama 35255

Prepared by

Wayne E. Lundblad
Head, Applied Thermal Section

Approved by

John R. Koenig
Research Director
Thermophysical Research Department

ERRATA: All references to E-glass should read as S-2 glass.

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INTRODUCTION

This is an interim report for the work performed under purchase order number 62550, NASA prime contract NAS8-38261, "SRB Thermal Curtain Redesign Support". This report covers the period from 1 April to 31 October 1990.

Two topics are covered in this report. They are:

1] Preliminary thermophysical properties estimations.

2] Computer-aided thermal analysis.

OBJECTIVE

The objective during this time period was to perform a preliminary thermal analysis using some measured and estimated thermal properties on the angle-interlock materials. This preliminary thermal analysis is to serve as a guide for identifying any potential problems in blanket construction and identifying future tests.

1] Preliminary Thermophysical Properties Estimations

Three materials were received for thermophysical properties measurements. They were:

1] Angle-interlock Quartz

2] Angle-interlock E-glass

3] Angle-interlock Kevlar

Densities were evaluated for each material. Table 1 lists the densities, material thicknesses and maximum use temperatures.

Thermal conductivity and specific heat were to be measured on each material. The temperature ranges of interest were as follows:

Quartz	70 °F to 2500 °F
E-glass	70 °F to 1800 °F
Kevlar	70 °F to 600 °F

Preliminary low temperature data (less than 1000 °F) were obtained on all three materials. These low temperature data were then extrapolated with a best "engineering estimate" of the high temperature behavior. Figures 1 through 6 depict these estimated thermal properties for the angle-interlock woven materials. The conductivity curves are non-conservative estimates since potential radiation transport is neglected. Specific heat estimates are based on data obtained at SRI on similar materials. These estimated properties were used in the preliminary thermal analysis presented in Section 2 of this report. The actual data, both low and high temperature, will be reported at a later time.

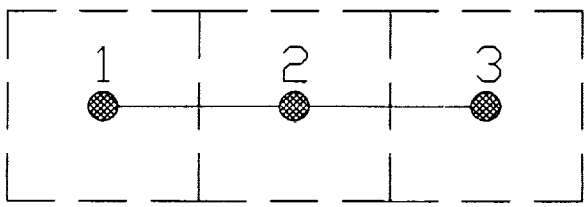
All the curves were fitted by polynomials for input into the computer data base. Table 2 lists the curve fits. The preliminary thermal evaluations indicated that a low conductivity filler material may be required. Fiberfrax was selected. Its estimated properties are also given in Table 2. It should be noted that should a low conductivity filler material be required its thermal properties will have to be measured.

2] Computer-Aided Thermal Analysis

A finite element computer program was developed to aid in the preliminary thermal analysis and redesign of the SRB Thermal curtain.

An implicit, forward-differencing technique was used with the nodal spacing taken at the interface of each blanket layer. Figure 7 shows the nodal configuration for a blanket comprised of angle interlock quartz, fiberfrax, angle interlock E-glass, fiberfrax and angle interlock Kevlar. The thicknesses of all the layers is the same and taken to be an average of 0.250 inches. The computer program is versatile in that the user may select the combination of materials and thicknesses, although all thicknesses must be the same. The program can be modified to handle different thicknesses. The thermal properties for each material are stored in a data file that is accessed by the computer. Thermal conductivity and specific heat, as functions of temperature, are stored in these files. Density is taken to be a constant and is also stored in a file. These files are easily changed to accommodate different materials.

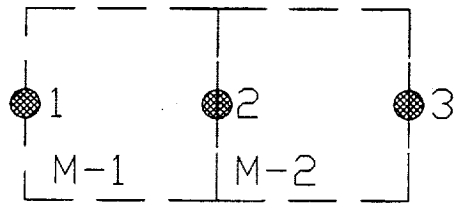
The implicit technique involves evaluating an energy balance on a node. Consider a small section of a large plate. The section is divided into three nodes as shown below:



An energy balance has the heat flow from 1→2 minus the heat flow from 2→3 equal to the amount of heat stored in node 2. That is:

$$q_{1\to 2} - q_{2\to 3} = \rho v c \frac{\partial T}{\partial t}$$

It is necessary to write an energy balance for a composite material. To do this the nodes are selected such that a node lies on an interface:



Here node 2 lies at the interface of materials 1 and 2. Since node 2 is actually made up of two materials the energy storage term is adjusted to reflect an average value:

$$q_{1\to 2} - q_{2\to 3} = \frac{\rho_1 v_1 c_1 + \rho_2 v_2 c_2}{2} \frac{\partial T}{\partial t}$$

Table 3 depicts the implicit equations for the exterior and interior nodes of the blanket configuration in Figure 7. These equations are then put into matrix form (Table 4), with the coefficients of the matrix given in Table 5. Node 6 is fixed at 70 °F, a necessary boundary condition. Later on in the program this node will be modified to include radiation and convection effects from the surface. Matrix coefficients are recalculated at every iteration to reflect the changing thermal properties. Gaussian elimination is used to solve for the temperatures. Heat flux is varied as a function of time. The heat flux curve was obtained from NASA SRB thermal design data (Figure 8).

Although Tables 3 through 5 reflect only a five node system the matrix can be expanded if a larger layer system is selected.

SUMMARY

The computer has coded the materials as follows:

Code Letter	Material
A	Kevlar
B	E-glass
C	Quartz
D	Fiberfrax

Consider a thermal blanket design of:

C - D - B - D - A

Figure 9 shows the temperature-time response of this blanket, subjected to the design flux for 120 seconds. As can be seen the temperature of the first node (surface of quartz) is at about 2700 °F after 120 seconds. This is above the recommended use temperature which should be less than 2500 °F.

Figure 10 is a C-B-A combination. Although the quartz temperature is low the Kevlar temperature is high (about 400 °F). This may still be a viable combination since interfacial resistances, which are not included in the analysis, will reduce the Kevlar temperature.

A combination of C-B-D-A is shown in Figure 11. This looks like it may work well. The fiberfrax insulation helps to keep the operating temperature of the Kevlar below 500 °F. The quartz temperature is within it's operating range.

The low temperature thermal data, and estimated high temperature data, indicate that a viable combination of layers is possible for the SRB blanket. It is recommended that the two blanket configurations:

C - B - A

and

C - B - D - A

be evaluated for effective thermal conductivity. Thermal response testing should also be performed on these two designs. However, the low conductivity filler (fiberfrax) was arbitrarily selected. More thought needs to go into this selection before further testing.

Appendices A, B and C are the output files for the blanket configurations analyzed above. Appendix D lists the source code and subroutines used in the thermal analysis. Appendix E contains instructions for operating the computer code.

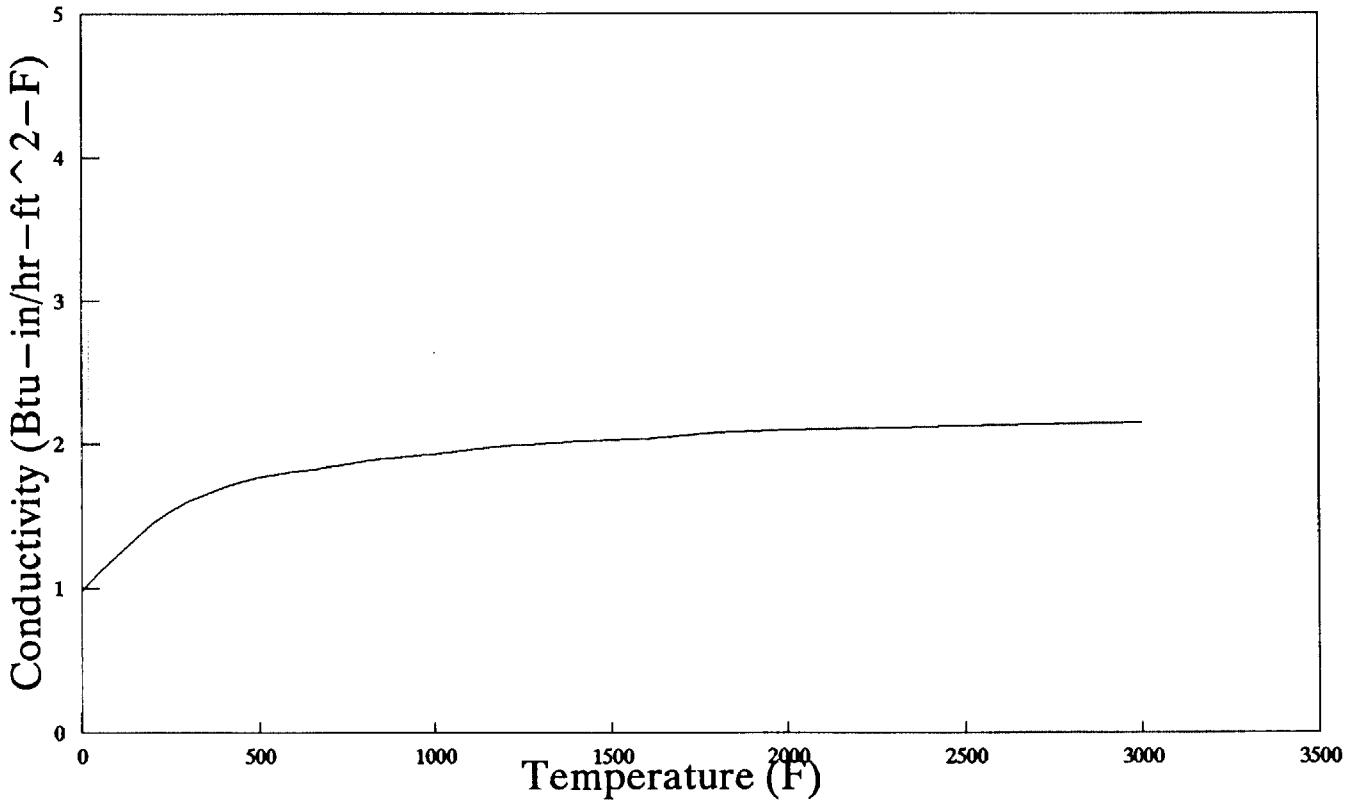


Figure 1. Estimated Conductivity of Angle-Interlock Quartz

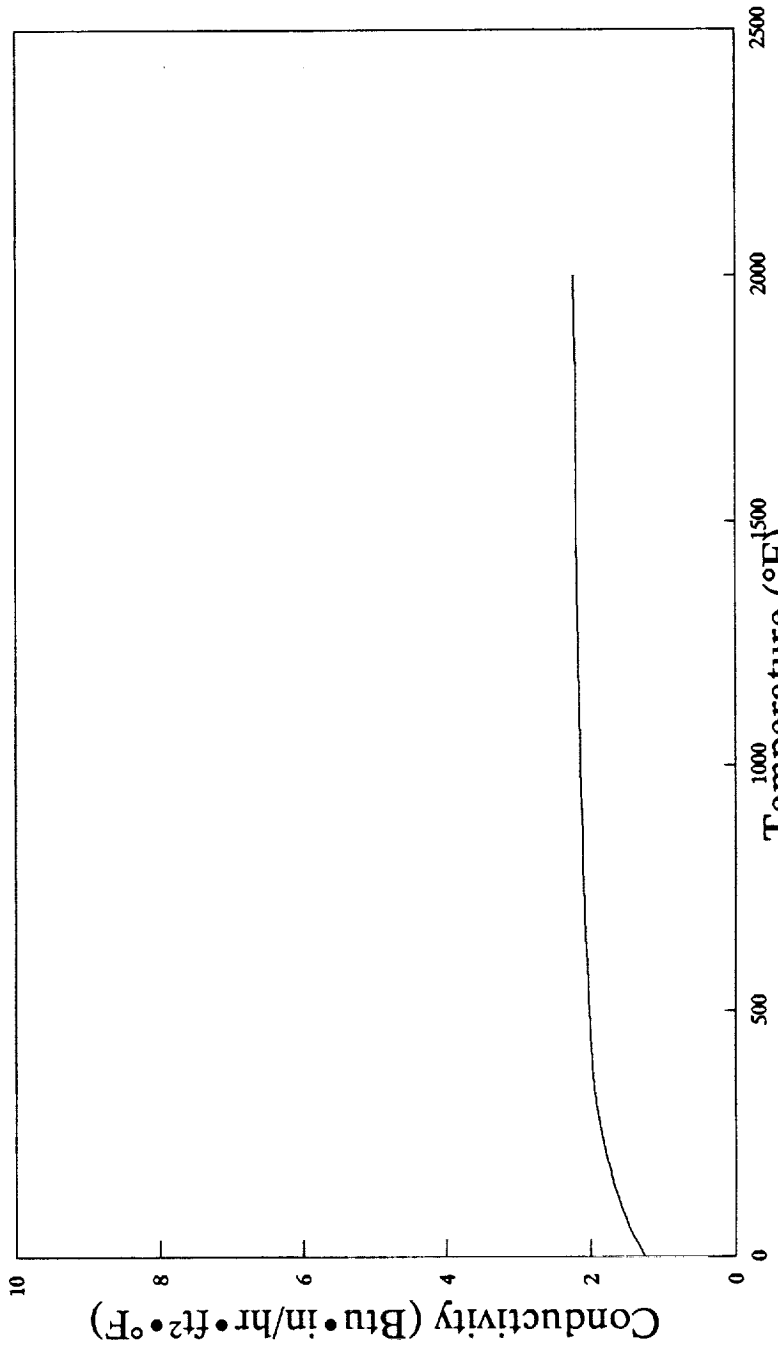


Figure 2. Estimated Conductivity of Angle-Interlock E-glass

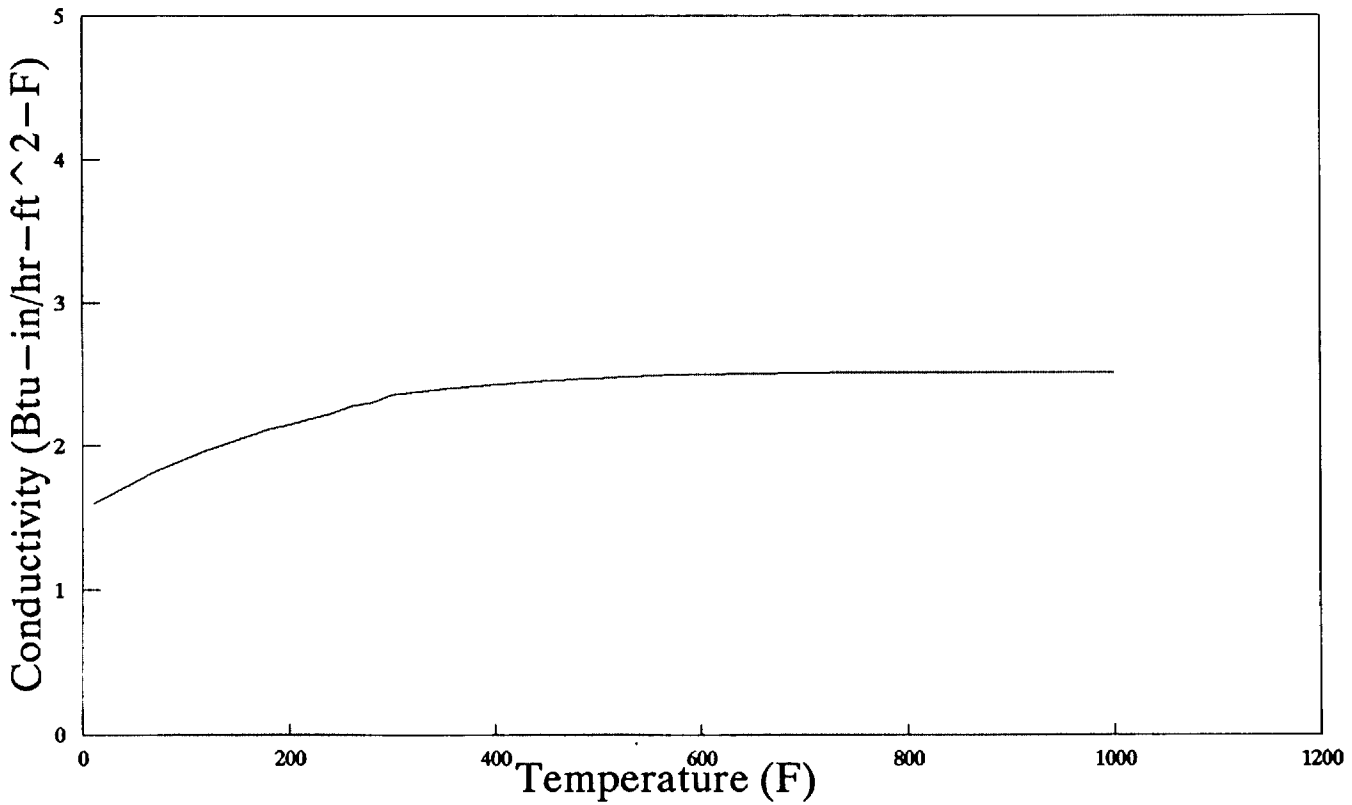


Figure 3. Estimated Conductivity of Angle-Interlock Kevlar

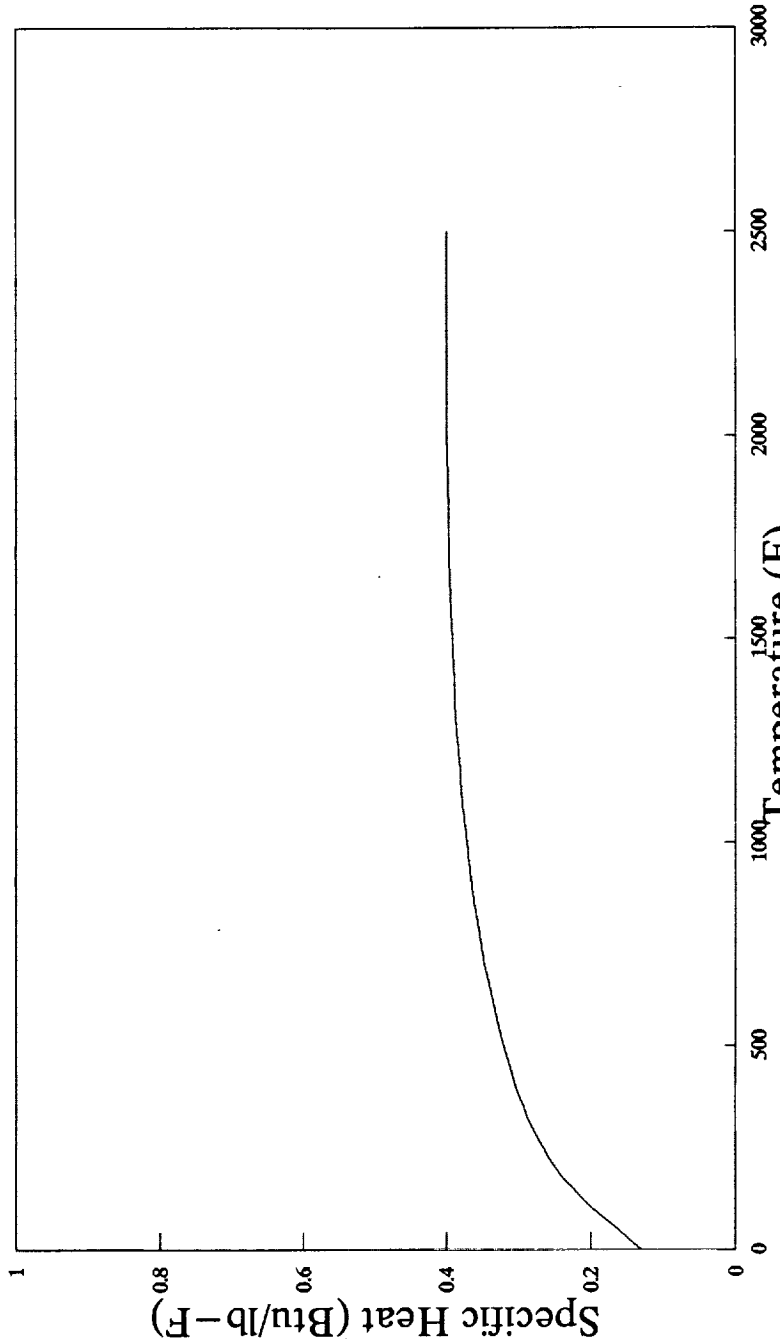


Figure 4. Estimated Specific Heat of Angle-Interlock Quartz

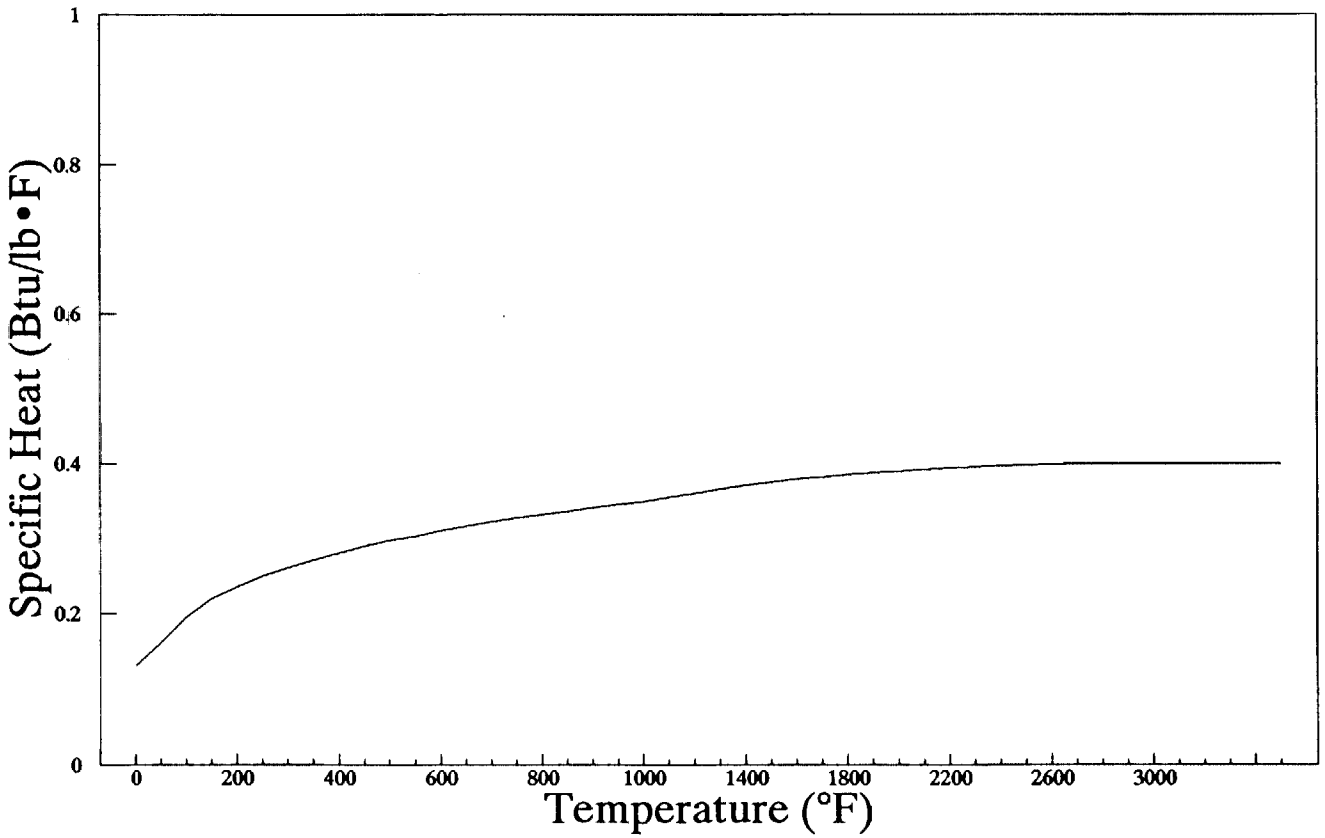


Figure 5. Estimated Specific Heat of Angle-Interlock E-glass

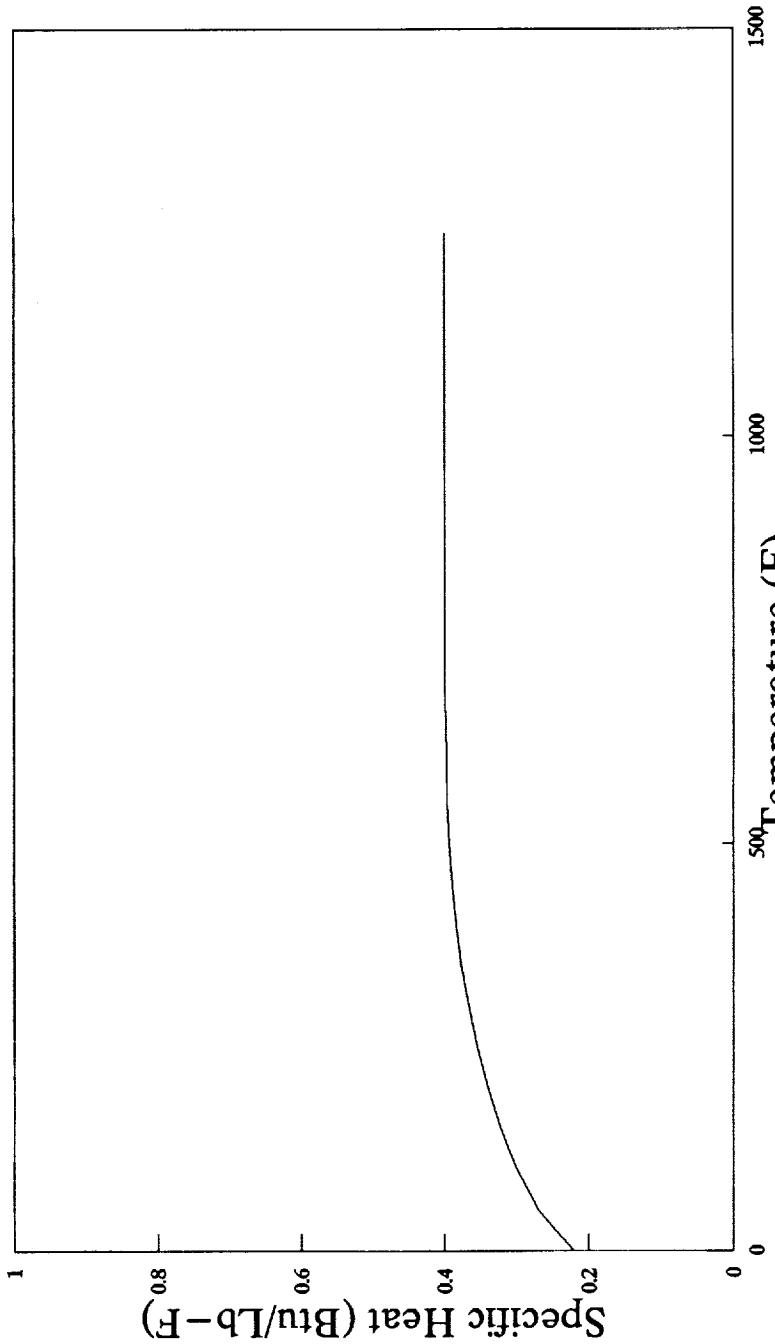


Figure 6. Estimated Specific Heat of Angle-Interlock Kevlar

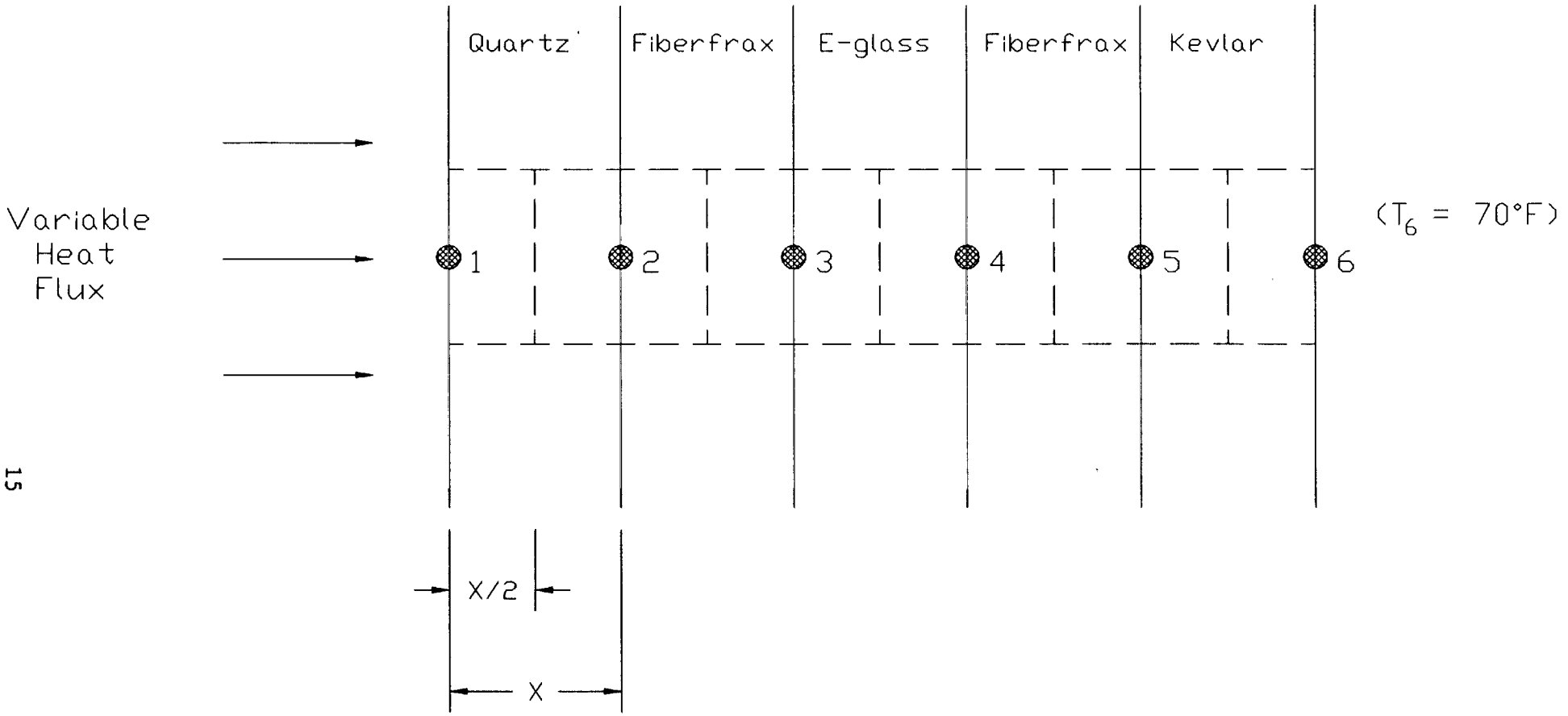


Figure 7. Nodal Configuration

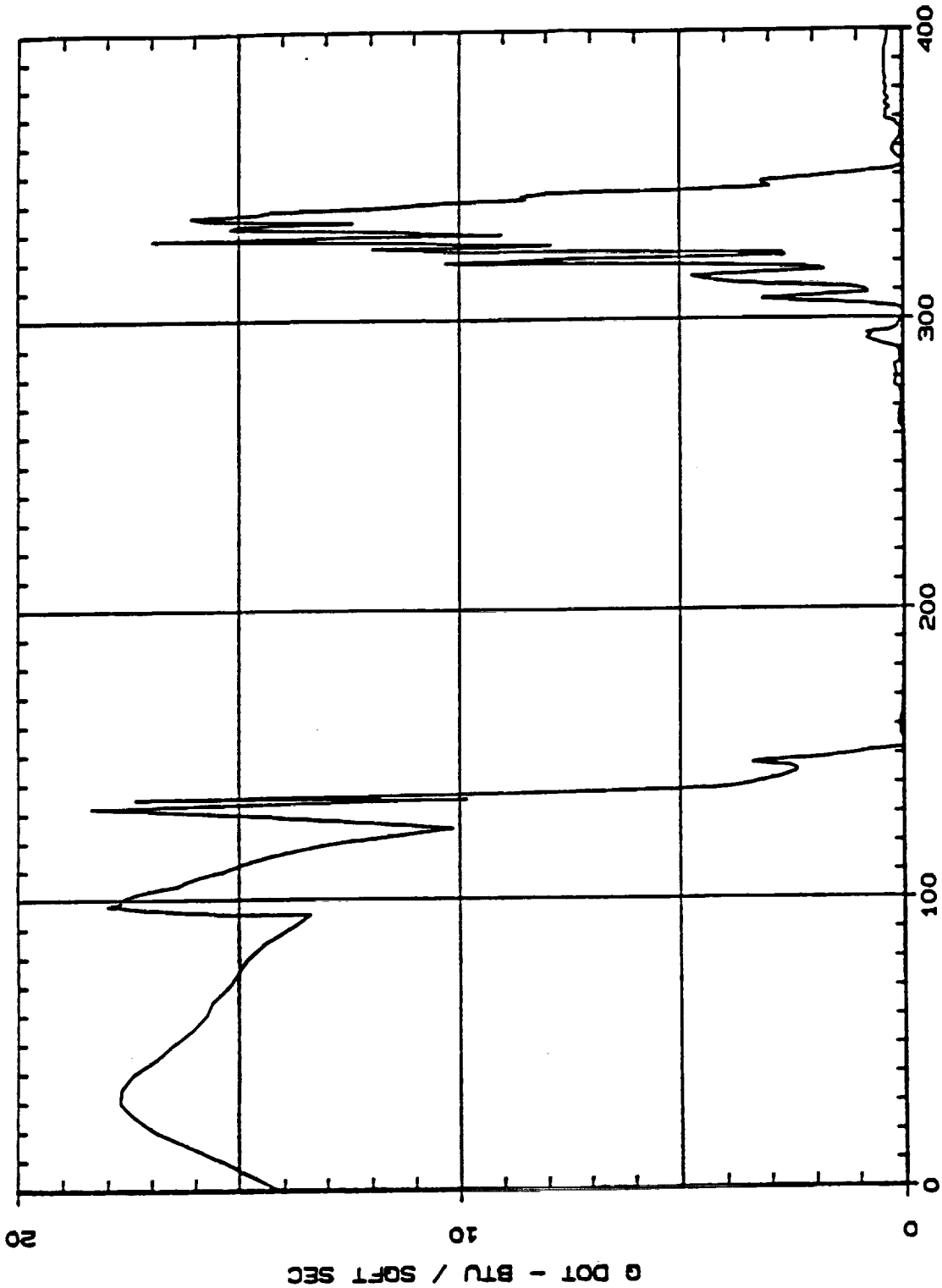


Figure 8. Heat Flux Input as a Function of Time

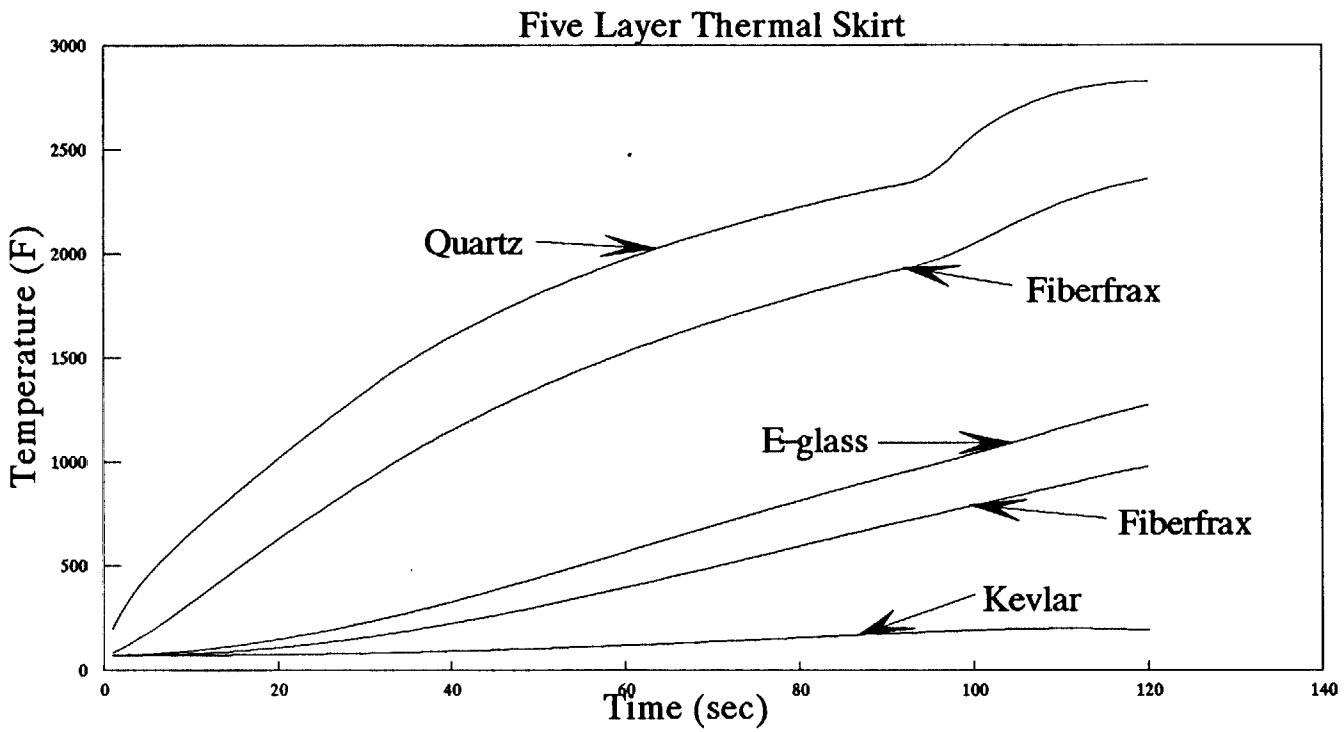


Figure 9. Thermal Response of Blanket Configuration C-D-B-D-A

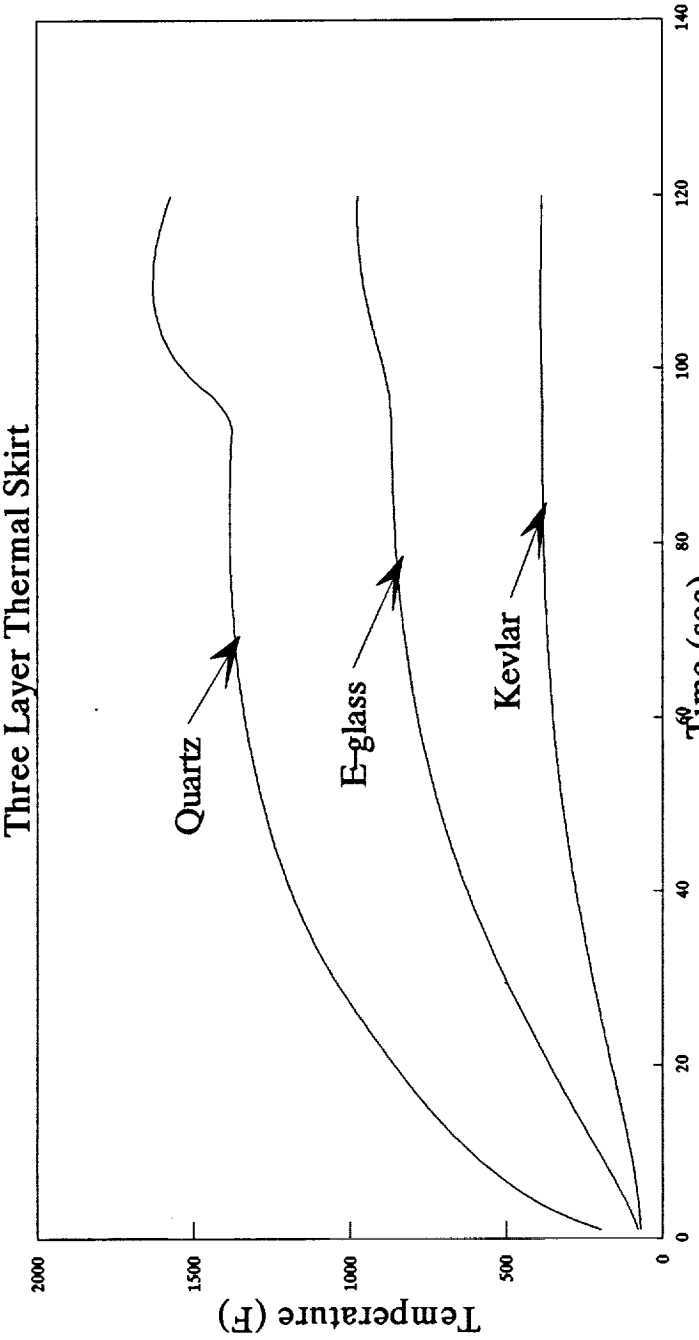


Figure 10. Thermal Response of Blanket Configuration C-B-A

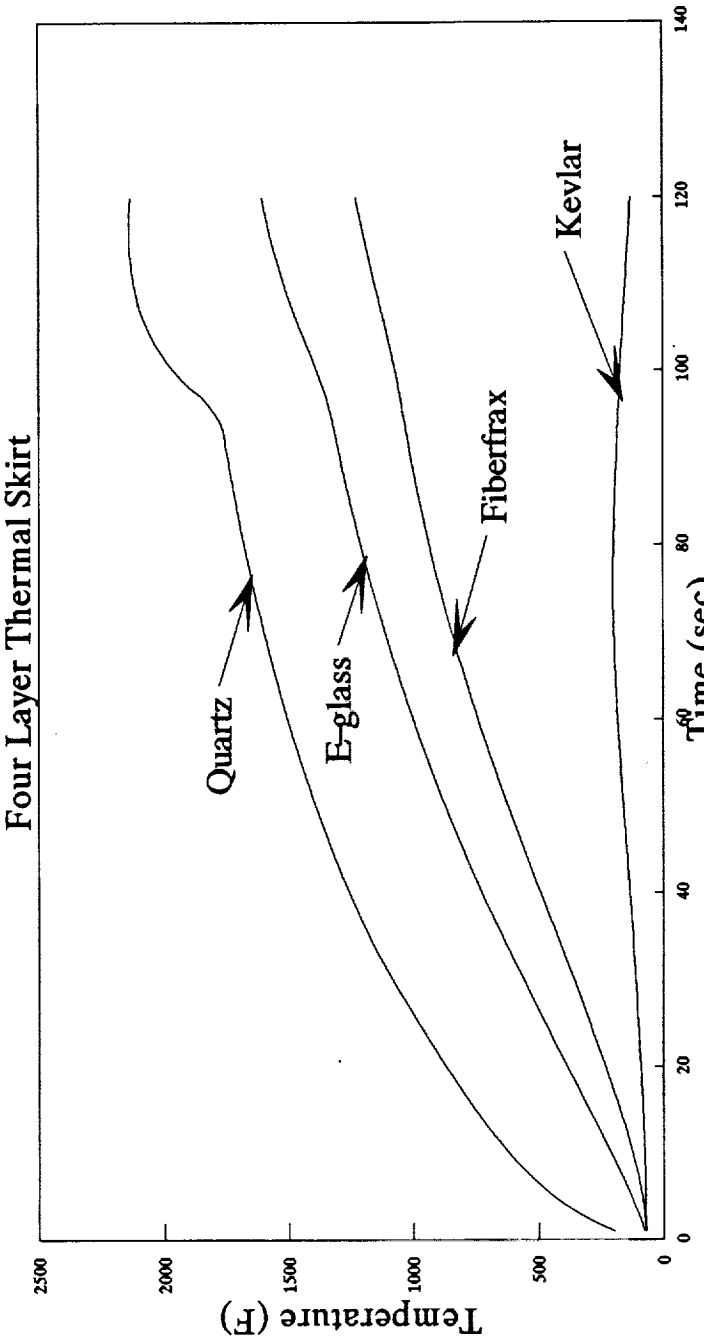


Figure 11. Thermal Response of Blanket Configuration C-B-D-A

Table 1

Material Thicknesses and Densities

Material	Density	Thickness	Maximum Use Short Time Temperature
Quartz	53.88 lb/ft^3	0.248 in.	2700 °F
E-glass	62.90 lb/ft^3	0.236 in.	1700 °F
Kevlar	37.41 lb/ft^3	0.221 in.	600 °F

Table 2

Estimated Thermophysical Properties in Polynomial Form

Quartz

$$K = 0.96668 + 3.2353E\text{-}3T - 4.9604E\text{-}6T^2 + 4.2154E\text{-}9T^3 - 1.9331E\text{-}12T^4 + 4.485E\text{-}16T^5 - 4.1285E\text{-}20T^6$$

$$C_p = 0.12914 + 7.9542E\text{-}4T - 1.3367E\text{-}6T^2 + 1.263E\text{-}9T^3 - 6.7072E\text{-}13T^4 + 1.9852E\text{-}16T^5 - 3.0384E\text{-}20T^6 + 1.8532E\text{-}24T^7$$

E-glass

$$K = 1.2292 + 4.0169E\text{-}3T - 8.5928E\text{-}6T^2 + 1.0037E\text{-}8T^3 - 6.3611E\text{-}12T^4 + 2.0532E\text{-}15T^5 - 2.641E\text{-}19T^6$$

$$C_p = 0.13348 + 6.8486E\text{-}4T - 8.6683E\text{-}7T^2 + 6.1745E\text{-}10T^3 - 2.2943E\text{-}13T^4 + 3.4227E\text{-}17T^5$$

Kevlar

$$K = 1.5544 + 4.2148E\text{-}3T - 6.7157E\text{-}6T^2 + 4.229E\text{-}9T^3 - 1.0567E\text{-}12T^4$$

$$C_p = 0.2815 + 9.5004E\text{-}4T - 3.909E\text{-}6T^2 + 8.8455E\text{-}9T^3 - 1.0357E\text{-}11T^4 + 4.879E\text{-}15T^5$$

Fiberfrax

$$K = 0.417 + 1.519E\text{-}4T$$

$$C_p = 0.15651 + 3.609E\text{-}4T - 4.5935E\text{-}7T^2 + 3.2081E\text{-}10T^3 - 1.1115E\text{-}13T^4 + 1.4762E\text{-}17T^5$$

Table 3

Nodal Equations

Node 1 (given Q) $$\left[1 + \frac{2K_1\Delta t}{\rho_1 C_1 \Delta X^2}\right] T_1^1 - \frac{2K_1\Delta t}{\rho_1 C_1 \Delta X^2} T_2^1 = \frac{2Q\Delta t}{\rho_1 C_1 \Delta X} + T_1$$

Node 2 (Composite) $$\frac{K_1}{\Delta X}\left[T_1^1 - T_2^1\right] + \frac{K_2}{\Delta X}\left[T_3^1 - T_2^1\right] = \left[\frac{\rho_1 C_1 + \rho_2 C_2}{2}\right] \frac{\Delta X}{\Delta t}\left[T_2^1 - T_2\right]$$

Node 3 $$\frac{K_2}{\Delta X}\left[T_2^1 - T_3^1\right] + \frac{K_3}{\Delta X}\left[T_4^1 - T_3^1\right] = \left[\frac{\rho_2 C_2 + \rho_3 C_3}{2}\right] \frac{\Delta X}{\Delta t}\left[T_3^1 - T_3\right]$$

Node 4 $$\frac{K_3}{\Delta X}\left[T_3^1 - T_4^1\right] + \frac{K_4}{\Delta X}\left[T_5^1 - T_4^1\right] = \left[\frac{\rho_3 C_3 + \rho_4 C_4}{2}\right] \frac{\Delta X}{\Delta t}\left[T_4^1 - T_4\right]$$

Node 5 $$\frac{K_4}{\Delta X}\left[T_4^1 - T_5^1\right] + \frac{K_5}{\Delta X}\left[T_6^1 - T_5^1\right] = \left[\frac{\rho_4 C_4 + \rho_5 C_5}{2}\right] \frac{\Delta X}{\Delta t}\left[T_5^1 - T_5\right]$$

Node 6 Fix at some T_6

Table 4

Matrix Form of Nodal Equations

Node 1

$$\left[1 + \frac{2K_1\Delta t}{\rho_1 C_1 \Delta X^2}\right] T_1^{\,1} - \left[\frac{2K_1\Delta t}{\rho_1 C_1 \Delta X^2}\right] T_2^{\,1} = \left[\frac{2Q\Delta t}{\rho_1 C_1 \Delta X}\right] + T_1$$

Node 2

$$-\left[\frac{2K_1\Delta t}{(\rho_1 C_1+\rho_2 C_2)\Delta X^2}\right] T_1^{\,1} + \left[\frac{2\Delta t}{(\rho_1 C_1+\rho_2 C_2)\Delta X}\right]\left[\frac{K_1+K_2}{\Delta X} + \frac{(\rho_1 C_1+\rho_2 C_2)\Delta X}{2\Delta t}\right] T_2^{\,1} - \left[\frac{2K_2\Delta t}{(\rho_1 C_1+\rho_2 C_2)\Delta X^2}\right] T_3^{\,1} = T_2$$

Node 3

$$-\left[\frac{2K_2\Delta t}{(\rho_2 C_2+\rho_3 C_3)\Delta X^2}\right] T_2^{\,1} + \left[\frac{2\Delta t}{(\rho_2 C_2+\rho_3 C_3)\Delta X}\right]\left[\frac{K_2+K_3}{\Delta X} + \frac{(\rho_2 C_2+\rho_3 C_3)\Delta X}{2\Delta t}\right] T_3^{\,1} - \left[\frac{2K_3\Delta t}{(\rho_2 C_2+\rho_3 C_3)\Delta X^2}\right] T_4^{\,1} = T_3$$

Node 4

$$-\left[\frac{2K_3\Delta t}{(\rho_3 C_3+\rho_4 C_4)\Delta X^2}\right] T_3^{\,1} + \left[\frac{2\Delta t}{(\rho_3 C_3+\rho_4 C_4)\Delta X}\right]\left[\frac{K_3+K_4}{\Delta X} + \frac{(\rho_3 C_3+\rho_4 C_4)\Delta X}{2\Delta t}\right] T_4^{\,1} - \left[\frac{2K_4\Delta t}{(\rho_3 C_3+\rho_4 C_4)\Delta X^2}\right] T_5^{\,1} = T_4$$

Node 5

$$-\left[\frac{2K_4\Delta t}{(\rho_4 C_4+\rho_5 C_5)\Delta X^2}\right] T_4^{\,1} + \left[\frac{2\Delta t}{(\rho_4 C_4+\rho_5 C_5)\Delta X}\right]\left[\frac{K_4+K_5}{\Delta X} + \frac{(\rho_4 C_4+\rho_5 C_5)\Delta X}{2\Delta t}\right] T_5^{\,1} = \left[\frac{2K_5\Delta t}{(\rho_4 C_4+\rho_5 C_5)\Delta X^2}\right] T_6^{\,1} + T_5$$

Table 5

Matrix Coefficients

$$A_{11} = [1 + 2K_1\Delta T/\rho_1 C_1 \Delta X^2]$$

$$A_{12} = -[2K_1\Delta t/\rho_1 C_1 \Delta X^2]$$

$$A_{21} = -[2K_1\Delta t/(\rho_1 C_1+\rho_2 C_2)\Delta X^2]$$

$$A_{22} = [(2\Delta t/(\rho_1 C_1+\rho_2 C_2)\Delta X)\ (K_1+K_2/\Delta X + (\rho_1 C_1+\rho_2 C_2)\Delta X/2\Delta t)]$$

$$A_{23} = -[2K_2\Delta t/(\rho_1 C_1+\rho_2 C_2)\Delta X^2]$$

$$A_{32} = -[2K_2\Delta t/(\rho_2 C_2+\rho_3 C_3)\Delta X^2]$$

$$A_{33} = [(2\Delta t/(\rho_2 C_2+\rho_3 C_3)\Delta X)\ (K_2+K_3/\Delta X + (\rho_2 C_2+\rho_3 C_3)\Delta X/2\Delta t)]$$

$$A_{34} = -[2K_3\Delta t/(\rho_2 C_2+\rho_3 C_3)\Delta X^2]$$

$$A_{43} = -[2K_3\Delta t/(\rho_3 C_3+\rho_4 C_4)\Delta X^2]$$

$$A_{44} = [(2\Delta t/(\rho_3 C_3+\rho_4 C_4)\Delta X)\ (K_3+K_4/\Delta X + (\rho_3 C_3+\rho_4 C_4)\Delta X/2\Delta t)]$$

$$A_{45} = -[2K_4\Delta t/(\rho_3 C_3+\rho_4 C_4)\Delta X^2]$$

$$A_{54} = -[2K_4\Delta t/(\rho_4 C_4+\rho_5 C_5)\Delta X^2]$$

$$A_{55} = [(2\Delta t/(\rho_4 C_4+\rho_5 C_5)\Delta X)\ (K_4+K_5/\Delta X + (\rho_4 C_4+\rho_5 C_5)\Delta X/2\Delta t)]$$

$$Z = 2Q\Delta t/\rho_1 C_1 \Delta X$$

$$W = [2K_5\Delta t/(\rho_4 C_4+\rho_5 C_5)\Delta X^2]\ T_6$$

LIST OF APPENDICES

APPENDIX A

DATA FOR FIVE LAYER BLANKET

RESULTS OF HEAT TRANSFER ANALYSIS FOR A THERMAL BLANKET
CONSISTING OF 5 LAYERS OF THE FOLLOWING COMPOSITIONS:

Layer 1 is Quartz
Layer 2 is Fiberfrax
Layer 3 is E-glass
Layer 4 is Fiberfrax
Layer 5 is Kevlar

where layer 1 is the high-temperature side.

AT t = 1.0 SECONDS

T 1 = 192.7903 Degrees F
T 2 = 83.4797 Degrees F
T 3 = 70.4936 Degrees F
T 4 = 70.0343 Degrees F
T 5 = 70.0013 Degrees F
T 6 = 70.0000 Degrees F

AT t = 2.0 SECONDS

T 1 = 274.2036 Degrees F
T 2 = 102.0491 Degrees F
T 3 = 71.4662 Degrees F
T 4 = 70.1786 Degrees F
T 5 = 70.0075 Degrees F
T 6 = 70.0000 Degrees F

AT t = 3.0 SECONDS

T 1 = 340.4485 Degrees F
T 2 = 124.3413 Degrees F
T 3 = 72.9156 Degrees F
T 4 = 70.4715 Degrees F
T 5 = 70.0228 Degrees F
T 6 = 70.0000 Degrees F

AT t = 4.0 SECONDS

T 1 = 397.8817 Degrees F
T 2 = 149.2825 Degrees F
T 3 = 74.8109 Degrees F

T 4 = 70.9422 Degrees F
T 5 = 70.0514 Degrees F
T 6 = 70.0000 Degrees F

AT t = 5.0 SECONDS

T 1 = 449.4568 Degrees F
T 2 = 176.1331 Degrees F
T 3 = 77.1139 Degrees F
T 4 = 71.6109 Degrees F
T 5 = 70.0976 Degrees F
T 6 = 70.0000 Degrees F

AT t = 6.0 SECONDS

T 1 = 496.8718 Degrees F
T 2 = 204.3625 Degrees F
T 3 = 79.7890 Degrees F
T 4 = 72.4908 Degrees F
T 5 = 70.1649 Degrees F
T 6 = 70.0000 Degrees F

AT t = 7.0 SECONDS

T 1 = 541.2167 Degrees F
T 2 = 233.5767 Degrees F
T 3 = 82.8065 Degrees F
T 4 = 73.5898 Degrees F
T 5 = 70.2567 Degrees F
T 6 = 70.0000 Degrees F

AT t = 8.0 SECONDS

T 1 = 583.2394 Degrees F
T 2 = 263.4767 Degrees F
T 3 = 86.1429 Degrees F
T 4 = 74.9116 Degrees F
T 5 = 70.3756 Degrees F
T 6 = 70.0000 Degrees F

AT t = 9.0 SECONDS

T 1 = 623.4745 Degrees F
T 2 = 293.8326 Degrees F
T 3 = 89.7802 Degrees F
T 4 = 76.4574 Degrees F

T 5 = 70.5238 Degrees F
T 6 = 70.0000 Degrees F

AT t = 10.0 SECONDS

T 1 = 662.3146 Degrees F
T 2 = 324.4656 Degrees F
T 3 = 93.7052 Degrees F
T 4 = 78.2266 Degrees F
T 5 = 70.7029 Degrees F
T 6 = 70.0000 Degrees F

AT t = 11.0 SECONDS

T 1 = 700.0527 Degrees F
T 2 = 355.2367 Degrees F
T 3 = 97.9082 Degrees F
T 4 = 80.2175 Degrees F
T 5 = 70.9143 Degrees F
T 6 = 70.0000 Degrees F

AT t = 12.0 SECONDS

T 1 = 736.9099 Degrees F
T 2 = 386.0377 Degrees F
T 3 = 102.3821 Degrees F
T 4 = 82.4277 Degrees F
T 5 = 71.1587 Degrees F
T 6 = 70.0000 Degrees F

AT t = 13.0 SECONDS

T 1 = 773.0540 Degrees F
T 2 = 416.7847 Degrees F
T 3 = 107.1219 Degrees F
T 4 = 84.8546 Degrees F
T 5 = 71.4368 Degrees F
T 6 = 70.0000 Degrees F

AT t = 14.0 SECONDS

T 1 = 808.6122 Degrees F
T 2 = 447.4131 Degrees F
T 3 = 112.1236 Degrees F
T 4 = 87.4952 Degrees F
T 5 = 71.7489 Degrees F

T 6 = 70.0000 Degrees F

AT t = 15.0 SECONDS

T 1 = 843.6813 Degrees F
T 2 = 477.8732 Degrees F
T 3 = 117.3847 Degrees F
T 4 = 90.3469 Degrees F
T 5 = 72.0952 Degrees F
T 6 = 70.0000 Degrees F

AT t = 16.0 SECONDS

T 1 = 878.3339 Degrees F
T 2 = 508.1279 Degrees F
T 3 = 122.9027 Degrees F
T 4 = 93.4069 Degrees F
T 5 = 72.4755 Degrees F
T 6 = 70.0000 Degrees F

AT t = 17.0 SECONDS

T 1 = 912.6245 Degrees F
T 2 = 538.1499 Degrees F
T 3 = 128.6760 Degrees F
T 4 = 96.6724 Degrees F
T 5 = 72.8899 Degrees F
T 6 = 70.0000 Degrees F

AT t = 18.0 SECONDS

T 1 = 946.5933 Degrees F
T 2 = 567.9194 Degrees F
T 3 = 134.7029 Degrees F
T 4 = 100.1412 Degrees F
T 5 = 73.3381 Degrees F
T 6 = 70.0000 Degrees F

AT t = 19.0 SECONDS

T 1 = 980.2697 Degrees F
T 2 = 597.4231 Degrees F
T 3 = 140.9819 Degrees F
T 4 = 103.8107 Degrees F
T 5 = 73.8197 Degrees F
T 6 = 70.0000 Degrees F

AT t = 20.0 SECONDS

T 1 =	1013.6750	Degrees F
T 2 =	626.6526	Degrees F
T 3 =	147.5115	Degrees F
T 4 =	107.6786	Degrees F
T 5 =	74.3346	Degrees F
T 6 =	70.0000	Degrees F

AT t = 21.0 SECONDS

T 1 =	1046.8230	Degrees F
T 2 =	655.6035	Degrees F
T 3 =	154.2903	Degrees F
T 4 =	111.7429	Degrees F
T 5 =	74.8823	Degrees F
T 6 =	70.0000	Degrees F

AT t = 22.0 SECONDS

T 1 =	1079.7250	Degrees F
T 2 =	684.2745	Degrees F
T 3 =	161.3167	Degrees F
T 4 =	116.0013	Degrees F
T 5 =	75.4626	Degrees F
T 6 =	70.0000	Degrees F

AT t = 23.0 SECONDS

T 1 =	1112.3880	Degrees F
T 2 =	712.6672	Degrees F
T 3 =	168.5890	Degrees F
T 4 =	120.4519	Degrees F
T 5 =	76.0751	Degrees F
T 6 =	70.0000	Degrees F

AT t = 24.0 SECONDS

T 1 =	1144.8150	Degrees F
T 2 =	740.7848	Degrees F
T 3 =	176.1055	Degrees F
T 4 =	125.0927	Degrees F
T 5 =	76.7195	Degrees F
T 6 =	70.0000	Degrees F

AT t = 25.0 SECONDS

T	1 =	1177.0090	Degrees F
T	2 =	768.6323	Degrees F
T	3 =	183.8645	Degrees F
T	4 =	129.9216	Degrees F
T	5 =	77.3955	Degrees F
T	6 =	70.0000	Degrees F

AT t = 26.0 SECONDS

T	1 =	1208.9730	Degrees F
T	2 =	796.2161	Degrees F
T	3 =	191.8639	Degrees F
T	4 =	134.9369	Degrees F
T	5 =	78.1028	Degrees F
T	6 =	70.0000	Degrees F

AT t = 27.0 SECONDS

T	1 =	1240.7070	Degrees F
T	2 =	823.5433	Degrees F
T	3 =	200.1018	Degrees F
T	4 =	140.1366	Degrees F
T	5 =	78.8413	Degrees F
T	6 =	70.0000	Degrees F

AT t = 28.0 SECONDS

T	1 =	1272.2130	Degrees F
T	2 =	850.6221	Degrees F
T	3 =	208.5762	Degrees F
T	4 =	145.5188	Degrees F
T	5 =	79.6106	Degrees F
T	6 =	70.0000	Degrees F

AT t = 29.0 SECONDS

T	1 =	1303.4930	Degrees F
T	2 =	877.4612	Degrees F
T	3 =	217.2848	Degrees F
T	4 =	151.0816	Degrees F
T	5 =	80.4107	Degrees F
T	6 =	70.0000	Degrees F

AT t = 30.0 SECONDS

T	1 =	1334.6050	Degrees F
T	2 =	904.0748	Degrees F
T	3 =	226.2256	Degrees F
T	4 =	156.8233	Degrees F
T	5 =	81.2414	Degrees F
T	6 =	70.0000	Degrees F

AT t = 31.0 SECONDS

T	1 =	1364.6590	Degrees F
T	2 =	930.3901	Degrees F
T	3 =	235.3946	Degrees F
T	4 =	162.7419	Degrees F
T	5 =	82.1025	Degrees F
T	6 =	70.0000	Degrees F

AT t = 32.0 SECONDS

T	1 =	1393.7480	Degrees F
T	2 =	956.3570	Degrees F
T	3 =	244.7862	Degrees F
T	4 =	168.8349	Degrees F
T	5 =	82.9939	Degrees F
T	6 =	70.0000	Degrees F

AT t = 33.0 SECONDS

T	1 =	1421.9510	Degrees F
T	2 =	981.9396	Degrees F
T	3 =	254.3938	Degrees F
T	4 =	175.1000	Degrees F
T	5 =	83.9155	Degrees F
T	6 =	70.0000	Degrees F

AT t = 34.0 SECONDS

T	1 =	1449.3310	Degrees F
T	2 =	1007.1140	Degrees F
T	3 =	264.2100	Degrees F
T	4 =	181.5341	Degrees F
T	5 =	84.8672	Degrees F
T	6 =	70.0000	Degrees F

AT t = 35.0 SECONDS

T	1 =	1475.9440	Degrees F
T	2 =	1031.8640	Degrees F
T	3 =	274.2271	Degrees F
T	4 =	188.1340	Degrees F
T	5 =	85.8488	Degrees F
T	6 =	70.0000	Degrees F

AT t = 36.0 SECONDS

T	1 =	1501.8350	Degrees F
T	2 =	1056.1810	Degrees F
T	3 =	284.4368	Degrees F
T	4 =	194.8964	Degrees F
T	5 =	86.8603	Degrees F
T	6 =	70.0000	Degrees F

AT t = 37.0 SECONDS

T	1 =	1527.0460	Degrees F
T	2 =	1080.0610	Degrees F
T	3 =	294.8309	Degrees F
T	4 =	201.8174	Degrees F
T	5 =	87.9014	Degrees F
T	6 =	70.0000	Degrees F

AT t = 38.0 SECONDS

T	1 =	1551.6110	Degrees F
T	2 =	1103.5060	Degrees F
T	3 =	305.4008	Degrees F
T	4 =	208.8933	Degrees F
T	5 =	88.9719	Degrees F
T	6 =	70.0000	Degrees F

AT t = 39.0 SECONDS

T	1 =	1575.5620	Degrees F
T	2 =	1126.5170	Degrees F
T	3 =	316.1383	Degrees F
T	4 =	216.1200	Degrees F
T	5 =	90.0716	Degrees F
T	6 =	70.0000	Degrees F

AT t = 40.0 SECONDS

T 1 = 1598.9260 Degrees F
T 2 = 1149.1000 Degrees F
T 3 = 327.0348 Degrees F
T 4 = 223.4933 Degrees F
T 5 = 91.2002 Degrees F
T 6 = 70.0000 Degrees F

AT t = 41.0 SECONDS

T 1 = 1621.7280 Degrees F
T 2 = 1171.2620 Degrees F
T 3 = 338.0821 Degrees F
T 4 = 231.0091 Degrees F
T 5 = 92.3575 Degrees F
T 6 = 70.0000 Degrees F

AT t = 42.0 SECONDS

T 1 = 1643.9920 Degrees F
T 2 = 1193.0120 Degrees F
T 3 = 349.2718 Degrees F
T 4 = 238.6632 Degrees F
T 5 = 93.5432 Degrees F
T 6 = 70.0000 Degrees F

AT t = 43.0 SECONDS

T 1 = 1665.7380 Degrees F
T 2 = 1214.3580 Degrees F
T 3 = 360.5957 Degrees F
T 4 = 246.4513 Degrees F
T 5 = 94.7568 Degrees F
T 6 = 70.0000 Degrees F

AT t = 44.0 SECONDS

T 1 = 1686.9860 Degrees F
T 2 = 1235.3100 Degrees F
T 3 = 372.0459 Degrees F
T 4 = 254.3691 Degrees F
T 5 = 95.9981 Degrees F
T 6 = 70.0000 Degrees F

AT t = 45.0 SECONDS

T 1 = 1707.7540 Degrees F
T 2 = 1255.8770 Degrees F
T 3 = 383.6143 Degrees F
T 4 = 262.4125 Degrees F
T 5 = 97.2666 Degrees F
T 6 = 70.0000 Degrees F

AT t = 46.0 SECONDS

T 1 = 1728.0600 Degrees F
T 2 = 1276.0700 Degrees F
T 3 = 395.2933 Degrees F
T 4 = 270.5772 Degrees F
T 5 = 98.5619 Degrees F
T 6 = 70.0000 Degrees F

AT t = 47.0 SECONDS

T 1 = 1747.9200 Degrees F
T 2 = 1295.8970 Degrees F
T 3 = 407.0751 Degrees F
T 4 = 278.8591 Degrees F
T 5 = 99.8837 Degrees F
T 6 = 70.0000 Degrees F

AT t = 48.0 SECONDS

T 1 = 1767.3470 Degrees F
T 2 = 1315.3700 Degrees F
T 3 = 418.9521 Degrees F
T 4 = 287.2542 Degrees F
T 5 = 101.2313 Degrees F
T 6 = 70.0000 Degrees F

AT t = 49.0 SECONDS

T 1 = 1786.3580 Degrees F
T 2 = 1334.4980 Degrees F
T 3 = 430.9171 Degrees F
T 4 = 295.7585 Degrees F
T 5 = 102.6044 Degrees F
T 6 = 70.0000 Degrees F

AT t = 50.0 SECONDS

T 1 = 1804.9650 Degrees F
T 2 = 1353.2900 Degrees F
T 3 = 442.9625 Degrees F
T 4 = 304.3679 Degrees F
T 5 = 104.0026 Degrees F
T 6 = 70.0000 Degrees F

AT t = 51.0 SECONDS

T 1 = 1823.1820 Degrees F
T 2 = 1371.7560 Degrees F
T 3 = 455.0814 Degrees F
T 4 = 313.0786 Degrees F
T 5 = 105.4252 Degrees F
T 6 = 70.0000 Degrees F

AT t = 52.0 SECONDS

T 1 = 1841.0200 Degrees F
T 2 = 1389.9050 Degrees F
T 3 = 467.2667 Degrees F
T 4 = 321.8868 Degrees F
T 5 = 106.8718 Degrees F
T 6 = 70.0000 Degrees F

AT t = 53.0 SECONDS

T 1 = 1858.4920 Degrees F
T 2 = 1407.7450 Degrees F
T 3 = 479.5115 Degrees F
T 4 = 330.7888 Degrees F
T 5 = 108.3419 Degrees F
T 6 = 70.0000 Degrees F

AT t = 54.0 SECONDS

T 1 = 1875.6090 Degrees F
T 2 = 1425.2860 Degrees F
T 3 = 491.8092 Degrees F
T 4 = 339.7809 Degrees F
T 5 = 109.8350 Degrees F
T 6 = 70.0000 Degrees F

AT t = 55.0 SECONDS

T 1 = 1892.3810 Degrees F
T 2 = 1442.5350 Degrees F
T 3 = 504.1533 Degrees F
T 4 = 348.8593 Degrees F
T 5 = 111.3506 Degrees F
T 6 = 70.0000 Degrees F

AT t = 56.0 SECONDS

T 1 = 1908.8180 Degrees F
T 2 = 1459.5000 Degrees F
T 3 = 516.5372 Degrees F
T 4 = 358.0206 Degrees F
T 5 = 112.8883 Degrees F
T 6 = 70.0000 Degrees F

AT t = 57.0 SECONDS

T 1 = 1924.9310 Degrees F
T 2 = 1476.1880 Degrees F
T 3 = 528.9547 Degrees F
T 4 = 367.2611 Degrees F
T 5 = 114.4475 Degrees F
T 6 = 70.0000 Degrees F

AT t = 58.0 SECONDS

T 1 = 1940.7290 Degrees F
T 2 = 1492.6090 Degrees F
T 3 = 541.3998 Degrees F
T 4 = 376.5774 Degrees F
T 5 = 116.0278 Degrees F
T 6 = 70.0000 Degrees F

AT t = 59.0 SECONDS

T 1 = 1956.2190 Degrees F
T 2 = 1508.7670 Degrees F
T 3 = 553.8665 Degrees F
T 4 = 385.9659 Degrees F
T 5 = 117.6287 Degrees F
T 6 = 70.0000 Degrees F

AT t = 60.0 SECONDS

T 1 = 1971.4120 Degrees F

T 2 = 1524.6700 Degrees F
T 3 = 566.3489 Degrees F
T 4 = 395.4231 Degrees F
T 5 = 119.2498 Degrees F
T 6 = 70.0000 Degrees F

AT t = 61.0 SECONDS

T 1 = 1986.3140 Degrees F
T 2 = 1540.3240 Degrees F
T 3 = 578.8417 Degrees F
T 4 = 404.9457 Degrees F
T 5 = 120.8906 Degrees F
T 6 = 70.0000 Degrees F

AT t = 62.0 SECONDS

T 1 = 2000.9340 Degrees F
T 2 = 1555.7360 Degrees F
T 3 = 591.3394 Degrees F
T 4 = 414.5301 Degrees F
T 5 = 122.5509 Degrees F
T 6 = 70.0000 Degrees F

AT t = 63.0 SECONDS

T 1 = 2015.2780 Degrees F
T 2 = 1570.9120 Degrees F
T 3 = 603.8367 Degrees F
T 4 = 424.1728 Degrees F
T 5 = 124.2300 Degrees F
T 6 = 70.0000 Degrees F

AT t = 64.0 SECONDS

T 1 = 2029.3540 Degrees F
T 2 = 1585.8570 Degrees F
T 3 = 616.3286 Degrees F
T 4 = 433.8704 Degrees F
T 5 = 125.9277 Degrees F
T 6 = 70.0000 Degrees F

AT t = 65.0 SECONDS

T 1 = 2043.1690 Degrees F
T 2 = 1600.5760 Degrees F

T 3 = 628.8103 Degrees F
T 4 = 443.6194 Degrees F
T 5 = 127.6436 Degrees F
T 6 = 70.0000 Degrees F

AT t = 66.0 SECONDS

T 1 = 2056.7290 Degrees F
T 2 = 1615.0750 Degrees F
T 3 = 641.2772 Degrees F
T 4 = 453.4163 Degrees F
T 5 = 129.3773 Degrees F
T 6 = 70.0000 Degrees F

AT t = 67.0 SECONDS

T 1 = 2070.0400 Degrees F
T 2 = 1629.3580 Degrees F
T 3 = 653.7247 Degrees F
T 4 = 463.2576 Degrees F
T 5 = 131.1285 Degrees F
T 6 = 70.0000 Degrees F

AT t = 68.0 SECONDS

T 1 = 2083.1070 Degrees F
T 2 = 1643.4300 Degrees F
T 3 = 666.1485 Degrees F
T 4 = 473.1396 Degrees F
T 5 = 132.8967 Degrees F
T 6 = 70.0000 Degrees F

AT t = 69.0 SECONDS

T 1 = 2095.9360 Degrees F
T 2 = 1657.2960 Degrees F
T 3 = 678.5446 Degrees F
T 4 = 483.0588 Degrees F
T 5 = 134.6815 Degrees F
T 6 = 70.0000 Degrees F

AT t = 70.0 SECONDS

T 1 = 2108.5330 Degrees F
T 2 = 1670.9590 Degrees F
T 3 = 690.9091 Degrees F

T 4 = 493.0116 Degrees F
T 5 = 136.4826 Degrees F
T 6 = 70.0000 Degrees F

AT t = 71.0 SECONDS

T 1 = 2120.9020 Degrees F
T 2 = 1684.4250 Degrees F
T 3 = 703.2382 Degrees F
T 4 = 502.9943 Degrees F
T 5 = 138.2994 Degrees F
T 6 = 70.0000 Degrees F

AT t = 72.0 SECONDS

T 1 = 2133.0480 Degrees F
T 2 = 1697.6960 Degrees F
T 3 = 715.5283 Degrees F
T 4 = 513.0033 Degrees F
T 5 = 140.1315 Degrees F
T 6 = 70.0000 Degrees F

AT t = 73.0 SECONDS

T 1 = 2144.9760 Degrees F
T 2 = 1710.7760 Degrees F
T 3 = 727.7759 Degrees F
T 4 = 523.0349 Degrees F
T 5 = 141.9783 Degrees F
T 6 = 70.0000 Degrees F

AT t = 74.0 SECONDS

T 1 = 2156.6910 Degrees F
T 2 = 1723.6680 Degrees F
T 3 = 739.9780 Degrees F
T 4 = 533.0852 Degrees F
T 5 = 143.8391 Degrees F
T 6 = 70.0000 Degrees F

AT t = 75.0 SECONDS

T 1 = 2168.1960 Degrees F
T 2 = 1736.3770 Degrees F
T 3 = 752.1314 Degrees F
T 4 = 543.1505 Degrees F

T 5 = 145.7132 Degrees F
T 6 = 70.0000 Degrees F

AT t = 76.0 SECONDS

T 1 = 2179.4950 Degrees F
T 2 = 1748.9040 Degrees F
T 3 = 764.2331 Degrees F
T 4 = 553.2270 Degrees F
T 5 = 147.5997 Degrees F
T 6 = 70.0000 Degrees F

AT t = 77.0 SECONDS

T 1 = 2190.5930 Degrees F
T 2 = 1761.2530 Degrees F
T 3 = 776.2805 Degrees F
T 4 = 563.3108 Degrees F
T 5 = 149.4977 Degrees F
T 6 = 70.0000 Degrees F

AT t = 78.0 SECONDS

T 1 = 2201.4910 Degrees F
T 2 = 1773.4270 Degrees F
T 3 = 788.2708 Degrees F
T 4 = 573.3980 Degrees F
T 5 = 151.4060 Degrees F
T 6 = 70.0000 Degrees F

AT t = 79.0 SECONDS

T 1 = 2212.1950 Degrees F
T 2 = 1785.4290 Degrees F
T 3 = 800.2015 Degrees F
T 4 = 583.4849 Degrees F
T 5 = 153.3233 Degrees F
T 6 = 70.0000 Degrees F

AT t = 80.0 SECONDS

T 1 = 2222.7060 Degrees F
T 2 = 1797.2600 Degrees F
T 3 = 812.0701 Degrees F
T 4 = 593.5673 Degrees F
T 5 = 155.2480 Degrees F

T 6 = 70.0000 Degrees F

AT t = 81.0 SECONDS

T 1 = 2233.0290 Degrees F
T 2 = 1808.9240 Degrees F
T 3 = 823.8745 Degrees F
T 4 = 603.6415 Degrees F
T 5 = 157.1786 Degrees F
T 6 = 70.0000 Degrees F

AT t = 82.0 SECONDS

T 1 = 2243.1670 Degrees F
T 2 = 1820.4230 Degrees F
T 3 = 835.6123 Degrees F
T 4 = 613.7034 Degrees F
T 5 = 159.1130 Degrees F
T 6 = 70.0000 Degrees F

AT t = 83.0 SECONDS

T 1 = 2253.1220 Degrees F
T 2 = 1831.7570 Degrees F
T 3 = 847.2815 Degrees F
T 4 = 623.7491 Degrees F
T 5 = 161.0490 Degrees F
T 6 = 70.0000 Degrees F

AT t = 84.0 SECONDS

T 1 = 2262.8970 Degrees F
T 2 = 1842.9310 Degrees F
T 3 = 858.8799 Degrees F
T 4 = 633.7747 Degrees F
T 5 = 162.9841 Degrees F
T 6 = 70.0000 Degrees F

AT t = 85.0 SECONDS

T 1 = 2272.4940 Degrees F
T 2 = 1853.9460 Degrees F
T 3 = 870.4057 Degrees F
T 4 = 643.7760 Degrees F
T 5 = 164.9157 Degrees F
T 6 = 70.0000 Degrees F

AT t = 86.0 SECONDS

T	1 =	2281.9170	Degrees F
T	2 =	1864.8030	Degrees F
T	3 =	881.8568	Degrees F
T	4 =	653.7490	Degrees F
T	5 =	166.8405	Degrees F
T	6 =	70.0000	Degrees F

AT t = 87.0 SECONDS

T	1 =	2291.1670	Degrees F
T	2 =	1875.5040	Degrees F
T	3 =	893.2313	Degrees F
T	4 =	663.6898	Degrees F
T	5 =	168.7552	Degrees F
T	6 =	70.0000	Degrees F

AT t = 88.0 SECONDS

T	1 =	2300.2460	Degrees F
T	2 =	1886.0520	Degrees F
T	3 =	904.5273	Degrees F
T	4 =	673.5943	Degrees F
T	5 =	170.6561	Degrees F
T	6 =	70.0000	Degrees F

AT t = 89.0 SECONDS

T	1 =	2309.1570	Degrees F
T	2 =	1896.4460	Degrees F
T	3 =	915.7432	Degrees F
T	4 =	683.4586	Degrees F
T	5 =	172.5390	Degrees F
T	6 =	70.0000	Degrees F

AT t = 90.0 SECONDS

T	1 =	2317.9030	Degrees F
T	2 =	1906.6900	Degrees F
T	3 =	926.8770	Degrees F
T	4 =	693.2785	Degrees F
T	5 =	174.3997	Degrees F
T	6 =	70.0000	Degrees F

AT t = 91.0 SECONDS

T	1 =	2326.4840	Degrees F
T	2 =	1916.7840	Degrees F
T	3 =	937.9268	Degrees F
T	4 =	703.0500	Degrees F
T	5 =	176.2333	Degrees F
T	6 =	70.0000	Degrees F

AT t = 92.0 SECONDS

T	1 =	2334.9030	Degrees F
T	2 =	1926.7310	Degrees F
T	3 =	948.8911	Degrees F
T	4 =	712.7692	Degrees F
T	5 =	178.0349	Degrees F
T	6 =	70.0000	Degrees F

AT t = 93.0 SECONDS

T	1 =	2343.0000	Degrees F
T	2 =	1936.5140	Degrees F
T	3 =	959.7673	Degrees F
T	4 =	722.4318	Degrees F
T	5 =	179.7991	Degrees F
T	6 =	70.0000	Degrees F

AT t = 94.0 SECONDS

T	1 =	2358.7110	Degrees F
T	2 =	1946.8850	Degrees F
T	3 =	970.5747	Degrees F
T	4 =	732.0360	Degrees F
T	5 =	181.5204	Degrees F
T	6 =	70.0000	Degrees F

AT t = 95.0 SECONDS

T	1 =	2381.2970	Degrees F
T	2 =	1958.4180	Degrees F
T	3 =	981.3540	Degrees F
T	4 =	741.5829	Degrees F
T	5 =	183.1933	Degrees F
T	6 =	70.0000	Degrees F

AT t = 96.0 SECONDS

T 1 =	2410.1460	Degrees F
T 2 =	1971.5540	Degrees F
T 3 =	992.1603	Degrees F
T 4 =	751.0784	Degrees F
T 5 =	184.8121	Degrees F
T 6 =	70.0000	Degrees F

AT t = 97.0 SECONDS

T 1 =	2444.7410	Degrees F
T 2 =	1986.6240	Degrees F
T 3 =	1003.0570	Degrees F
T 4 =	760.5329	Degrees F
T 5 =	186.3717	Degrees F
T 6 =	70.0000	Degrees F

AT t = 98.0 SECONDS

T 1 =	2488.6600	Degrees F
T 2 =	2004.2580	Degrees F
T 3 =	1014.1220	Degrees F
T 4 =	769.9620	Degrees F
T 5 =	187.8670	Degrees F
T 6 =	70.0000	Degrees F

AT t = 99.0 SECONDS

T 1 =	2527.9260	Degrees F
T 2 =	2023.6510	Degrees F
T 3 =	1025.4090	Degrees F
T 4 =	779.3842	Degrees F
T 5 =	189.2930	Degrees F
T 6 =	70.0000	Degrees F

AT t = 100.0 SECONDS

T 1 =	2563.1780	Degrees F
T 2 =	2044.1720	Degrees F
T 3 =	1036.9390	Degrees F
T 4 =	788.8171	Degrees F
T 5 =	190.6447	Degrees F
T 6 =	70.0000	Degrees F

AT t = 101.0 SECONDS

T 1 = 2594.9330 Degrees F
T 2 = 2065.3190 Degrees F
T 3 = 1048.7080 Degrees F
T 4 = 798.2759 Degrees F
T 5 = 191.9169 Degrees F
T 6 = 70.0000 Degrees F

AT t = 102.0 SECONDS

T 1 = 2623.6100 Degrees F
T 2 = 2086.7010 Degrees F
T 3 = 1060.6980 Degrees F
T 4 = 807.7724 Degrees F
T 5 = 193.1037 Degrees F
T 6 = 70.0000 Degrees F

AT t = 103.0 SECONDS

T 1 = 2649.5510 Degrees F
T 2 = 2108.0090 Degrees F
T 3 = 1072.8770 Degrees F
T 4 = 817.3139 Degrees F
T 5 = 194.1988 Degrees F
T 6 = 70.0000 Degrees F

AT t = 104.0 SECONDS

T 1 = 2673.0340 Degrees F
T 2 = 2129.0090 Degrees F
T 3 = 1085.2070 Degrees F
T 4 = 826.9034 Degrees F
T 5 = 195.1951 Degrees F
T 6 = 70.0000 Degrees F

AT t = 105.0 SECONDS

T 1 = 2694.2930 Degrees F
T 2 = 2149.5150 Degrees F
T 3 = 1097.6430 Degrees F
T 4 = 836.5396 Degrees F
T 5 = 196.0850 Degrees F
T 6 = 70.0000 Degrees F

AT t = 106.0 SECONDS

T 1 = 2713.5170 Degrees F
T 2 = 2169.3920 Degrees F
T 3 = 1110.1420 Degrees F
T 4 = 846.2169 Degrees F
T 5 = 196.8603 Degrees F
T 6 = 70.0000 Degrees F

AT t = 107.0 SECONDS

T 1 = 2730.8650 Degrees F
T 2 = 2188.5370 Degrees F
T 3 = 1122.6570 Degrees F
T 4 = 855.9263 Degrees F
T 5 = 197.5125 Degrees F
T 6 = 70.0000 Degrees F

AT t = 108.0 SECONDS

T 1 = 2746.4710 Degrees F
T 2 = 2206.8750 Degrees F
T 3 = 1135.1440 Degrees F
T 4 = 865.6555 Degrees F
T 5 = 198.0333 Degrees F
T 6 = 70.0000 Degrees F

AT t = 109.0 SECONDS

T 1 = 2760.4480 Degrees F
T 2 = 2224.3560 Degrees F
T 3 = 1147.5610 Degrees F
T 4 = 875.3899 Degrees F
T 5 = 198.4146 Degrees F
T 6 = 70.0000 Degrees F

AT t = 110.0 SECONDS

T 1 = 2772.8910 Degrees F
T 2 = 2240.9480 Degrees F
T 3 = 1159.8690 Degrees F
T 4 = 885.1127 Degrees F
T 5 = 198.6489 Degrees F
T 6 = 70.0000 Degrees F

AT t = 111.0 SECONDS

T 1 = 2783.8860 Degrees F
T 2 = 2256.6280 Degrees F
T 3 = 1172.0320 Degrees F
T 4 = 894.8057 Degrees F
T 5 = 198.7300 Degrees F
T 6 = 70.0000 Degrees F

AT t = 112.0 SECONDS

T 1 = 2793.5050 Degrees F
T 2 = 2271.3910 Degrees F
T 3 = 1184.0190 Degrees F
T 4 = 904.4501 Degrees F
T 5 = 198.6529 Degrees F
T 6 = 70.0000 Degrees F

AT t = 113.0 SECONDS

T 1 = 2801.8100 Degrees F
T 2 = 2285.2390 Degrees F
T 3 = 1195.8020 Degrees F
T 4 = 914.0265 Degrees F
T 5 = 198.4142 Degrees F
T 6 = 70.0000 Degrees F

AT t = 114.0 SECONDS

T 1 = 2808.8600 Degrees F
T 2 = 2298.1760 Degrees F
T 3 = 1207.3560 Degrees F
T 4 = 923.5157 Degrees F
T 5 = 198.0128 Degrees F
T 6 = 70.0000 Degrees F

AT t = 115.0 SECONDS

T 1 = 2814.7030 Degrees F
T 2 = 2310.2190 Degrees F
T 3 = 1218.6620 Degrees F
T 4 = 932.8994 Degrees F
T 5 = 197.4494 Degrees F
T 6 = 70.0000 Degrees F

AT t = 116.0 SECONDS

T 1 = 2819.3880 Degrees F
T 2 = 2321.3790 Degrees F
T 3 = 1229.7030 Degrees F
T 4 = 942.1592 Degrees F
T 5 = 196.7266 Degrees F
T 6 = 70.0000 Degrees F

AT t = 117.0 SECONDS

T 1 = 2822.9570 Degrees F
T 2 = 2331.6780 Degrees F
T 3 = 1240.4630 Degrees F
T 4 = 951.2786 Degrees F
T 5 = 195.8497 Degrees F
T 6 = 70.0000 Degrees F

AT t = 118.0 SECONDS

T 1 = 2825.4480 Degrees F
T 2 = 2341.1350 Degrees F
T 3 = 1250.9340 Degrees F
T 4 = 960.2421 Degrees F
T 5 = 194.8255 Degrees F
T 6 = 70.0000 Degrees F

AT t = 119.0 SECONDS

T 1 = 2826.8990 Degrees F
T 2 = 2349.7710 Degrees F
T 3 = 1261.1060 Degrees F
T 4 = 969.0356 Degrees F
T 5 = 193.6628 Degrees F
T 6 = 70.0000 Degrees F

AT t = 120.0 SECONDS

T 1 = 2827.3440 Degrees F
T 2 = 2357.6080 Degrees F
T 3 = 1270.9730 Degrees F
T 4 = 977.6468 Degrees F
T 5 = 192.3722 Degrees F
T 6 = 70.0000 Degrees F

APPENDIX B

DATA FOR THREE LAYER BLANKET

RESULTS OF HEAT TRANSFER ANALYSIS FOR A THERMAL BLANKET CONSISTING OF 3 LAYERS OF THE FOLLOWING COMPOSITIONS:

Layer 1 is Quartz
Layer 2 is E-glass
Layer 3 is Kevlar

where layer 1 is the high-temperature side.

AT t = 1.0 SECONDS

T 1 = 192.0011 Degrees F
T 2 = 77.6181 Degrees F
T 3 = 70.5710 Degrees F
T 4 = 70.0000 Degrees F

AT t = 2.0 SECONDS

T 1 = 271.7956 Degrees F
T 2 = 87.8398 Degrees F
T 3 = 71.7947 Degrees F
T 4 = 70.0000 Degrees F

AT t = 3.0 SECONDS

T 1 = 335.4980 Degrees F
T 2 = 99.9387 Degrees F
T 3 = 73.6954 Degrees F
T 4 = 70.0000 Degrees F

AT t = 4.0 SECONDS

T 1 = 389.4540 Degrees F
T 2 = 113.3264 Degrees F
T 3 = 76.2505 Degrees F
T 4 = 70.0000 Degrees F

AT t = 5.0 SECONDS

T 1 = 436.6357 Degrees F
T 2 = 127.6051 Degrees F
T 3 = 79.4127 Degrees F
T 4 = 70.0000 Degrees F

AT t = 6.0 SECONDS

T 1 = 478.7747 Degrees F
T 2 = 142.4984 Degrees F
T 3 = 83.1227 Degrees F
T 4 = 70.0000 Degrees F

AT t = 7.0 SECONDS

T 1 = 517.0031 Degrees F
T 2 = 157.8094 Degrees F
T 3 = 87.3174 Degrees F
T 4 = 70.0000 Degrees F

AT t = 8.0 SECONDS

T 1 = 552.1157 Degrees F
T 2 = 173.3948 Degrees F
T 3 = 91.9334 Degrees F
T 4 = 70.0000 Degrees F

AT t = 9.0 SECONDS

T 1 = 584.6975 Degrees F
T 2 = 189.1487 Degrees F
T 3 = 96.9104 Degrees F
T 4 = 70.0000 Degrees F

AT t = 10.0 SECONDS

T 1 = 615.1941 Degrees F
T 2 = 204.9919 Degrees F
T 3 = 102.1919 Degrees F
T 4 = 70.0000 Degrees F

AT t = 11.0 SECONDS

T 1 = 643.9526 Degrees F
T 2 = 220.8647 Degrees F
T 3 = 107.7264 Degrees F
T 4 = 70.0000 Degrees F

AT t = 12.0 SECONDS

T 1 = 671.2491 Degrees F
T 2 = 236.7216 Degrees F
T 3 = 113.4671 Degrees F
T 4 = 70.0000 Degrees F

AT t = 13.0 SECONDS

T 1 = 697.3057 Degrees F
T 2 = 252.5282 Degrees F
T 3 = 119.3721 Degrees F
T 4 = 70.0000 Degrees F

AT t = 14.0 SECONDS

T 1 = 722.3034 Degrees F
T 2 = 268.2577 Degrees F
T 3 = 125.4044 Degrees F
T 4 = 70.0000 Degrees F

AT t = 15.0 SECONDS

T 1 = 746.3907 Degrees F
T 2 = 283.8899 Degrees F
T 3 = 131.5314 Degrees F
T 4 = 70.0000 Degrees F

AT t = 16.0 SECONDS

T 1 = 769.6906 Degrees F
T 2 = 299.4095 Degrees F
T 3 = 137.7248 Degrees F
T 4 = 70.0000 Degrees F

AT t = 17.0 SECONDS

T 1 = 792.3055 Degrees F
T 2 = 314.8046 Degrees F
T 3 = 143.9601 Degrees F
T 4 = 70.0000 Degrees F

AT t = 18.0 SECONDS

T 1 = 814.3207 Degrees F
T 2 = 330.0664 Degrees F
T 3 = 150.2162 Degrees F
T 4 = 70.0000 Degrees F

AT t = 19.0 SECONDS

T 1 = 835.8081 Degrees F
T 2 = 345.1885 Degrees F
T 3 = 156.4755 Degrees F
T 4 = 70.0000 Degrees F

AT t = 20.0 SECONDS

T 1 = 856.8281 Degrees F
T 2 = 360.1663 Degrees F
T 3 = 162.7231 Degrees F
T 4 = 70.0000 Degrees F

AT t = 21.0 SECONDS

T 1 = 877.4315 Degrees F
T 2 = 374.9965 Degrees F
T 3 = 168.9468 Degrees F
T 4 = 70.0000 Degrees F

AT t = 22.0 SECONDS

T 1 = 897.6614 Degrees F
T 2 = 389.6772 Degrees F
T 3 = 175.1367 Degrees F
T 4 = 70.0000 Degrees F

AT t = 23.0 SECONDS

T 1 = 917.5546 Degrees F
T 2 = 404.2074 Degrees F
T 3 = 181.2848 Degrees F
T 4 = 70.0000 Degrees F

AT t = 24.0 SECONDS

T 1 = 937.1422 Degrees F
T 2 = 418.5868 Degrees F
T 3 = 187.3851 Degrees F
T 4 = 70.0000 Degrees F

AT t = 25.0 SECONDS

T 1 = 956.4508 Degrees F
T 2 = 432.8158 Degrees F
T 3 = 193.4330 Degrees F
T 4 = 70.0000 Degrees F

AT t = 26.0 SECONDS

T 1 = 975.5031 Degrees F
T 2 = 446.8952 Degrees F
T 3 = 199.4252 Degrees F
T 4 = 70.0000 Degrees F

AT t = 27.0 SECONDS

T 1 = 994.3182 Degrees F
T 2 = 460.8264 Degrees F
T 3 = 205.3597 Degrees F
T 4 = 70.0000 Degrees F

AT t = 28.0 SECONDS

T 1 = 1012.9130 Degrees F
T 2 = 474.6110 Degrees F
T 3 = 211.2352 Degrees F
T 4 = 70.0000 Degrees F

AT t = 29.0 SECONDS

T 1 = 1031.3020 Degrees F
T 2 = 488.2509 Degrees F
T 3 = 217.0512 Degrees F
T 4 = 70.0000 Degrees F

AT t = 30.0 SECONDS

T 1 = 1049.5560 Degrees F
T 2 = 501.7513 Degrees F
T 3 = 222.8081 Degrees F
T 4 = 70.0000 Degrees F

AT t = 31.0 SECONDS

T 1 = 1066.7620 Degrees F
T 2 = 515.0692 Degrees F
T 3 = 228.5035 Degrees F
T 4 = 70.0000 Degrees F

AT t = 32.0 SECONDS

T 1 = 1083.0310 Degrees F
T 2 = 528.1729 Degrees F
T 3 = 234.1339 Degrees F
T 4 = 70.0000 Degrees F

AT t = 33.0 SECONDS

T 1 = 1098.4570 Degrees F
T 2 = 541.0378 Degrees F
T 3 = 239.6948 Degrees F
T 4 = 70.0000 Degrees F

AT t = 34.0 SECONDS

T 1 = 1113.1190 Degrees F
T 2 = 553.6454 Degrees F
T 3 = 245.1818 Degrees F
T 4 = 70.0000 Degrees F

AT t = 35.0 SECONDS

```
     T  1 =   1127.0840 Degrees F
     T  2 =    565.9819 Degrees F
     T  3 =    250.5900 Degrees F
     T  4 =     70.0000 Degrees F


AT t =  36.0 SECONDS

     T  1 =   1140.4100 Degrees F
     T  2 =    578.0371 Degrees F
     T  3 =    255.9147 Degrees F
     T  4 =     70.0000 Degrees F


AT t =  37.0 SECONDS

     T  1 =   1153.1440 Degrees F
     T  2 =    589.8043 Degrees F
     T  3 =    261.1513 Degrees F
     T  4 =     70.0000 Degrees F


AT t =  38.0 SECONDS

     T  1 =   1165.3300 Degrees F
     T  2 =    601.2788 Degrees F
     T  3 =    266.2955 Degrees F
     T  4 =     70.0000 Degrees F


AT t =  39.0 SECONDS

     T  1 =   1177.0030 Degrees F
     T  2 =    612.4582 Degrees F
     T  3 =    271.3431 Degrees F
     T  4 =     70.0000 Degrees F


AT t =  40.0 SECONDS

     T  1 =   1188.1940 Degrees F
     T  2 =    623.3415 Degrees F
     T  3 =    276.2902 Degrees F
     T  4 =     70.0000 Degrees F


AT t =  41.0 SECONDS
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T 1 = 1198.9310 Degrees F
T 2 = 633.9290 Degrees F
T 3 = 281.1332 Degrees F
T 4 = 70.0000 Degrees F

AT t = 42.0 SECONDS

T 1 = 1209.2370 Degrees F
T 2 = 644.2219 Degrees F
T 3 = 285.8685 Degrees F
T 4 = 70.0000 Degrees F

AT t = 43.0 SECONDS

T 1 = 1219.1330 Degrees F
T 2 = 654.2225 Degrees F
T 3 = 290.4930 Degrees F
T 4 = 70.0000 Degrees F

AT t = 44.0 SECONDS

T 1 = 1228.6370 Degrees F
T 2 = 663.9333 Degrees F
T 3 = 295.0037 Degrees F
T 4 = 70.0000 Degrees F

AT t = 45.0 SECONDS

T 1 = 1237.7660 Degrees F
T 2 = 673.3572 Degrees F
T 3 = 299.3979 Degrees F
T 4 = 70.0000 Degrees F

AT t = 46.0 SECONDS

T 1 = 1246.5330 Degrees F
T 2 = 682.4979 Degrees F
T 3 = 303.6730 Degrees F
T 4 = 70.0000 Degrees F

AT t = 47.0 SECONDS

T 1 = 1254.9520 Degrees F
T 2 = 691.3589 Degrees F
T 3 = 307.8268 Degrees F
T 4 = 70.0000 Degrees F

AT t = 48.0 SECONDS

T 1 = 1263.0340 Degrees F
T 2 = 699.9440 Degrees F
T 3 = 311.8571 Degrees F
T 4 = 70.0000 Degrees F

AT t = 49.0 SECONDS

T 1 = 1270.7890 Degrees F
T 2 = 708.2573 Degrees F
T 3 = 315.7625 Degrees F
T 4 = 70.0000 Degrees F

AT t = 50.0 SECONDS

T 1 = 1278.2290 Degrees F
T 2 = 716.3027 Degrees F
T 3 = 319.5412 Degrees F
T 4 = 70.0000 Degrees F

AT t = 51.0 SECONDS

T 1 = 1285.3600 Degrees F
T 2 = 724.0844 Degrees F
T 3 = 323.1922 Degrees F
T 4 = 70.0000 Degrees F

AT t = 52.0 SECONDS

T 1 = 1292.1920 Degrees F
T 2 = 731.6063 Degrees F
T 3 = 326.7146 Degrees F
T 4 = 70.0000 Degrees F

AT t = 53.0 SECONDS

T 1 = 1298.7320 Degrees F
T 2 = 738.8725 Degrees F
T 3 = 330.1077 Degrees F
T 4 = 70.0000 Degrees F

AT t = 54.0 SECONDS

T 1 = 1304.9860 Degrees F
T 2 = 745.8872 Degrees F
T 3 = 333.3713 Degrees F
T 4 = 70.0000 Degrees F

AT t = 55.0 SECONDS

T 1 = 1310.9610 Degrees F
T 2 = 752.6545 Degrees F
T 3 = 336.5055 Degrees F
T 4 = 70.0000 Degrees F

AT t = 56.0 SECONDS

T 1 = 1316.6640 Degrees F
T 2 = 759.1782 Degrees F
T 3 = 339.5106 Degrees F
T 4 = 70.0000 Degrees F

AT t = 57.0 SECONDS

T 1 = 1322.0990 Degrees F
T 2 = 765.4625 Degrees F
T 3 = 342.3873 Degrees F
T 4 = 70.0000 Degrees F

AT t = 58.0 SECONDS

T 1 = 1327.2730 Degrees F
T 2 = 771.5115 Degrees F
T 3 = 345.1366 Degrees F
T 4 = 70.0000 Degrees F

AT t = 59.0 SECONDS

T 1 = 1332.1910 Degrees F
T 2 = 777.3289 Degrees F
T 3 = 347.7599 Degrees F
T 4 = 70.0000 Degrees F

AT t = 60.0 SECONDS

T 1 = 1336.8570 Degrees F
T 2 = 782.9188 Degrees F
T 3 = 350.2587 Degrees F
T 4 = 70.0000 Degrees F

AT t = 61.0 SECONDS

T 1 = 1341.2760 Degrees F
T 2 = 788.2851 Degrees F
T 3 = 352.6350 Degrees F
T 4 = 70.0000 Degrees F

AT t = 62.0 SECONDS

T 1 = 1345.4540 Degrees F
T 2 = 793.4319 Degrees F
T 3 = 354.8910 Degrees F
T 4 = 70.0000 Degrees F

AT t = 63.0 SECONDS

T 1 = 1349.3940 Degrees F
T 2 = 798.3630 Degrees F
T 3 = 357.0291 Degrees F
T 4 = 70.0000 Degrees F

AT t = 64.0 SECONDS

T 1 = 1353.1010 Degrees F
T 2 = 803.0823 Degrees F
T 3 = 359.0520 Degrees F
T 4 = 70.0000 Degrees F

AT t = 65.0 SECONDS

T 1 = 1356.5780 Degrees F
T 2 = 807.5938 Degrees F
T 3 = 360.9627 Degrees F
T 4 = 70.0000 Degrees F

AT t = 66.0 SECONDS

T 1 = 1359.8310 Degrees F
T 2 = 811.9014 Degrees F
T 3 = 362.7643 Degrees F
T 4 = 70.0000 Degrees F

AT t = 67.0 SECONDS

T 1 = 1362.8630 Degrees F
T 2 = 816.0090 Degrees F
T 3 = 364.4601 Degrees F
T 4 = 70.0000 Degrees F

AT t = 68.0 SECONDS

T 1 = 1365.6780 Degrees F
T 2 = 819.9207 Degrees F
T 3 = 366.0536 Degrees F
T 4 = 70.0000 Degrees F

AT t = 69.0 SECONDS

T 1 = 1368.2800 Degrees F
T 2 = 823.6403 Degrees F
T 3 = 367.5482 Degrees F
T 4 = 70.0000 Degrees F

AT t = 70.0 SECONDS

T 1 = 1370.6730 Degrees F
T 2 = 827.1719 Degrees F
T 3 = 368.9477 Degrees F
T 4 = 70.0000 Degrees F

AT t = 71.0 SECONDS

T 1 = 1372.8620 Degrees F
T 2 = 830.5193 Degrees F
T 3 = 370.2559 Degrees F
T 4 = 70.0000 Degrees F

AT t = 72.0 SECONDS

T 1 = 1374.8480 Degrees F
T 2 = 833.6868 Degrees F
T 3 = 371.4765 Degrees F
T 4 = 70.0000 Degrees F

AT t = 73.0 SECONDS

T 1 = 1376.6370 Degrees F
T 2 = 836.6780 Degrees F
T 3 = 372.6135 Degrees F
T 4 = 70.0000 Degrees F

AT t = 74.0 SECONDS

T 1 = 1378.2330 Degrees F
T 2 = 839.4971 Degrees F
T 3 = 373.6705 Degrees F
T 4 = 70.0000 Degrees F

AT t = 75.0 SECONDS

T 1 = 1379.6390 Degrees F
T 2 = 842.1480 Degrees F
T 3 = 374.6515 Degrees F
T 4 = 70.0000 Degrees F

AT t = 76.0 SECONDS

T 1 = 1380.8580 Degrees F
T 2 = 844.6348 Degrees F
T 3 = 375.5603 Degrees F
T 4 = 70.0000 Degrees F

AT t = 77.0 SECONDS

T 1 = 1381.8950 Degrees F
T 2 = 846.9612 Degrees F
T 3 = 376.4005 Degrees F
T 4 = 70.0000 Degrees F

AT t = 78.0 SECONDS

T 1 = 1382.7530 Degrees F
T 2 = 849.1314 Degrees F
T 3 = 377.1758 Degrees F
T 4 = 70.0000 Degrees F

AT t = 79.0 SECONDS

T 1 = 1383.4370 Degrees F
T 2 = 851.1492 Degrees F
T 3 = 377.8899 Degrees F
T 4 = 70.0000 Degrees F

AT t = 80.0 SECONDS

T 1 = 1383.9490 Degrees F
T 2 = 853.0186 Degrees F
T 3 = 378.5462 Degrees F
T 4 = 70.0000 Degrees F

AT t = 81.0 SECONDS

T 1 = 1384.2930 Degrees F
T 2 = 854.7432 Degrees F
T 3 = 379.1480 Degrees F
T 4 = 70.0000 Degrees F

AT t = 82.0 SECONDS

T 1 = 1384.4740 Degrees F
T 2 = 856.3270 Degrees F
T 3 = 379.6986 Degrees F
T 4 = 70.0000 Degrees F

AT t = 83.0 SECONDS

T 1 = 1384.4940 Degrees F
T 2 = 857.7737 Degrees F
T 3 = 380.2012 Degrees F
T 4 = 70.0000 Degrees F

AT t = 84.0 SECONDS

T 1 = 1384.3580 Degrees F
T 2 = 859.0873 Degrees F
T 3 = 380.6587 Degrees F
T 4 = 70.0000 Degrees F

AT t = 85.0 SECONDS

T 1 = 1384.0690 Degrees F
T 2 = 860.2712 Degrees F
T 3 = 381.0738 Degrees F
T 4 = 70.0000 Degrees F

AT t = 86.0 SECONDS

T 1 = 1383.6300 Degrees F
T 2 = 861.3292 Degrees F
T 3 = 381.4494 Degrees F
T 4 = 70.0000 Degrees F

AT t = 87.0 SECONDS

T 1 = 1383.0460 Degrees F
T 2 = 862.2648 Degrees F
T 3 = 381.7880 Degrees F
T 4 = 70.0000 Degrees F

AT t = 88.0 SECONDS

T 1 = 1382.3190 Degrees F
T 2 = 863.0817 Degrees F
T 3 = 382.0919 Degrees F
T 4 = 70.0000 Degrees F

AT t = 89.0 SECONDS

T 1 = 1381.4540 Degrees F
T 2 = 863.7831 Degrees F
T 3 = 382.3634 Degrees F
T 4 = 70.0000 Degrees F

AT t = 90.0 SECONDS

T 1 = 1380.4530 Degrees F
T 2 = 864.3726 Degrees F
T 3 = 382.6046 Degrees F
T 4 = 70.0000 Degrees F

AT t = 91.0 SECONDS

T 1 = 1379.3210 Degrees F
T 2 = 864.8534 Degrees F
T 3 = 382.8175 Degrees F
T 4 = 70.0000 Degrees F

AT t = 92.0 SECONDS

T 1 = 1378.0600 Degrees F
T 2 = 865.2289 Degrees F
T 3 = 383.0038 Degrees F
T 4 = 70.0000 Degrees F

AT t = 93.0 SECONDS

T 1 = 1376.5020 Degrees F
T 2 = 865.4933 Degrees F
T 3 = 383.1648 Degrees F
T 4 = 70.0000 Degrees F

AT t = 94.0 SECONDS

T 1 = 1383.1000 Degrees F
T 2 = 866.0792 Degrees F
T 3 = 383.3282 Degrees F
T 4 = 70.0000 Degrees F

AT t = 95.0 SECONDS

T 1 = 1396.9630 Degrees F
T 2 = 867.3301 Degrees F
T 3 = 383.5214 Degrees F
T 4 = 70.0000 Degrees F

AT t = 96.0 SECONDS

T 1 = 1417.3160 Degrees F
T 2 = 869.5161 Degrees F
T 3 = 383.7701 Degrees F
T 4 = 70.0000 Degrees F

AT t = 97.0 SECONDS

T 1 = 1443.4810 Degrees F
T 2 = 872.8467 Degrees F
T 3 = 384.0967 Degrees F
T 4 = 70.0000 Degrees F

AT t = 98.0 SECONDS

T 1 = 1479.1230 Degrees F
T 2 = 877.7024 Degrees F
T 3 = 384.5323 Degrees F
T 4 = 70.0000 Degrees F

AT t = 99.0 SECONDS

T 1 = 1509.2910 Degrees F
T 2 = 883.6548 Degrees F
T 3 = 385.0553 Degrees F
T 4 = 70.0000 Degrees F

AT t = 100.0 SECONDS

T 1 = 1534.7590 Degrees F
T 2 = 890.3528 Degrees F
T 3 = 385.6372 Degrees F
T 4 = 70.0000 Degrees F

AT t = 101.0 SECONDS

T 1 = 1556.1650 Degrees F
T 2 = 897.5112 Degrees F
T 3 = 386.2455 Degrees F
T 4 = 70.0000 Degrees F

AT t = 102.0 SECONDS

T 1 = 1574.0380 Degrees F
T 2 = 904.8983 Degrees F
T 3 = 386.8471 Degrees F
T 4 = 70.0000 Degrees F

AT t = 103.0 SECONDS

T 1 = 1588.8160 Degrees F
T 2 = 912.3264 Degrees F
T 3 = 387.4102 Degrees F
T 4 = 70.0000 Degrees F

AT t = 104.0 SECONDS

T 1 = 1600.8620 Degrees F
T 2 = 919.6448 Degrees F
T 3 = 387.9072 Degrees F
T 4 = 70.0000 Degrees F

AT t = 105.0 SECONDS

T 1 = 1610.4810 Degrees F
T 2 = 926.7325 Degrees F
T 3 = 388.3154 Degrees F
T 4 = 70.0000 Degrees F

AT t = 106.0 SECONDS

T 1 = 1617.9280 Degrees F
T 2 = 933.4933 Degrees F
T 3 = 388.6183 Degrees F
T 4 = 70.0000 Degrees F

AT t = 107.0 SECONDS

T 1 = 1623.4160 Degrees F
T 2 = 939.8520 Degrees F
T 3 = 388.8060 Degrees F
T 4 = 70.0000 Degrees F

AT t = 108.0 SECONDS

T 1 = 1627.1250 Degrees F
T 2 = 945.7502 Degrees F
T 3 = 388.8745 Degrees F
T 4 = 70.0000 Degrees F

AT t = 109.0 SECONDS

T 1 = 1629.2080 Degrees F
T 2 = 951.1439 Degrees F
T 3 = 388.8257 Degrees F
T 4 = 70.0000 Degrees F

AT t = 110.0 SECONDS

T 1 = 1629.7970 Degrees F
T 2 = 956.0007 Degrees F
T 3 = 388.6666 Degrees F
T 4 = 70.0000 Degrees F

AT t = 111.0 SECONDS

T 1 = 1629.0020 Degrees F
T 2 = 960.2985 Degrees F
T 3 = 388.4083 Degrees F
T 4 = 70.0000 Degrees F

AT t = 112.0 SECONDS

T 1 = 1626.9210 Degrees F
T 2 = 964.0229 Degrees F
T 3 = 388.0652 Degrees F
T 4 = 70.0000 Degrees F

AT t = 113.0 SECONDS

T 1 = 1623.6360 Degrees F
T 2 = 967.1671 Degrees F
T 3 = 387.6536 Degrees F
T 4 = 70.0000 Degrees F

AT t = 114.0 SECONDS

T 1 = 1619.2220 Degrees F
T 2 = 969.7288 Degrees F
T 3 = 387.1913 Degrees F
T 4 = 70.0000 Degrees F

AT t = 115.0 SECONDS

T 1 = 1613.7420 Degrees F
T 2 = 971.7112 Degrees F
T 3 = 386.6967 Degrees F
T 4 = 70.0000 Degrees F

AT t = 116.0 SECONDS

T 1 = 1607.2550 Degrees F
T 2 = 973.1208 Degrees F
T 3 = 386.1875 Degrees F
T 4 = 70.0000 Degrees F

AT t = 117.0 SECONDS

T 1 = 1599.8120 Degrees F
T 2 = 973.9673 Degrees F
T 3 = 385.6809 Degrees F
T 4 = 70.0000 Degrees F

AT t = 118.0 SECONDS

T 1 = 1591.4590 Degrees F
T 2 = 974.2623 Degrees F
T 3 = 385.1924 Degrees F
T 4 = 70.0000 Degrees F

AT t = 119.0 SECONDS

T 1 = 1582.2390 Degrees F
T 2 = 974.0195 Degrees F
T 3 = 384.7357 Degrees F
T 4 = 70.0000 Degrees F

AT t = 120.0 SECONDS

T 1 = 1572.1910 Degrees F
T 2 = 973.2542 Degrees F
T 3 = 384.3226 Degrees F
T 4 = 70.0000 Degrees F

APPENDIX C

DATA FOR FOUR LAYER BLANKET

RESULTS OF HEAT TRANSFER ANALYSIS FOR A THERMAL BLANKET CONSISTING OF 4 LAYERS OF THE FOLLOWING COMPOSITIONS:

Layer 1 is Quartz
Layer 2 is E-glass
Layer 3 is Fiberfrax
Layer 4 is Kevlar

where layer 1 is the high-temperature side.

AT t = 1.0 SECONDS

T 1 = 192.0047 Degrees F
T 2 = 77.6452 Degrees F
T 3 = 70.9110 Degrees F
T 4 = 70.0334 Degrees F
T 5 = 70.0000 Degrees F

AT t = 2.0 SECONDS

T 1 = 271.8125 Degrees F
T 2 = 87.9477 Degrees F
T 3 = 72.8756 Degrees F
T 4 = 70.1294 Degrees F
T 5 = 70.0000 Degrees F

AT t = 3.0 SECONDS

T 1 = 335.5456 Degrees F
T 2 = 100.2056 Degrees F
T 3 = 75.9381 Degrees F
T 4 = 70.3126 Degrees F
T 5 = 70.0000 Degrees F

AT t = 4.0 SECONDS

T 1 = 389.5589 Degrees F
T 2 = 113.8516 Degrees F
T 3 = 80.0682 Degrees F
T 4 = 70.6010 Degrees F
T 5 = 70.0000 Degrees F

AT t = 5.0 SECONDS

T 1 = 436.8340 Degrees F
T 2 = 128.5049 Degrees F
T 3 = 85.1977 Degrees F
T 4 = 71.0065 Degrees F
T 5 = 70.0000 Degrees F

AT t = 6.0 SECONDS

T 1 = 479.1118 Degrees F
T 2 = 143.9024 Degrees F
T 3 = 91.2414 Degrees F
T 4 = 71.5352 Degrees F
T 5 = 70.0000 Degrees F

AT t = 7.0 SECONDS

T 1 = 517.5341 Degrees F
T 2 = 159.8564 Degrees F
T 3 = 98.1091 Degrees F
T 4 = 72.1889 Degrees F
T 5 = 70.0000 Degrees F

AT t = 8.0 SECONDS

T 1 = 552.9044 Degrees F
T 2 = 176.2301 Degrees F
T 3 = 105.7126 Degrees F
T 4 = 72.9657 Degrees F
T 5 = 70.0000 Degrees F

AT t = 9.0 SECONDS

T 1 = 585.8163 Degrees F
T 2 = 192.9219 Degrees F
T 3 = 113.9687 Degrees F
T 4 = 73.8617 Degrees F
T 5 = 70.0000 Degrees F

AT t = 10.0 SECONDS

T 1 = 616.7230 Degrees F

T 2 = 209.8548 Degrees F
T 3 = 122.8019 Degrees F
T 4 = 74.8710 Degrees F
T 5 = 70.0000 Degrees F

AT t = 11.0 SECONDS

T 1 = 645.9786 Degrees F
T 2 = 226.9698 Degrees F
T 3 = 132.1438 Degrees F
T 4 = 75.9873 Degrees F
T 5 = 70.0000 Degrees F

AT t = 12.0 SECONDS

T 1 = 673.8657 Degrees F
T 2 = 244.2215 Degrees F
T 3 = 141.9339 Degrees F
T 4 = 77.2035 Degrees F
T 5 = 70.0000 Degrees F

AT t = 13.0 SECONDS

T 1 = 700.6119 Degrees F
T 2 = 261.5743 Degrees F
T 3 = 152.1189 Degrees F
T 4 = 78.5127 Degrees F
T 5 = 70.0000 Degrees F

AT t = 14.0 SECONDS

T 1 = 726.4034 Degrees F
T 2 = 279.0004 Degrees F
T 3 = 162.6516 Degrees F
T 4 = 79.9081 Degrees F
T 5 = 70.0000 Degrees F

AT t = 15.0 SECONDS

T 1 = 751.3933 Degrees F
T 2 = 296.4777 Degrees F
T 3 = 173.4914 Degrees F
T 4 = 81.3834 Degrees F
T 5 = 70.0000 Degrees F

AT t = 16.0 SECONDS

T 1 = 775.7083 Degrees F
T 2 = 313.9890 Degrees F
T 3 = 184.6024 Degrees F
T 4 = 82.9326 Degrees F
T 5 = 70.0000 Degrees F

AT t = 17.0 SECONDS

T 1 = 799.4540 Degrees F
T 2 = 331.5204 Degrees F
T 3 = 195.9539 Degrees F
T 4 = 84.5503 Degrees F
T 5 = 70.0000 Degrees F

AT t = 18.0 SECONDS

T 1 = 822.7188 Degrees F
T 2 = 349.0612 Degrees F
T 3 = 207.5191 Degrees F
T 4 = 86.2314 Degrees F
T 5 = 70.0000 Degrees F

AT t = 19.0 SECONDS

T 1 = 845.5765 Degrees F
T 2 = 366.6027 Degrees F
T 3 = 219.2749 Degrees F
T 4 = 87.9714 Degrees F
T 5 = 70.0000 Degrees F

AT t = 20.0 SECONDS

T 1 = 868.0895 Degrees F
T 2 = 384.1381 Degrees F
T 3 = 231.2014 Degrees F
T 4 = 89.7661 Degrees F
T 5 = 70.0000 Degrees F

AT t = 21.0 SECONDS

T 1 = 890.3103 Degrees F

T 2 = 401.6620 Degrees F
T 3 = 243.2818 Degrees F
T 4 = 91.6118 Degrees F
T 5 = 70.0000 Degrees F

AT t = 22.0 SECONDS

T 1 = 912.2828 Degrees F
T 2 = 419.1702 Degrees F
T 3 = 255.5013 Degrees F
T 4 = 93.5051 Degrees F
T 5 = 70.0000 Degrees F

AT t = 23.0 SECONDS

T 1 = 934.0447 Degrees F
T 2 = 436.6596 Degrees F
T 3 = 267.8476 Degrees F
T 4 = 95.4430 Degrees F
T 5 = 70.0000 Degrees F

AT t = 24.0 SECONDS

T 1 = 955.6273 Degrees F
T 2 = 454.1276 Degrees F
T 3 = 280.3100 Degrees F
T 4 = 97.4227 Degrees F
T 5 = 70.0000 Degrees F

AT t = 25.0 SECONDS

T 1 = 977.0572 Degrees F
T 2 = 471.5724 Degrees F
T 3 = 292.8796 Degrees F
T 4 = 99.4418 Degrees F
T 5 = 70.0000 Degrees F

AT t = 26.0 SECONDS

T 1 = 998.3568 Degrees F
T 2 = 488.9927 Degrees F
T 3 = 305.5488 Degrees F
T 4 = 101.4979 Degrees F
T 5 = 70.0000 Degrees F

AT t = 27.0 SECONDS

T 1 = 1019.5450 Degrees F
T 2 = 506.3875 Degrees F
T 3 = 318.3112 Degrees F
T 4 = 103.5892 Degrees F
T 5 = 70.0000 Degrees F

AT t = 28.0 SECONDS

T 1 = 1040.6380 Degrees F
T 2 = 523.7561 Degrees F
T 3 = 331.1615 Degrees F
T 4 = 105.7139 Degrees F
T 5 = 70.0000 Degrees F

AT t = 29.0 SECONDS

T 1 = 1061.6500 Degrees F
T 2 = 541.0985 Degrees F
T 3 = 344.0951 Degrees F
T 4 = 107.8703 Degrees F
T 5 = 70.0000 Degrees F

AT t = 30.0 SECONDS

T 1 = 1082.6480 Degrees F
T 2 = 558.4175 Degrees F
T 3 = 357.1084 Degrees F
T 4 = 110.0573 Degrees F
T 5 = 70.0000 Degrees F

AT t = 31.0 SECONDS

T 1 = 1102.7250 Degrees F
T 2 = 575.6684 Degrees F
T 3 = 370.1942 Degrees F
T 4 = 112.2735 Degrees F
T 5 = 70.0000 Degrees F

AT t = 32.0 SECONDS

T 1 = 1121.9880 Degrees F

T 2 = 592.8171 Degrees F
T 3 = 383.3436 Degrees F
T 4 = 114.5177 Degrees F
T 5 = 70.0000 Degrees F

AT t = 33.0 SECONDS

T 1 = 1140.5310 Degrees F
T 2 = 609.8372 Degrees F
T 3 = 396.5465 Degrees F
T 4 = 116.7887 Degrees F
T 5 = 70.0000 Degrees F

AT t = 34.0 SECONDS

T 1 = 1158.4290 Degrees F
T 2 = 626.7078 Degrees F
T 3 = 409.7924 Degrees F
T 4 = 119.0850 Degrees F
T 5 = 70.0000 Degrees F

AT t = 35.0 SECONDS

T 1 = 1175.7490 Degrees F
T 2 = 643.4130 Degrees F
T 3 = 423.0708 Degrees F
T 4 = 121.4053 Degrees F
T 5 = 70.0000 Degrees F

AT t = 36.0 SECONDS

T 1 = 1192.5460 Degrees F
T 2 = 659.9408 Degrees F
T 3 = 436.3706 Degrees F
T 4 = 123.7483 Degrees F
T 5 = 70.0000 Degrees F

AT t = 37.0 SECONDS

T 1 = 1208.8670 Degrees F
T 2 = 676.2821 Degrees F
T 3 = 449.6814 Degrees F
T 4 = 126.1127 Degrees F
T 5 = 70.0000 Degrees F

AT t = 38.0 SECONDS

T 1 = 1224.7500 Degrees F
T 2 = 692.4306 Degrees F
T 3 = 462.9926 Degrees F
T 4 = 128.4969 Degrees F
T 5 = 70.0000 Degrees F

AT t = 39.0 SECONDS

T 1 = 1240.2320 Degrees F
T 2 = 708.3819 Degrees F
T 3 = 476.2942 Degrees F
T 4 = 130.8996 Degrees F
T 5 = 70.0000 Degrees F

AT t = 40.0 SECONDS

T 1 = 1255.3390 Degrees F
T 2 = 724.1334 Degrees F
T 3 = 489.5765 Degrees F
T 4 = 133.3193 Degrees F
T 5 = 70.0000 Degrees F

AT t = 41.0 SECONDS

T 1 = 1270.0990 Degrees F
T 2 = 739.6837 Degrees F
T 3 = 502.8300 Degrees F
T 4 = 135.7545 Degrees F
T 5 = 70.0000 Degrees F

AT t = 42.0 SECONDS

T 1 = 1284.5310 Degrees F
T 2 = 755.0323 Degrees F
T 3 = 516.0458 Degrees F
T 4 = 138.2036 Degrees F
T 5 = 70.0000 Degrees F

AT t = 43.0 SECONDS

T 1 = 1298.6560 Degrees F

T 2 = 770.1800 Degrees F
T 3 = 529.2154 Degrees F
T 4 = 140.6649 Degrees F
T 5 = 70.0000 Degrees F

AT t = 44.0 SECONDS

T 1 = 1312.4890 Degrees F
T 2 = 785.1277 Degrees F
T 3 = 542.3305 Degrees F
T 4 = 143.1366 Degrees F
T 5 = 70.0000 Degrees F

AT t = 45.0 SECONDS

T 1 = 1326.0440 Degrees F
T 2 = 799.8772 Degrees F
T 3 = 555.3834 Degrees F
T 4 = 145.6165 Degrees F
T 5 = 70.0000 Degrees F

AT t = 46.0 SECONDS

T 1 = 1339.3350 Degrees F
T 2 = 814.4305 Degrees F
T 3 = 568.3667 Degrees F
T 4 = 148.1024 Degrees F
T 5 = 70.0000 Degrees F

AT t = 47.0 SECONDS

T 1 = 1352.3720 Degrees F
T 2 = 828.7900 Degrees F
T 3 = 581.2734 Degrees F
T 4 = 150.5917 Degrees F
T 5 = 70.0000 Degrees F

AT t = 48.0 SECONDS

T 1 = 1365.1650 Degrees F
T 2 = 842.9585 Degrees F
T 3 = 594.0969 Degrees F
T 4 = 153.0815 Degrees F
T 5 = 70.0000 Degrees F

AT t = 49.0 SECONDS

T 1 = 1377.7230 Degrees F
T 2 = 856.9385 Degrees F
T 3 = 606.8309 Degrees F
T 4 = 155.5683 Degrees F
T 5 = 70.0000 Degrees F

AT t = 50.0 SECONDS

T 1 = 1390.0550 Degrees F
T 2 = 870.7327 Degrees F
T 3 = 619.4695 Degrees F
T 4 = 158.0486 Degrees F
T 5 = 70.0000 Degrees F

AT t = 51.0 SECONDS

T 1 = 1402.1670 Degrees F
T 2 = 884.3440 Degrees F
T 3 = 632.0071 Degrees F
T 4 = 160.5181 Degrees F
T 5 = 70.0000 Degrees F

AT t = 52.0 SECONDS

T 1 = 1414.0660 Degrees F
T 2 = 897.7753 Degrees F
T 3 = 644.4383 Degrees F
T 4 = 162.9719 Degrees F
T 5 = 70.0000 Degrees F

AT t = 53.0 SECONDS

T 1 = 1425.7580 Degrees F
T 2 = 911.0294 Degrees F
T 3 = 656.7581 Degrees F
T 4 = 165.4049 Degrees F
T 5 = 70.0000 Degrees F

AT t = 54.0 SECONDS

T 1 = 1437.2490 Degrees F

T 2 = 924.1089 Degrees F
T 3 = 668.9617 Degrees F
T 4 = 167.8112 Degrees F
T 5 = 70.0000 Degrees F

AT t = 55.0 SECONDS

T 1 = 1448.5430 Degrees F
T 2 = 937.0164 Degrees F
T 3 = 681.0448 Degrees F
T 4 = 170.1844 Degrees F
T 5 = 70.0000 Degrees F

AT t = 56.0 SECONDS

T 1 = 1459.6460 Degrees F
T 2 = 949.7545 Degrees F
T 3 = 693.0030 Degrees F
T 4 = 172.5176 Degrees F
T 5 = 70.0000 Degrees F

AT t = 57.0 SECONDS

T 1 = 1470.5610 Degrees F
T 2 = 962.3255 Degrees F
T 3 = 704.8322 Degrees F
T 4 = 174.8035 Degrees F
T 5 = 70.0000 Degrees F

AT t = 58.0 SECONDS

T 1 = 1481.2930 Degrees F
T 2 = 974.7318 Degrees F
T 3 = 716.5287 Degrees F
T 4 = 177.0340 Degrees F
T 5 = 70.0000 Degrees F

AT t = 59.0 SECONDS

T 1 = 1491.8450 Degrees F
T 2 = 986.9755 Degrees F
T 3 = 728.0890 Degrees F
T 4 = 179.2008 Degrees F
T 5 = 70.0000 Degrees F

AT t = 60.0 SECONDS

T 1 = 1502.2220 Degrees F
T 2 = 999.0583 Degrees F
T 3 = 739.5095 Degrees F
T 4 = 181.2954 Degrees F
T 5 = 70.0000 Degrees F

AT t = 61.0 SECONDS

T 1 = 1512.4250 Degrees F
T 2 = 1010.9820 Degrees F
T 3 = 750.7869 Degrees F
T 4 = 183.3089 Degrees F
T 5 = 70.0000 Degrees F

AT t = 62.0 SECONDS

T 1 = 1522.4590 Degrees F
T 2 = 1022.7490 Degrees F
T 3 = 761.9182 Degrees F
T 4 = 185.2321 Degrees F
T 5 = 70.0000 Degrees F

AT t = 63.0 SECONDS

T 1 = 1532.3260 Degrees F
T 2 = 1034.3610 Degrees F
T 3 = 772.9003 Degrees F
T 4 = 187.0562 Degrees F
T 5 = 70.0000 Degrees F

AT t = 64.0 SECONDS

T 1 = 1542.0280 Degrees F
T 2 = 1045.8180 Degrees F
T 3 = 783.7305 Degrees F
T 4 = 188.7722 Degrees F
T 5 = 70.0000 Degrees F

AT t = 65.0 SECONDS

T 1 = 1551.5680 Degrees F

T 2 = 1057.1210 Degrees F
T 3 = 794.4063 Degrees F
T 4 = 190.3716 Degrees F
T 5 = 70.0000 Degrees F

AT t = 66.0 SECONDS

T 1 = 1560.9480 Degrees F
T 2 = 1068.2730 Degrees F
T 3 = 804.9250 Degrees F
T 4 = 191.8463 Degrees F
T 5 = 70.0000 Degrees F

AT t = 67.0 SECONDS

T 1 = 1570.1710 Degrees F
T 2 = 1079.2740 Degrees F
T 3 = 815.2847 Degrees F
T 4 = 193.1887 Degrees F
T 5 = 70.0000 Degrees F

AT t = 68.0 SECONDS

T 1 = 1579.2370 Degrees F
T 2 = 1090.1240 Degrees F
T 3 = 825.4829 Degrees F
T 4 = 194.3921 Degrees F
T 5 = 70.0000 Degrees F

AT t = 69.0 SECONDS

T 1 = 1588.1500 Degrees F
T 2 = 1100.8250 Degrees F
T 3 = 835.5179 Degrees F
T 4 = 195.4505 Degrees F
T 5 = 70.0000 Degrees F

AT t = 70.0 SECONDS

T 1 = 1596.9100 Degrees F
T 2 = 1111.3770 Degrees F
T 3 = 845.3878 Degrees F
T 4 = 196.3591 Degrees F
T 5 = 70.0000 Degrees F

AT t = 71.0 SECONDS

T 1 = 1605.5200 Degrees F
T 2 = 1121.7800 Degrees F
T 3 = 855.0911 Degrees F
T 4 = 197.1141 Degrees F
T 5 = 70.0000 Degrees F

AT t = 72.0 SECONDS

T 1 = 1613.9790 Degrees F
T 2 = 1132.0340 Degrees F
T 3 = 864.6264 Degrees F
T 4 = 197.7129 Degrees F
T 5 = 70.0000 Degrees F

AT t = 73.0 SECONDS

T 1 = 1622.2900 Degrees F
T 2 = 1142.1400 Degrees F
T 3 = 873.9927 Degrees F
T 4 = 198.1542 Degrees F
T 5 = 70.0000 Degrees F

AT t = 74.0 SECONDS

T 1 = 1630.4530 Degrees F
T 2 = 1152.0980 Degrees F
T 3 = 883.1892 Degrees F
T 4 = 198.4380 Degrees F
T 5 = 70.0000 Degrees F

AT t = 75.0 SECONDS

T 1 = 1638.4690 Degrees F
T 2 = 1161.9080 Degrees F
T 3 = 892.2151 Degrees F
T 4 = 198.5654 Degrees F
T 5 = 70.0000 Degrees F

AT t = 76.0 SECONDS

T 1 = 1646.3400 Degrees F

T 2 = 1171.5710 Degrees F
T 3 = 901.0704 Degrees F
T 4 = 198.5390 Degrees F
T 5 = 70.0000 Degrees F

AT t = 77.0 SECONDS

T 1 = 1654.0650 Degrees F
T 2 = 1181.0850 Degrees F
T 3 = 909.7545 Degrees F
T 4 = 198.3623 Degrees F
T 5 = 70.0000 Degrees F

AT t = 78.0 SECONDS

T 1 = 1661.6450 Degrees F
T 2 = 1190.4510 Degrees F
T 3 = 918.2679 Degrees F
T 4 = 198.0403 Degrees F
T 5 = 70.0000 Degrees F

AT t = 79.0 SECONDS

T 1 = 1669.0820 Degrees F
T 2 = 1199.6690 Degrees F
T 3 = 926.6109 Degrees F
T 4 = 197.5785 Degrees F
T 5 = 70.0000 Degrees F

AT t = 80.0 SECONDS

T 1 = 1676.3740 Degrees F
T 2 = 1208.7390 Degrees F
T 3 = 934.7842 Degrees F
T 4 = 196.9838 Degrees F
T 5 = 70.0000 Degrees F

AT t = 81.0 SECONDS

T 1 = 1683.5240 Degrees F
T 2 = 1217.6610 Degrees F
T 3 = 942.7888 Degrees F
T 4 = 196.2634 Degrees F
T 5 = 70.0000 Degrees F

AT t = 82.0 SECONDS

T 1 = 1690.5300 Degrees F
T 2 = 1226.4340 Degrees F
T 3 = 950.6255 Degrees F
T 4 = 195.4254 Degrees F
T 5 = 70.0000 Degrees F

AT t = 83.0 SECONDS

T 1 = 1697.3940 Degrees F
T 2 = 1235.0590 Degrees F
T 3 = 958.2960 Degrees F
T 4 = 194.4783 Degrees F
T 5 = 70.0000 Degrees F

AT t = 84.0 SECONDS

T 1 = 1704.1150 Degrees F
T 2 = 1243.5360 Degrees F
T 3 = 965.8016 Degrees F
T 4 = 193.4308 Degrees F
T 5 = 70.0000 Degrees F

AT t = 85.0 SECONDS

T 1 = 1710.6950 Degrees F
T 2 = 1251.8650 Degrees F
T 3 = 973.1443 Degrees F
T 4 = 192.2921 Degrees F
T 5 = 70.0000 Degrees F

AT t = 86.0 SECONDS

T 1 = 1717.1320 Degrees F
T 2 = 1260.0450 Degrees F
T 3 = 980.3259 Degrees F
T 4 = 191.0710 Degrees F
T 5 = 70.0000 Degrees F

AT t = 87.0 SECONDS

T 1 = 1723.4270 Degrees F

T 2 = 1268.0770 Degrees F
T 3 = 987.3484 Degrees F
T 4 = 189.7768 Degrees F
T 5 = 70.0000 Degrees F

AT t = 88.0 SECONDS

T 1 = 1729.5800 Degrees F
T 2 = 1275.9600 Degrees F
T 3 = 994.2143 Degrees F
T 4 = 188.4182 Degrees F
T 5 = 70.0000 Degrees F

AT t = 89.0 SECONDS

T 1 = 1735.5920 Degrees F
T 2 = 1283.6970 Degrees F
T 3 = 1000.9250 Degrees F
T 4 = 187.0040 Degrees F
T 5 = 70.0000 Degrees F

AT t = 90.0 SECONDS

T 1 = 1741.4620 Degrees F
T 2 = 1291.2850 Degrees F
T 3 = 1007.4850 Degrees F
T 4 = 185.5426 Degrees F
T 5 = 70.0000 Degrees F

AT t = 91.0 SECONDS

T 1 = 1747.1910 Degrees F
T 2 = 1298.7270 Degrees F
T 3 = 1013.8940 Degrees F
T 4 = 184.0418 Degrees F
T 5 = 70.0000 Degrees F

AT t = 92.0 SECONDS

T 1 = 1752.7790 Degrees F
T 2 = 1306.0210 Degrees F
T 3 = 1020.1560 Degrees F
T 4 = 182.5093 Degrees F
T 5 = 70.0000 Degrees F

AT t = 93.0 SECONDS

T 1 = 1758.0600 Degrees F
T 2 = 1313.1610 Degrees F
T 3 = 1026.2730 Degrees F
T 4 = 180.9522 Degrees F
T 5 = 70.0000 Degrees F

AT t = 94.0 SECONDS

T 1 = 1771.1510 Degrees F
T 2 = 1320.5610 Degrees F
T 3 = 1032.2840 Degrees F
T 4 = 179.3779 Degrees F
T 5 = 70.0000 Degrees F

AT t = 95.0 SECONDS

T 1 = 1791.2160 Degrees F
T 2 = 1328.5620 Degrees F
T 3 = 1038.2520 Degrees F
T 4 = 177.7917 Degrees F
T 5 = 70.0000 Degrees F

AT t = 96.0 SECONDS

T 1 = 1817.5340 Degrees F
T 2 = 1337.4320 Degrees F
T 3 = 1044.2550 Degrees F
T 4 = 176.1954 Degrees F
T 5 = 70.0000 Degrees F

AT t = 97.0 SECONDS

T 1 = 1849.4840 Degrees F
T 2 = 1347.3840 Degrees F
T 3 = 1050.3810 Degrees F
T 4 = 174.5863 Degrees F
T 5 = 70.0000 Degrees F

AT t = 98.0 SECONDS

T 1 = 1890.6260 Degrees F

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T 2 = 1358.7940 Degrees F
T 3 = 1056.7400 Degrees F
T 4 = 172.9584 Degrees F
T 5 = 70.0000 Degrees F

AT t = 99.0 SECONDS

T 1 = 1926.6260 Degrees F
T 2 = 1371.2510 Degrees F
T 3 = 1063.3880 Degrees F
T 4 = 171.2995 Degrees F
T 5 = 70.0000 Degrees F

AT t = 100.0 SECONDS

T 1 = 1958.1770 Degrees F
T 2 = 1384.4140 Degrees F
T 3 = 1070.3490 Degrees F
T 4 = 169.5961 Degrees F
T 5 = 70.0000 Degrees F

AT t = 101.0 SECONDS

T 1 = 1985.8530 Degrees F
T 2 = 1398.0120 Degrees F
T 3 = 1077.6200 Degrees F
T 4 = 167.8360 Degrees F
T 5 = 70.0000 Degrees F

AT t = 102.0 SECONDS

T 1 = 2010.1340 Degrees F
T 2 = 1411.8250 Degrees F
T 3 = 1085.1800 Degrees F
T 4 = 166.0099 Degrees F
T 5 = 70.0000 Degrees F

AT t = 103.0 SECONDS

T 1 = 2031.4200 Degrees F
T 2 = 1425.6810 Degrees F
T 3 = 1092.9960 Degrees F
T 4 = 164.1123 Degrees F
T 5 = 70.0000 Degrees F

AT t = 104.0 SECONDS

T 1 = 2050.0480 Degrees F
T 2 = 1439.4400 Degrees F
T 3 = 1101.0280 Degrees F
T 4 = 162.1416 Degrees F
T 5 = 70.0000 Degrees F

AT t = 105.0 SECONDS

T 1 = 2066.3020 Degrees F
T 2 = 1452.9950 Degrees F
T 3 = 1109.2300 Degrees F
T 4 = 160.0997 Degrees F
T 5 = 70.0000 Degrees F

AT t = 106.0 SECONDS

T 1 = 2080.4210 Degrees F
T 2 = 1466.2600 Degrees F
T 3 = 1117.5560 Degrees F
T 4 = 157.9924 Degrees F
T 5 = 70.0000 Degrees F

AT t = 107.0 SECONDS

T 1 = 2092.6130 Degrees F
T 2 = 1479.1690 Degrees F
T 3 = 1125.9600 Degrees F
T 4 = 155.8278 Degrees F
T 5 = 70.0000 Degrees F

AT t = 108.0 SECONDS

T 1 = 2103.0510 Degrees F
T 2 = 1491.6720 Degrees F
T 3 = 1134.3980 Degrees F
T 4 = 153.6165 Degrees F
T 5 = 70.0000 Degrees F

AT t = 109.0 SECONDS

T 1 = 2111.8860 Degrees F

T 2 = 1503.7290 Degrees F
T 3 = 1142.8260 Degrees F
T 4 = 151.3705 Degrees F
T 5 = 70.0000 Degrees F

AT t = 110.0 SECONDS

T 1 = 2119.2500 Degrees F
T 2 = 1515.3120 Degrees F
T 3 = 1151.2050 Degrees F
T 4 = 149.1027 Degrees F
T 5 = 70.0000 Degrees F

AT t = 111.0 SECONDS

T 1 = 2125.2530 Degrees F
T 2 = 1526.3990 Degrees F
T 3 = 1159.5000 Degrees F
T 4 = 146.8264 Degrees F
T 5 = 70.0000 Degrees F

AT t = 112.0 SECONDS

T 1 = 2129.9950 Degrees F
T 2 = 1536.9760 Degrees F
T 3 = 1167.6760 Degrees F
T 4 = 144.5547 Degrees F
T 5 = 70.0000 Degrees F

AT t = 113.0 SECONDS

T 1 = 2133.5610 Degrees F
T 2 = 1547.0330 Degrees F
T 3 = 1175.7050 Degrees F
T 4 = 142.3001 Degrees F
T 5 = 70.0000 Degrees F

AT t = 114.0 SECONDS

T 1 = 2136.0260 Degrees F
T 2 = 1556.5630 Degrees F
T 3 = 1183.5600 Degrees F
T 4 = 140.0745 Degrees F
T 5 = 70.0000 Degrees F

AT t = 115.0 SECONDS

T 1 = 2137.4550 Degrees F
T 2 = 1565.5640 Degrees F
T 3 = 1191.2180 Degrees F
T 4 = 137.8886 Degrees F
T 5 = 70.0000 Degrees F

AT t = 116.0 SECONDS

T 1 = 2137.9080 Degrees F
T 2 = 1574.0330 Degrees F
T 3 = 1198.6570 Degrees F
T 4 = 135.7518 Degrees F
T 5 = 70.0000 Degrees F

AT t = 117.0 SECONDS

T 1 = 2137.4360 Degrees F
T 2 = 1581.9730 Degrees F
T 3 = 1205.8600 Degrees F
T 4 = 133.6724 Degrees F
T 5 = 70.0000 Degrees F

AT t = 118.0 SECONDS

T 1 = 2136.0860 Degrees F
T 2 = 1589.3850 Degrees F
T 3 = 1212.8120 Degrees F
T 4 = 131.6575 Degrees F
T 5 = 70.0000 Degrees F

AT t = 119.0 SECONDS

T 1 = 2133.8970 Degrees F
T 2 = 1596.2710 Degrees F
T 3 = 1219.4980 Degrees F
T 4 = 129.7129 Degrees F
T 5 = 70.0000 Degrees F

AT t = 120.0 SECONDS

T 1 = 2130.9080 Degrees F

```
T  2 =   1602.6360 Degrees F
T  3 =   1225.9070 Degrees F
T  4 =    127.8433 Degrees F
T  5 =     70.0000 Degrees F
```

APPENDIX D

SOURCE CODE AND SUBROUTINES

```
C  ************************************************************************
C  *                                                                      *
C  *              THERMAL CURTAIN ANALYSIS PROGRAM                        *
C  *                       Version 1.20                                   *
C  *                  Coded by Dale E. Matthews                           *
C  *                       September 1990                                 *
C  *                                                                      *
C  *                    Applied Thermal Section                           *
C  *                  Southern Research Institute                         *
C  *                     Birmingham, Alabama                              *
C  *                                                                      *
C  *                                                                      *
C  ************************************************************************

      INTERFACE TO SUBROUTINE LETTER [C] ()

      END

      INTERFACE TO SUBROUTINE CAPS [C] ()

      END

      INCLUDE 'FGRAPH.FI'

      INCLUDE 'FGRAPH.FD'

      REAL T[ALLOCATABLE](:),TMOD[ALLOCATABLE](:),K[ALLOCATABLE](:,:)

      REAL C[ALLOCATABLE](:,:),P[ALLOCATABLE](:),A[ALLOCATABLE](:,:)

      REAL W,Z,Q,DX,DX2,DT,DT2,TINC,TF

      INTEGER I,J,N,COUNT,NODE_ID[ALLOCATABLE](:),NUMK,NUMC,L

      INTEGER ISCOMP[ALLOCATABLE](:),NUMP

      INTEGER*2 X1,X2,Y1,Y2,D2

      CHARACTER*30 OUTPUT,SPRD,STR30

      CHARACTER*1 COMP[ALLOCATABLE](:),ASK

      CHARACTER STR*2,STR2*12,BEEP,STR5*5,STR8*8,STRA*2,STRB*2

      CHARACTER*12 TYPE[ALLOCATABLE](:)

      RECORD /RCCOORD /CURPOS

      RECORD /VIDEOCONFIG/VC

C     Function statements for heat flux

      QQ1(X)=(0.120*X+13.90)*3600
      QQ2(X)=(19.643-0.071*X)*3600
      QQ3(X)=(1.850*X-159.050)*3600
      QQ4(X)=(-0.433*X+65.682)*3600


      CALL GETVIDEOCONFIG(VC)

      X1=(VC.NUMTEXTCOLS)/15
      X2=X1*4
      Y1=(VC.NUMTEXTROWS)/5
      Y2=Y1*15

      D2=SETBKCOLOR(7)
```

```
   CALL CLEARSCREEN($GCLEARSCREEN)
   D2=SETBKCOLOR(4)
   D2=SETTEXTCOLOR(15)
   CALL SETTEXTWINDOW(X1+18,Y1,X2+2,Y2)
   CALL CLEARSCREEN($GWINDOW)
   CALL SETTEXTPOSITION(X1+10,Y1+9,CURPOS)
   CALL OUTTEXT('Developed by Southern Research Institute')
   D2=SETBKCOLOR(1)
   CALL SETTEXTWINDOW(X1-2,Y1,X2,Y2)
   D2=SETTEXTCOLOR(15)
   CALL CLEARSCREEN($GWINDOW)
   CALL SETTEXTPOSITION(X1-3,Y1+8,CURPOS)
   CALL OUTTEXT('AFT SKIRT THERMAL CURTAIN ANALYSIS PROGRAM')
   CALL SETTEXTPOSITION(X1-1,Y1+6,CURPOS)
   CALL OUTTEXT('To use this program, you will be asked to enter')
   CALL SETTEXTPOSITION(X1+1,Y1+6,CURPOS)
   CALL OUTTEXT('a blanket construction configuration code and to')
   CALL SETTEXTPOSITION(X1+3,Y1+6,CURPOS)
   CALL OUTTEXT('specify an output file for both a spreadsheet file
$')
   CALL SETTEXTPOSITION(X1+5,Y1+6,CURPOS)
   CALL OUTTEXT('and a text file. ')
   CALL SETTEXTPOSITION(X1+11,Y1+17,CURPOS)
   CALL OUTTEXT('Press a key to begin.......')
   CALL LETTER()

   CALL GETTIM(IHR1,IMIN1,ISEC1,I100TH1)
   CALL CLEARSCREEN($GWINDOW)
   D2=SETBKCOLOR(4)
   D2=SETTEXTCOLOR(15)
   CALL SETTEXTWINDOW(X1+18,Y1,X2+2,Y2)
   CALL CLEARSCREEN($GWINDOW)
   CALL SETTEXTPOSITION(X1+12,Y1+4,CURPOS)
   CALL OUTTEXT('Aft Skirt Thermal Curtain Analysis Program   SRI 19
```

```
$90')
      CALL SETTEXTWINDOW(X1-2,Y1,X2,Y2)
      D2=SETBKCOLOR(1)
      CALL CLEARSCREEN($GWINDOW)

      CALL SETTEXTPOSITION(X1-1,Y1+6,CURPOS)
      CALL OUTTEXT('Name of output file? --------> ')
      CALL SETTEXTPOSITION(X1,Y1+6,CURPOS)
      CALL OUTTEXT('(include drive spec)')
      CALL SETTEXTPOSITION(X1-1,Y1+37,CURPOS)
      READ(*,'(A)')OUTPUT
      CALL SETTEXTPOSITION(X1+3,Y1+6,CURPOS)
      CALL OUTTEXT('Name of spreadsheet file? ---> ')
      CALL SETTEXTPOSITION(X1+4,Y1+6,CURPOS)
      CALL OUTTEXT('(include drive spec)')
      CALL SETTEXTPOSITION(X1+3,Y1+37,CURPOS)
      READ(*,'(A)')SPRD
      CALL SETTEXTPOSITION(X1+7,Y1+6,CURPOS)
      CALL OUTTEXT('Number of blanket layers? ---> ')
      READ*,N
      CALL SETTEXTPOSITION(X1+10,Y1+6,CURPOS)
      CALL OUTTEXT('Thickness (in inches) of')
      CALL SETTEXTPOSITION(X1+11,Y1+6,CURPOS)
      CALL OUTTEXT('each blanket layer? ---------> ')
      READ*,DX

      CALL CLEARSCREEN($GWINDOW)

C     Open datafiles containing polynomial coefficients for the conductivity,
C     heat capacity, and density curves.

      OPEN(6,FILE='KDATA')
      OPEN(7,FILE='CDATA')
      OPEN(8,FILE='PDATA')
      OPEN(10,FILE=OUTPUT)
      OPEN(11,FILE=SPRD)

C     The first entry in each datafile is the order+1 of the curve.
C     It is read here.

      READ(6,*)NUMK
```

```
      READ(7,*)NUMC
      READ(8,*)NUMP

C     Allocate memory to the thermal property arrays.

      ALLOCATE(K(NUMK,4),C(NUMC,4),P(NUMP))

C     Read the thermal property coefficients

      DO 5 I=1,NUMK
      READ(6,*)(K(I,J),J=1,4)
5     CONTINUE

      DO 10 I=1,NUMC
      READ(7,*)(C(I,J),J=1,4)
10    CONTINUE

      DO 15 I=1,NUMP
      READ(8,*)P(I)
15    CONTINUE

C     Initializations

      DX=DX/12.0
      DX2=DX**2
      TINC=0.000
      DT=1.0/3600.0
      DT2=2*DT
      COUNT=0
      BEEP=CHAR(07)

      D2=SETBKCOLOR(3)

      D2=SETTEXTCOLOR(5)

      CALL SETTEXTWINDOW(X1+5,Y1+6,X1+9,Y2-6)

      CALL CLEARSCREEN($GWINDOW)

      WRITE(*,*)BEEP

      CALL SETTEXTPOSITION(X1-2,Y1+12,CURPOS)

      CALL OUTTEXT('LOCK CAPS BEFORE PROCEEDING')

      CALL CAPS()

      D2=SETBKCOLOR(1)

      D2=SETTEXTCOLOR(15)

      CALL SETTEXTWINDOW(X1-2,Y1,X2,Y2)

      CALL CLEARSCREEN($GWINDOW)

C     Allocate memory to the matrix terms and node identification variables.

      ALLOCATE(A(N,N),T(N+1),TMOD(N+1),COMP(N),ISCOMP(N),TYPE(N))
      ALLOCATE(NODE_ID(N))

C     Initialize matrix coefficients at zero and temperatures at 70 F.
```

```
      DO 21 I=1,N
      DO 20 J=1,N
      A(I,J)=0.00
20    CONTINUE
21    CONTINUE

      DO 22 I=1,N+1
      T(I)=70.000
22     CONTINUE


C     Fix back-face node at 70 F

      TF=T(N+1)
      TMOD(N+1)=70.00


C     Prompt the user for description of the blanket.

23    CONTINUE

      DO 24 I=1,N

      CALL SETTEXTPOSITION(X1-3,Y1+3,CURPOS)

      CALL OUTTEXT('You now need to enter the composition of the blanke
     $t.')

      CALL SETTEXTPOSITION(X1-1,Y1-1,CURPOS)

      CALL OUTTEXT('Using the following codes, enter the composition of
     $ the blanket.')

      CALL SETTEXTPOSITION(X1+1,Y1+7,CURPOS)

      CALL OUTTEXT('Begin with the high-temperature (nozzle) side.')


      CALL SETTEXTPOSITION(X1+5,Y1+24,CURPOS)
      CALL OUTTEXT('A = Kevlar')
      CALL SETTEXTPOSITION(X1+6,Y1+24,CURPOS)
      CALL OUTTEXT('B = E-glass')
      CALL SETTEXTPOSITION(X1+7,Y1+24,CURPOS)
      CALL OUTTEXT('C = Quartz')
      CALL SETTEXTPOSITION(X1+8,Y1+24,CURPOS)
      CALL OUTTEXT('D = Fiberfrax')

      IF (I.EQ.1)THEN
      CALL SETTEXTPOSITION(X1+10,Y1+14,CURPOS)
      CALL OUTTEXT('Press ENTER when ready to continue')
      READ(*,*)
      CALL SETTEXTPOSITION(X1+10,Y1+14,CURPOS)
      CALL OUTTEXT('                                        ')
      ELSE
      END IF

      CALL SETTEXTPOSITION(X1+12,Y1+6,CURPOS)

      WRITE(STR,'(I2)')I

      CALL OUTTEXT('Material code for blanket layer '//STR//'----->')

      READ(*,'(A)')COMP(I)

      CALL CLEARSCREEN($GWINDOW)
```

```
24      CONTINUE

        DO 28 I=1,N
           IF(COMP(I).EQ.'A')THEN
           TYPE(I)='Kevlar'
           ELSE IF(COMP(I).EQ.'B')THEN
           TYPE(I)='E-glass'
           ELSE IF(COMP(I).EQ.'C')THEN
           TYPE(I)='Quartz'
           ELSE IF(COMP(I).EQ.'D')THEN
           TYPE(I)='Fiberfrax'
           ELSE


           D2=SETBKCOLOR(3)
           D2=SETTEXTCOLOR(5)
           CALL SETTEXTWINDOW(X1+5,Y1+6,X1+9,Y2-6)
           CALL CLEARSCREEN($GWINDOW)
           CALL SETTEXTPOSITION(X1-2,Y1+12,CURPOS)
           WRITE(*,*)BEEP
           WRITE(STR,'(A)')COMP(I)

           CALL OUTTEXT('Unrecognized material ID code: '//STR)
           READ(*,*)
           CALL CLEARSCREEN($GWINDOW)
           D2=SETBKCOLOR(1)
           D2=SETTEXTCOLOR(15)
           CALL SETTEXTWINDOW(X1-2,Y1,X2,Y2)
           CALL CLEARSCREEN($GWINDOW)

           GO TO 23
           END IF
28      CONTINUE
1280    CONTINUE

        CALL CLEARSCREEN($GWINDOW)

        CALL SETTEXTPOSITION(X1-3,Y1+13,CURPOS)

        CALL OUTTEXT('BLANKET CONSTRUCTION VERIFICATION')


        L=1
        DO 29 I=1,N
        CALL SETTEXTPOSITION(X1-2+L,Y1+13,CURPOS)

        IF(MOD(I,13).EQ.0)THEN
        CALL SETTEXTPOSITION(X1+12,Y1+13,CURPOS)
        CALL OUTTEXT('Press ENTER for more')
        READ(*,*)
        CALL CLEARSCREEN($GWINDOW)
        CALL SETTEXTPOSITION(X1-3,Y1+8,CURPOS)
        CALL OUTTEXT('BLANKET CONSTRUCTION VERIFICATION (continued)')
        L=0
        CALL SETTEXTPOSITION(X1-1,Y1+13,CURPOS)

        ELSE
        END IF


        WRITE(STR,'(I2)')I
        WRITE(STR2,'(A)')TYPE(I)
        CALL OUTTEXT('Layer '//STR//' of the blanket is '//STR2)
        L=L+1
29      CONTINUE
```

```
30      CALL SETTEXTPOSITION(X1-3+(2*7+1),Y1+17,CURPOS)

        CALL OUTTEXT('Are these correct (y/n) ? ')

        READ(*,'(A)')ASK

        IF(ASK.EQ.'Y')THEN
        CONTINUE
        ELSE IF(ASK.EQ.'N')THEN
        CALL CLEARSCREEN($GWINDOW)
        GO TO 23
        ELSE
           D2=SETBKCOLOR(3)
           D2=SETTEXTCOLOR(5)
           CALL SETTEXTWINDOW(X1+5,Y1+6,X1+9,Y2-6)
           CALL CLEARSCREEN($GWINDOW)
           CALL SETTEXTPOSITION(X1-2,Y1+12,CURPOS)
           WRITE(*,*)BEEP
           WRITE(STR,'(A)')ASK

           CALL OUTTEXT('Invalid response: '//STR)
           READ(*,*)
           CALL CLEARSCREEN($GWINDOW)
           D2=SETBKCOLOR(1)
           D2=SETTEXTCOLOR(15)
           CALL SETTEXTWINDOW(X1-2,Y1,X2,Y2)
           CALL CLEARSCREEN($GWINDOW)
         GO TO 1280
        END IF

        CALL CLEARSCREEN($GWINDOW)

C       This loop determines whether or not each node is composite.

        ISCOMP(1)=0

        DO 31 I=1,N-1
           IF(COMP(I).EQ.COMP(I+1))THEN
           ISCOMP(I+1)=0
           ELSE
           ISCOMP(I+1)=1
           END IF
31      CONTINUE


C       This loop assigns an identification integer to each node.

        DO 35 I=1,N
           IF(COMP(I).EQ.'A')THEN
           NODE_ID(I)=1
           ELSE IF(COMP(I).EQ.'B')THEN
           NODE_ID(I)=2
           ELSE IF(COMP(I).EQ.'C')THEN
           NODE_ID(I)=3
           ELSE IF(COMP(I).EQ.'D')THEN
           NODE_ID(I)=4
           ELSE
           END IF
35      CONTINUE


        WRITE(10,300)N
300     FORMAT(//20X,'RESULTS OF HEAT TRANSFER ANALYSIS FOR A THERMAL BLAN
       $KET '
       $/20X,'CONSISTING OF ',I2,' LAYERS OF THE FOLLOWING COMPOSITIONS:'/
```

```
     $/)

       DO 36 I=1,N
       WRITE(10,301)I,TYPE(I)
301    FORMAT(30X,'Layer ',I2,' is ',A)
36     CONTINUE

       WRITE(10,302)
302    FORMAT(//20X,'where layer 1 is the high-temperature side.'///)


       DEALLOCATE(COMP)


C      The actual analysis begins here.


40     TINC=TINC+1.00
       COUNT=COUNT+1


C      Determine the heat flux for the current time.

       IF(TINC.LT.30)THEN
       Q=QQ1(TINC)
       ELSE IF(TINC.GE.30.AND.TINC.LT.93)THEN
       Q=QQ2(TINC)
       ELSE IF(TINC.GE.93.AND.TINC.LT.98)THEN
       Q=QQ3(TINC)
       ELSE
       Q=QQ4(TINC)
       END IF


C      The matrix coefficients are determined here.


45     W=TF*(2*PN(K,TF,NODE_ID(N),NUMK)*DT) / (( P(NODE_ID(N-1))*PN(C,
     $ TF,NODE_ID(N-1),NUMC) + P(NODE_ID(N))*PN(C,TF,NODE_ID(N),NUMC))
     $  *DX2)


       Z=(2*Q*DT)/(P(NODE_ID(1))*PN(C,T(1),NODE_ID(1),NUMC)*DX)


       A(1,1)= 1.00 + ((2*PN(K,T(1),NODE_ID(1),NUMK)*DT)/(P(NODE_ID(1))*
     $ PN(C,T(1),NODE_ID(1),NUMC)*DX2))



       A(1,2)= -(2*PN(K,T(2),NODE_ID(1),NUMK)*DT) / (P(NODE_ID(1))*PN(C,
     $ T(2),NODE_ID(1),NUMC)*DX2)



       DO 50 I=2,N


C      Composite node terms.


        A(I,I-1)=-(2*PN(K,T(I-1),NODE_ID(I-1),NUMK)*DT) /

     $ ((P(NODE_ID(I-1))*PN(C,T(I-1),NODE_ID(I-1),NUMC) + P(NODE_ID(I))*
```

```
     $  PN(C,T(I-1),NODE_ID(I),NUMC))*DX2)


        A(I,I)=((DT2)/((P(NODE_ID(I-1))*PN(C,T(I),NODE_ID(I-1),NUMC)
     $ +P(NODE_ID(I))*PN(C,T(I),NODE_ID(I),NUMC))*DX))*
     $  (((PN(K,T(I),NODE_ID(I-1),NUMK)+PN(K,T(I),NODE_ID(I),NUMK))/DX)
     $  + ((P(NODE_ID(I-1))*PN(C,T(I),NODE_ID(I-1),NUMC)+P(NODE_ID(I))
     $  * PN(C,T(I),NODE_ID(I),NUMC))*DX)/(DT2))


        IF(I.LT.N)THEN
        A(I,I+1)=-(2*PN(K,T(I+1),NODE_ID(I),NUMK)*DT)/((P(NODE_ID(I-1))
     $ *PN(C,T(I+1),NODE_ID(I),NUMC)+P(NODE_ID(I))*PN(C,T(I+1),
     $  NODE_ID(I),NUMC))*DX2)
        ELSE
        END IF
50      CONTINUE


        T(1)=T(1)+Z
        T(N)=T(N)+W


C       Solve the matrix.
        CALL TRIDIAG(A,T,N,TMOD)


        DO 55 I=1,N
        T(I)=TMOD(I)
55      CONTINUE

100     CONTINUE

        WRITE(10,216)TINC
216     FORMAT(4(/),25X,'AT t = ',F5.1,' SECONDS'//)


        CALL SETTEXTPOSITION(X1-3,Y1+17,CURPOS)
        WRITE(STR5,'(F5.1)')TINC
        CALL OUTTEXT('At t = '//STR5//' seconds;')

        WRITE(11,261,ERR=119)TINC,(T(I),I=1,N+1)
261     FORMAT(F5.1,',',30(F8.3,','),F8.3)
119     CONTINUE

        DO 120 I=1,N+1
        CALL SETTEXTPOSITION(X1-2+I,Y1+15,CURPOS)
        WRITE(STR8,'(F8.3)')T(I)
        WRITE(STR,'(I2)')I
        CALL OUTTEXT('T '//STR//' = '//STR8//' degrees F')
        WRITE(10,217)I,T(I)
217     FORMAT(30X,'T ',I2,' = ',F11.4,' Degrees F')

120     CONTINUE
```

```
IF(TINC.LT.120)GOTO 40


CALL GETTIM(IHR2,IMIN2,ISEC2,I100TH2)

IF(ISEC2.LT.ISEC1)THEN
ISEC2=ISEC2+60
IMIN2=IMIN2-1
ELSE
END IF

IF(IMIN2.LT.IMIN1)THEN
IMIN2=IMIN2+60
IHR2=IHR2-1
ELSE
END IF

IHR=IHR2-IHR1
IMIN=IMIN2-IMIN1
ISEC=ISEC2-ISEC1
I100TH=I100TH2-I100TH1

CALL CLEARSCREEN($GWINDOW)

CALL SETTEXTPOSITION(X1+1,Y1+13,CURPOS)

WRITE(STR,'(I2)')IHR

WRITE(STRA,'(I2)')IMIN

WRITE(STRB,'(I2)')ISEC

CALL OUTTEXT('Total CPU time :'//STR//':'//STRA//':'//STRB)

CALL SETTEXTPOSITION(X1+5,Y1+13,CURPOS)

WRITE(STR30,'(A)')OUTPUT

CALL OUTTEXT('Results are in textfile '//STR30)

CALL SETTEXTPOSITION(X1+7,Y1+13,CURPOS)

WRITE(STR30,'(A)')SPRD

CALL OUTTEXT('and in spreadsheet file '//STR30)

CALL SETTEXTPOSITION(X1+12,Y1+13,CURPOS)

CALL OUTTEXT('Press a key to exit.......')

CALL LETTER()

D2=SETVIDEOMODE($DEFAULTMODE)

END
```

```
      SUBROUTINE TRIDIAG(A,S,N,X)

C     Subroutine to solve a tridiagonal (only) matrix.

C     Developed by Dale E. Matthews
C     Applied Thermal Section
C     Southern Research Institue
C     Birmingham, Alabama


      REAL A(N,N),S(N),X(N)
      INTEGER I,N

      DO 20 I=1,N-1
      A(I+1,I+1)=A(I+1,I+1)-((A(I+1,I)*A(I,I+1))/A(I,I))
      S(I+1)=S(I+1)-((A(I+1,I)*S(I))/A(I,I))
20    CONTINUE

      X(N)=S(N)/A(N,N)

      DO 30 I=N-1,1,-1
      X(I)=(S(I)-A(I,I+1)*X(I+1))/A(I,I)
30    CONTINUE

      RETURN
      END
```

```
      FUNCTION PN(X,T,J,ORDER)

C     This subroutine takes the coefficients of a polynomial from
C     a datafile and evaluates the polynomial, using the variable
C     "T" as it's argument.

C     Developed by Dale E. Matthews
C     Applied Thermal Section
C     Southern Research Institute
C     Birmingham, Alabama


      REAL SUM,T
      INTEGER J,ORDER
      DIMENSION X(ORDER,4)

      SUM=0.00

      DO 10 I=1,ORDER

      SUM=SUM+X(I,J)*(T**(I-1))

10    CONTINUE

      PN=SUM

      RETURN

      END
```

APPENDIX E

CODE OPERATING INSTRUCTIONS

This program will run on any IBM or compatible computer having a standard amount of memory (640K). It has not been tested on computers having less memory, but it does not require an extensive amount of memory and should run on machines having 512K or maybe less. A math co-processor is recommended but not required. It will also run directly off of the diskette on which it came, but will run considerably faster if it is copied (with the three accompanying datafiles) to a hard drive and run from it.

To run the program, make the drive/directory containing the program and datafiles (they must exist in the same directory) the current directory and type "ASTC". After a brief introduction, you will be prompted for two datafile names, one of which is for a text file containing the results of the program for easy review, the other being a spreadsheet file containing the results in comma-separated ASCII format for easy importation to most spreadsheets, including Lotus, Supercalc, or Harvard Graphics. The datafiles may be written to any drive or directory by including the drive/directory specification in the filename specified, for example, to name the textfile "OUTPUT.TXT" and write it to the A:> drive, enter "A:\OUTPUT.TXT" at the textfile prompt. The spreadsheet file works the same way. Do not specify the same name for both files.

The next several prompts will be for the thermal curtain configuration to be analyzed. After the number of curtain layers and their thickness has been entered (if they differ, use an average), a menu will be displayed listing the material codes for Quartz, E-glass,Fiberfrax, and Kevlar. It will ask for each layer beginning at the high temperature side, so simply enter the code (A,B,C, or D) for the composition of each layer. It will then display what has been entered for verification, allowing for changes if necessary, and then begin the analysis.

Once the program has finished the analysis, it will display again where the output has been placed for retrieval.