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MINIVER UPGRADE FOR THE AVID SYSTEM

VOLUME III: EXITS USER'S AND INPUT GUIDE

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FOREWORD

This final report presents work which was conducted for Langley Research Center (LaRC) in response to requirements of Contract NAS1-16983. The work presented was performed by REMTECH, Inc., Huntsville, Alabama and is entitled ''MINIVER Upgrade For The AVID System''. The final report consists of three volumes.

VOLUME 1: LANMIN User's Manual

VOLUME 2: LANMIN Input Guide

VOLUME 3: EXITS User's and Input Guide

The NASA technical coordination for this study was provided by Ms. Kathryn E. Wurster of the Vehicle Analysis Branch of the Space Systems Division.

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Section 1.0

INTRODUCTION

The EXITS code described in this document is a thermal analysis tool which allows the user to rapidly predict thermal protection system performance for advanced space transportation vehicle reentry. Design and weights optimization can be accomplished by repeated analysis within the constraints and guidelines of system performance.

EXITS is designed to run interactively on a small or mainframe computing system in conjunction with the LANMIN code. LANMIN, as described in Volume I and II is run, given a trajectory, geometry, heating rate methods, etc., to provide an input file containing the thermal environment information needed for the body points specified. Information flow for this process is depicted in Figure 1.1.

The user then calls EXITS in an interactive mode and sets certain input parameters, start time, end time, print time, etc. and defines the TPS structure by selecting structure types from a menu presented to him. In its present form, the menu contains seven different structure types, including an ablator, slab, radiation gap, etc. By stacking these structures, the entire TPS is defined and a nodal mesh is automatically generated. EXITS thus uses the LANMIN generated input file and calculates the temperature history of each node through the structure.

During the calculation, all of the heats are integrated and printed out. These include the convected, reradiated, sensible heat, ablated heat, and advected heat. A total energy balance is made to determine the method's conservation.

EXITS uses an explicit (Euler) integration of the energy equation using equivalent radiation conductors where internal or reradiation exists. An abla-

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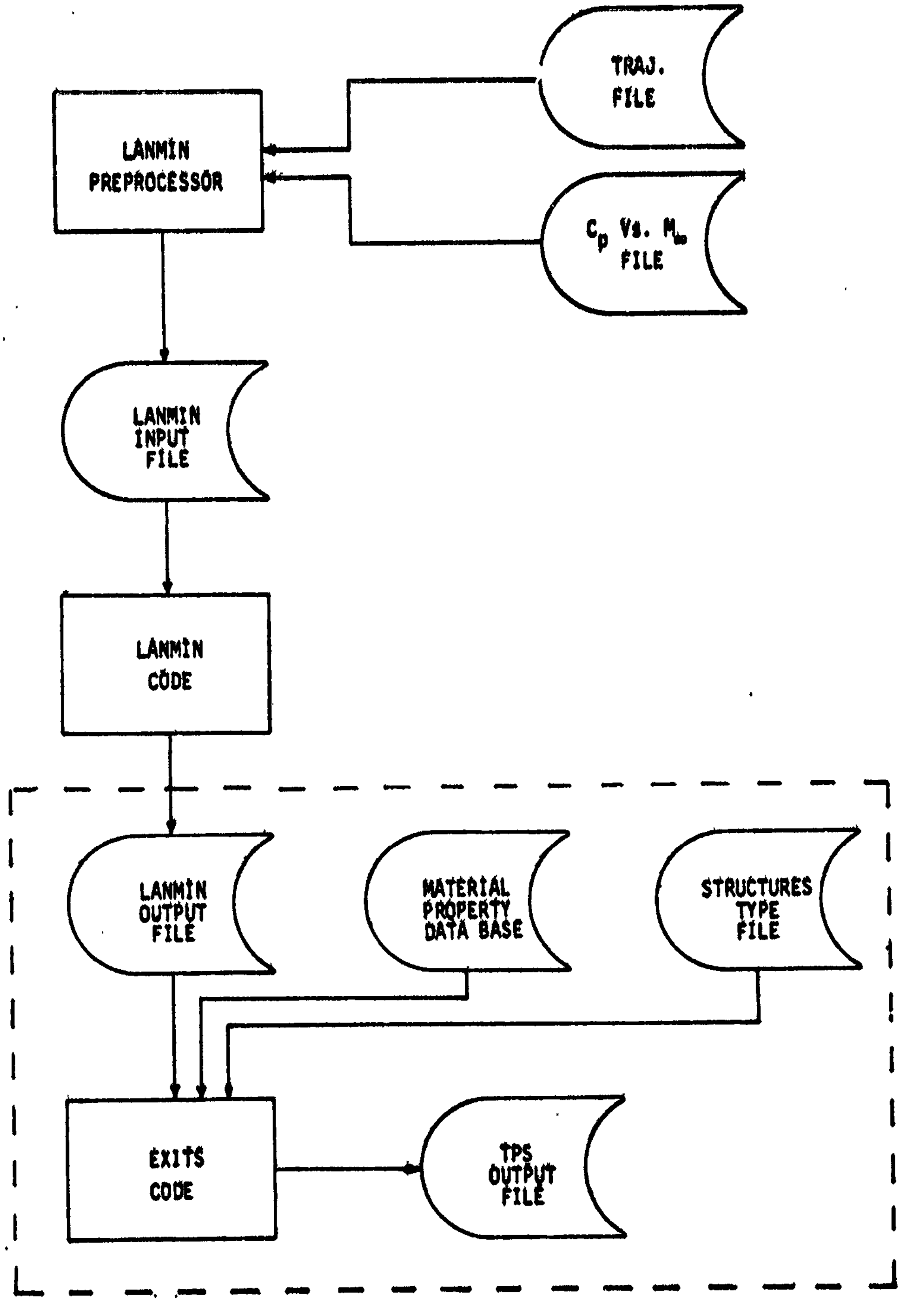


Fig. 1.1 Information Flow For Thermal Protection System Analysis

tion routine has been included using a simple ablator-sublimer model which includes the latent heat and heat required for the moving interface (advected). For materials with high thermal conductivity (aluminum, copper, etc.), a thermally ''thin'' structure has been included to avoid the time step problems explicit methods have with these materials. Details of these methods are described in the Technical Discussion, Section II.

The program structure, flow charts, etc. are given in Section III, Description of Program. Each subroutine is described in Section IV.

Input and Output data is described in Sections V and VI respectively. Finally, conclusions and recommendations are presented in Section VII. A listing of the code is presented in the Appendix.

Section 2.0

TECHNICAL DISCUSSION

This section describes the methods used in calculating the thermal response of the TPS structure. A basic energy balance performed at each node during the time marching using an explicit Euler integration forms the basis of the code. Special methods are used to describe the response of the ablator-sublimer and thermally thin structures. However, when complicated structures are used, the program logic branches off and constructs equivalent thermal networks, and from solutions of these networks, equivalent thermal conductance is computed and placed into the primary thermal network.

Presently, EXITS contains the capability to analyze seven different structure types. These are listed below as follows:

STRUCTURE TYPE ---	NUMBER
SLAB	1
RADIATION GAP	2
HONEYCOMB	3
CORRUGATED	4
Z STANDOFF	5
THIN SKIN	6
ABLATOR SUBLIMER	7

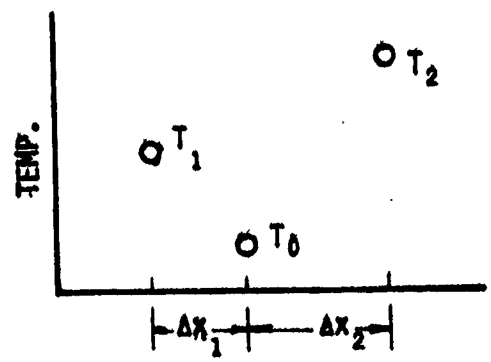
The methods used for analysis of the slab, thin skin, and ablator-sublimer are contained in this section. The methods for the radiation gap, honeycomb, corrugated, and Z-standoff structure are actually the same as the slab so therefore the logic used to compute the equivalent conductivity is not presented here but is given in Section IV, Description of Subroutines.

2.1 SLAB MODEL

The thermal slab model is the finite difference representation of the heat conduction equation and is used to obtain the temperature response of the slab and ablator structure types. To obtain a finite difference numerical solution to the heat conduction equation, the derivatives in space and time are replaced by finite difference analogs. The heat conduction equation for an isotropic material with one spacial dimension is:

$$\rho C \frac{\partial T}{\partial \theta} = k \frac{\partial^2 T}{\partial x^2}$$

The space derivatives can be represented in the following manner referring to the temperature distribution depicted below.



Finite Difference Temperature Distribution

Expanding about point 0 using Taylor's series for the temperature at 2

$$T_2 = T_0 + \Delta x_2 \frac{\partial T}{\partial x}\Big|_0 + \frac{\Delta x_2^2}{2!} \frac{\partial^2 T}{\partial x^2}\Big|_0 + 0\,(\Delta x_2^3) + \ldots$$

In a like manner, expanding about 0 for the temperature at 1

$$T_1 = T_0 - \Delta x_1 \frac{\partial T}{\partial x}\Big|_0 + \frac{\Delta x_1^2}{2!} \frac{\partial^2 T}{\partial x^2}\Big|_0 - 0\,(\Delta x^3) + \ldots$$

Combining these two expressions, ignoring higher order terms and solving for

$\frac{\partial^2 T}{\partial x^2}\Big|$ at time step n we find

$$\frac{\partial^2 T}{\partial x^2}\Big|_0^n = \frac{2}{(\Delta x_1 + \Delta x_2)}\left[\frac{T_1^n\,\Delta x_2 + T_2^n\,\Delta x_1 - T_0^n\,(\Delta x_1 + \Delta x_2)}{\Delta x_1\,\Delta x_2}\right].$$

If we take a forward difference approximation for the time derivative as shown below

$$\frac{\partial T}{\partial \theta} = \frac{T_0^{n+1} - T_0^n}{\Delta \theta}$$

and substitute into the heat conduction equation we find

$$\rho C \left(\frac{\Delta x_1 + \Delta x_2}{2}\right) \frac{T_0^{n+1} - T_0^n}{2} = \frac{k}{\Delta x_1}\,(T_1^n - T_0^n) + \frac{k}{\Delta x_2}\,(T_2^n - T_0^n)$$

If the thermal capacitance is defined as

$$C_i = \rho C\, V_i = \rho C \left(\frac{\Delta x_1 + \Delta x_2}{2}\right)$$

and the conductors as

$$K_{ij} = \frac{k}{\Delta x_{ij}}$$

we have, upon substitution and some algebra

$$T_i^{n+1} = T_j^n + \frac{\Delta \theta}{C_i} \sum_{j=1}^{2} K_{ij}\,(T_j^n - T_i^n)\,.$$

This expression is the basis of the thermal balance at each node in the conduction network. However, for nodes adjacent to a radiation gap or structure in which the heat transfer mechanism is not by pure conduction, we can form equivalent conductors.

The maximum stable time step, $\Delta\Theta$, which can be taken can be found by rearranging our finite difference algorithm as follows

$$T_i^{n+1} = T_i^n \left(1 - \frac{\Delta\Theta}{C_i}\sum_j K_{ij}\right) + \frac{\Delta\Theta}{C_i}\sum_j K_{ij}\, T_j^n$$

and noting that the coefficient of T_i^n must remain positive for all $\Delta\Theta$. A negative coefficient would mean that the greater the temperature at time step n, the less the temperature at time step n + 1 which would not make sense. We now have

$$1 - \frac{\Delta\Theta}{C_i}\sum_j K_{ij} \geq 0$$

or

$$\Delta\Theta \leq \frac{C_i}{\sum_j K_{ij}} \, .$$

This criteria is used for all cases except the thermally thin sections. To insure stability especially when the K_{ij}'s are nonlinear radiative conductors, the time step is divided by the input parameter STAB.

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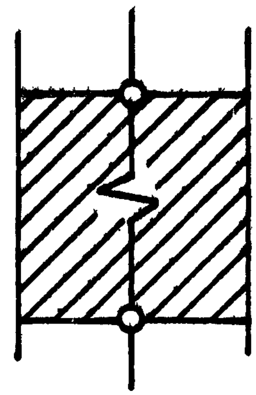
A major feature in the development of this code was the thermal element which consists of a thermal mass and a heat transfer path between two nodes located at the ends of the element shown below



Typical Thermal Element

Half of the thermal mass of an element is assigned to each node. The thermal elements are then stacked to define the complete thermal protection system. The slab and ablator materials are divided into several elements by the program. All other structure types consist of a single thermal element which are stacked upon each other sharing their common node points.

Constructing the network in this manner introduces slight errors where structures of varying capacitance are adjacent to one another and also at the surface node. In these cases, the node is not placed in the exact center of the thermal mass, however, energy is conserved.

2.2 COMPARISON WITH ANALYTICAL SOLUTION

As a check on the accuracy of the numerical algorithm, the solution was compared to an analytical solution, Ref. 1, of the partial differential equation. The convective heating of a plate of thickness $2\delta_i$ from both sides is analogous to heating of a slab of thickness δ_i from one side with an adiabatic backwall boundary condition. If the convective heat transfer coefficient, h, is held constant then the following boundary conditions will apply, where $T = t - t_f$.

$$T = T_i \quad \text{at } \theta = 0$$

$$\frac{\partial T}{\partial x} = 0 \text{ at } x = 0 \quad \text{(center of slab)}$$

$$\mp \frac{\partial T}{\partial x} = \frac{h}{k} T \text{ at } x = \pm \delta_1 \text{ (surface).}$$

The product solution is found to be

$$\frac{T}{T_i} = \frac{t - t_f}{t_i - t_f} = 4 \sum_{n=1}^{\infty} \left(\frac{\sin M_n}{2M_n + \sin 2 M_n} \right) e^{-M_n^2 \theta} \cos M_n \left(\frac{x}{\delta_1} \right)$$

where M_n are the roots of the trancendental equation

$$N_u = M_n \tan M_n$$

Nu being the Nusselt number given as

$$N_u = \frac{h \delta_1}{k} .$$

Nomenclature for this case and a graphical representation of the trancendental equation are shown in Fig. 2.1.

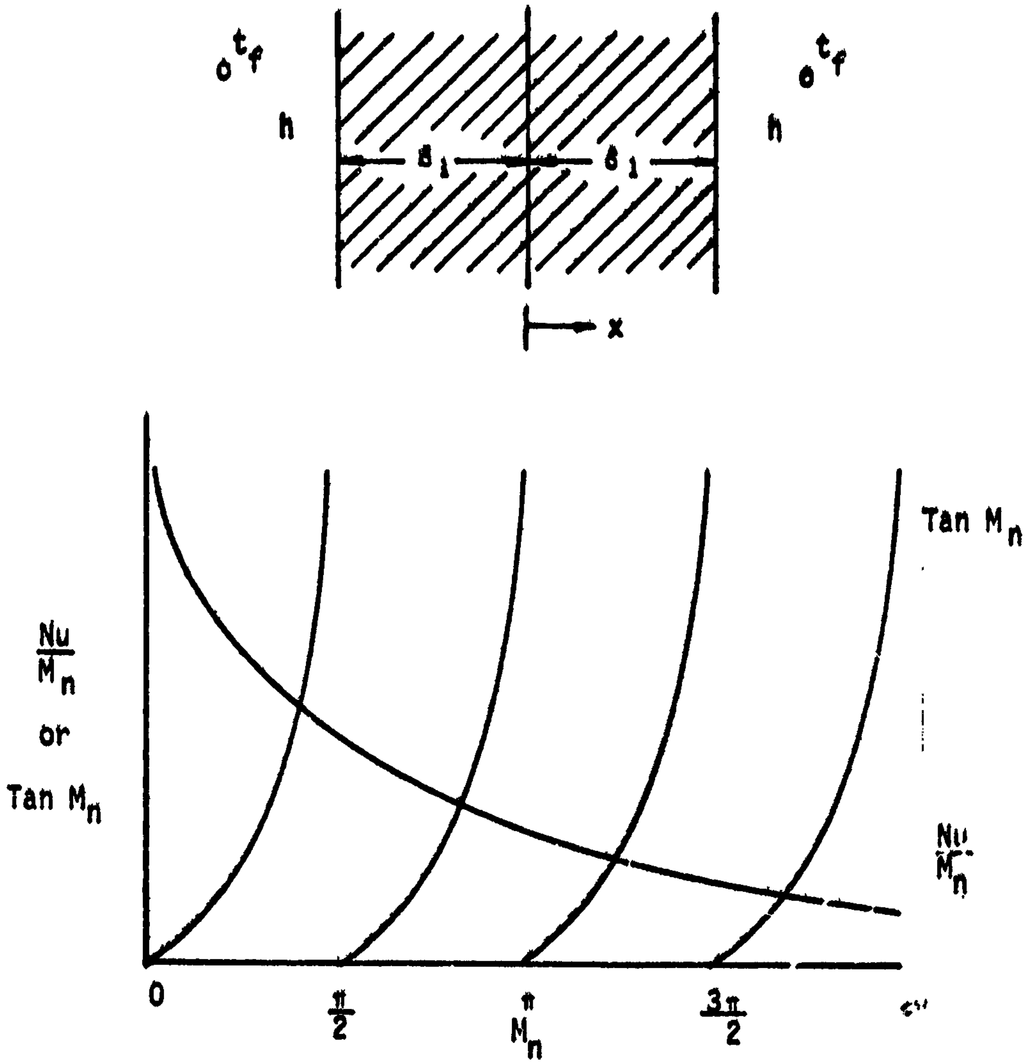
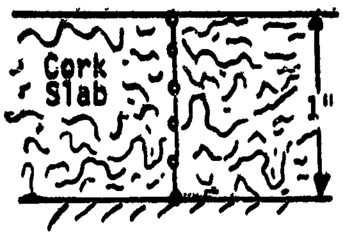


Fig. 2.1 Infinite Slab Heated From Both Sides With Graphical Solution For M_n

A digital computer program was written to find the roots M_n and evaluate the analytical solution. Various numbers of terms were taken in the infinite series to check for convergence. A satisfactory solution was found after 50 terms were used.

The test case consisted of a layer of cork one inch thick with an adiabatic backside model using six nodes through the thickness. A comparison of this case with the analytical solution is presented in Fig. 2.2. Agreement appears to be quite good.



NOTES:

1. 6 Node Model, Cork Slab
2. Insulated Backside
3. Adabatic Wall Temp = 10,416.6°R
4. Film Coefficient = .001276 Btu/ft²-°R

PROPERTIES
Density 10 lbm/ft³
Sp. Heat .04 Btu/lbm-°R
Conductivity 6.9 x 10⁻⁶ Btu/lbm-ft-°R

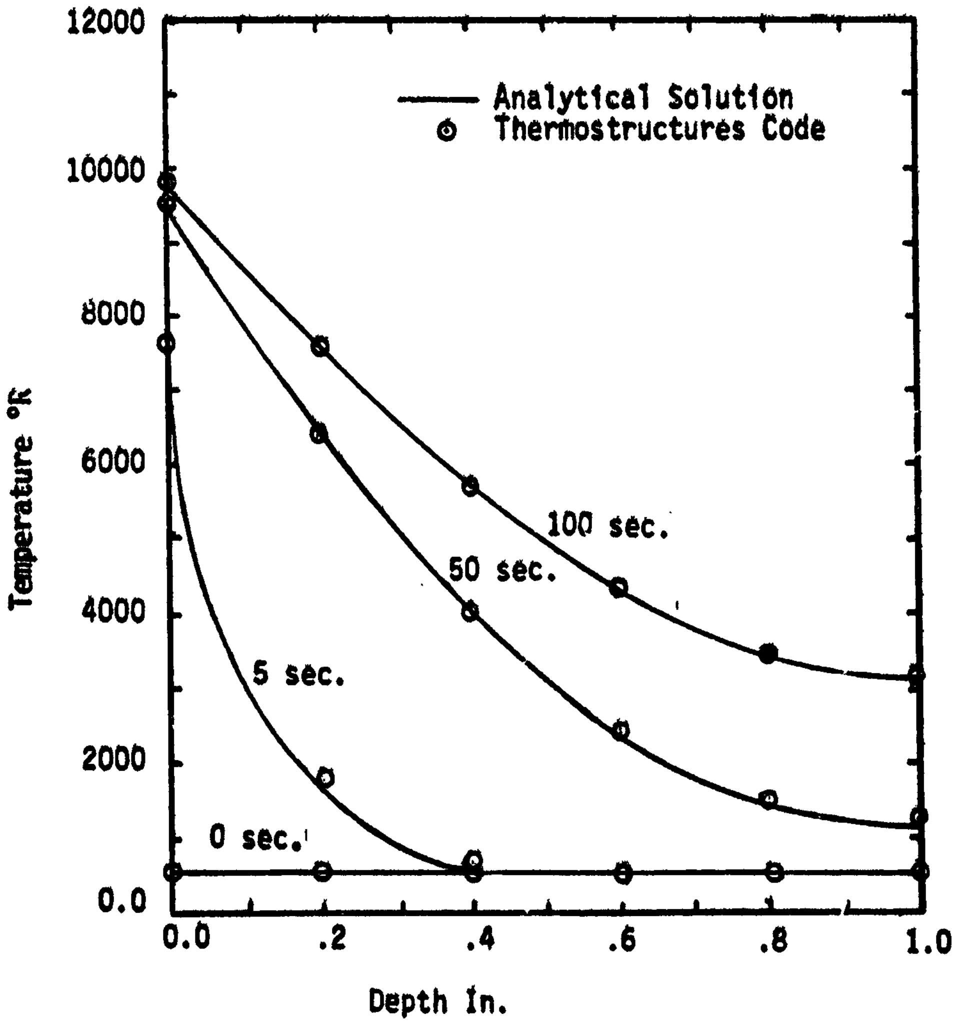


Fig. 2.2 Comparison of Thermostructures Code with Analytical Solution

2.3 THIN SKIN MODEL

For a slab type structure which is made of a material which has a high thermal conductivity, the temperature gradient through the material can be expected to be small for relatively thin sections and the heat fluxes encountered during reentry. If this gradient is to be modeled using the slab option, we see that the time step required to resolve this gradient will be very small since in general, $\Delta\theta_i \sim \frac{C_i}{\Sigma K_{ij}}$, where one or more of the K_{ij}'s will be large. The small time step will result in long run times with very little increase in accuracy of the analysis.

If, however, we assume that the temperature gradient through the thin skin type structure is zero while still allowing heat to be stored in the structure, we can circumvent this time step restriction since we have effectively taken the conductors in the high thermal conductivity material out of the network. The resulting slab of material now becomes thermally ''thin'', i.e. no temperature gradient and long run times can be avoided.

Consider the generalized slab of material and model network in Figure 2.3

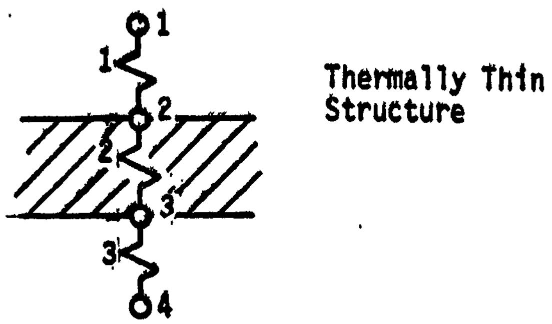


Fig. 2.3 Typical Thermally Thin Structure

If we write the equations for a heat balance at time step n + 1 at nodes 2 and 3, we have

$$C_2T_2^{n+1} = T_2^n C_2 + (T_1K_1 + T_3K_2 - T_2K_1 - T_2K_2)^n\Delta\theta$$

and

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$$C_3T_3^{n+1} = T_3^n C_3 + (T_2K_2 + T_4K_3 - T_3K_2 - T_3K_3)^n \Delta\theta .$$

Now if we assume there is no temperature gradient between node 2 and 3 and add the two equations together to find the total energy stored at the end of time step n + 1, we have

$$C_2T_2^{n+1} + C_3T_3^{n+1} = T_2^n C_2 + T_3^n C_3 + (T_1K_1 - T_2K_1 + T_4K_3 - T_3K_3)^n \Delta\theta$$

Solving for the temperature of the thin section, T_{2-3}, we arrive at the algorithm for the thin skin section temperature below

$$T_{2-3}^{n+1} = T_{2-3}^n + \frac{\Delta\theta}{C_2 + C_3} (T_1^nK_1 - T_2^nK_1 + T_4^nK_3 - T_3^nK_3) .$$

Looking at this expression, we note that the conductor K_2 has been eliminated and will no longer cause the small time step problem.

Considering the second law and finding a stable time step criteria can be accomplished as follows. Factoring T^n_{2-3} we have

$$T_{2\ 3}^{n+1} = T_{2\ 3}^n \left[1 - \frac{\Delta\theta}{C_2 + C_3}(k_1 + K_3)\right] + \frac{\Delta\theta}{C_2 + C_3} \left[T_1^nK_1 - T_4^nK_4\right] .$$

The first term in brackets must remain positive for any stable time step so it follows that

$$\frac{\Delta\theta}{C_2 + C_2}(K_1 + K_3) \leq 1$$

or

$$\Delta\theta \leq \frac{C_2 + C_3}{K_1 + K_3} .$$

We see that the stable time step expression is in the familar form $\frac{C_j}{\Sigma K_{ij}}$ but does not have large conduction values which will cause the small time step problems.

The previous discussion considers the thin skin section to be a general case. For the case where the slab is on the surface exposed to the reentry environment or is located on the backside where the adiabatic boundary condition is used or where it exists by itself where both conditions exist, special logic is imposed.

2.4 Ablator-Sublimer Model

The logic used to compute sublimer-ablator performance takes into account the energy management requirement at the material surface as follows:

1. The energy conducted away from the surface
2. The sensible energy stored in the material
3. The latent heat required to sublime the material
4. The convected or advected energy required due to the receding surface.

The numerical scheme devised to account for these effects is incorporated into the program's network by special logic which considers the moving boundary and the latent heat required to sublime the material using the slab logic. When the temperature of the surface remains below the temperature of sublimation, the thermal balance is performed just as it would be done in any nonablator material. If, however, at the end of any time step we see that the temperature has exceeded the sublimation temperature, the amount of energy that was required to exceed the sublimation temperature is computed and the surface node temperature is set to the sublimation temperature. The excess energy is then used to compute the amount of material which is sublimed.

Considering the four node network shown in Figure 2.4, we see that the surface has

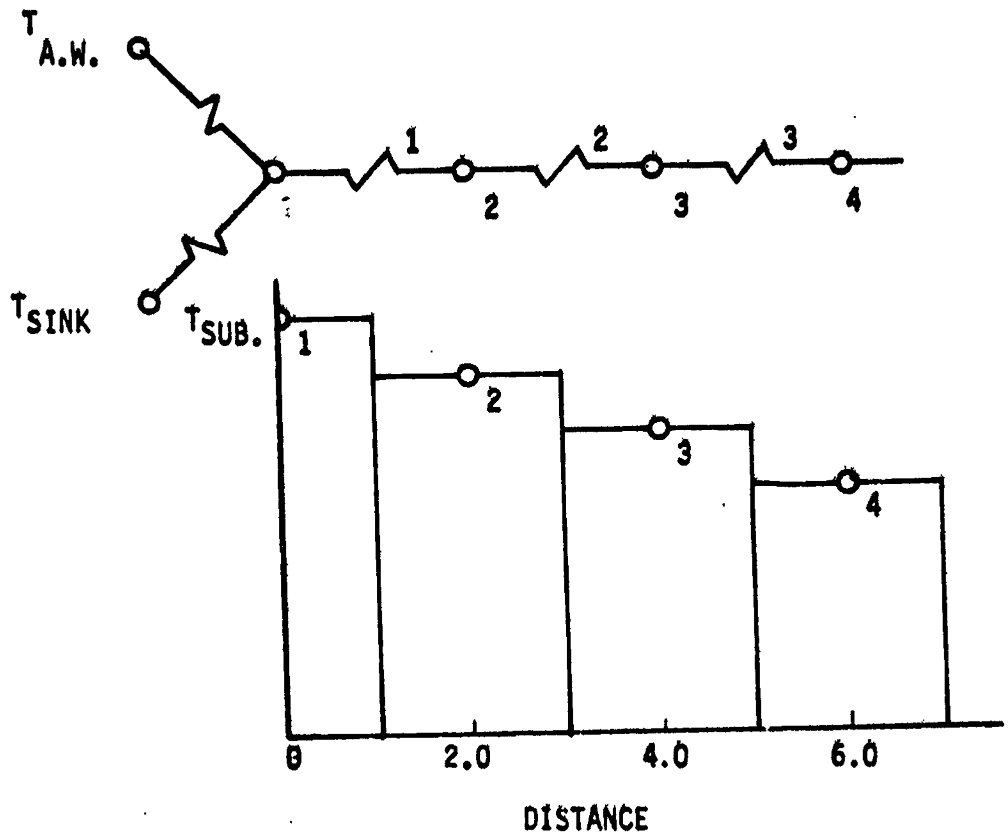


Fig. 2.4 Nodal Mesh And Temperature Distribution For Ablator-Sublimer

reached the sublimation temperature. Additional heat added to the surface which is not radiated or conducted away is heat which sublimes the surface material and advances the surface into the cooler material.

We first compute an excess amount of heat which was used to take the surface node temperature over the sublimation temperature with the following expression

$$\Delta q = C_1 \left(T_1 - T_{SUB}\right)$$

and then set

$$T_1 = T_{SUB}.$$

Next, we compute the surface recession distance from the latent heat of sublimation, L, and the density as follows

$$\Delta S = \frac{\Delta q}{\rho L_{eff}} .$$

As the surface recedes, the melt line must also recede, so we move the boundary between node 1 and 2. This results in the mass in node 2 at temperature T_s being brought to the sublimation temperature Tsub. Thus, the energy added to the system must be taken into account.

If we look at Figure 2.5 below where the temperature through the ablator is shown and

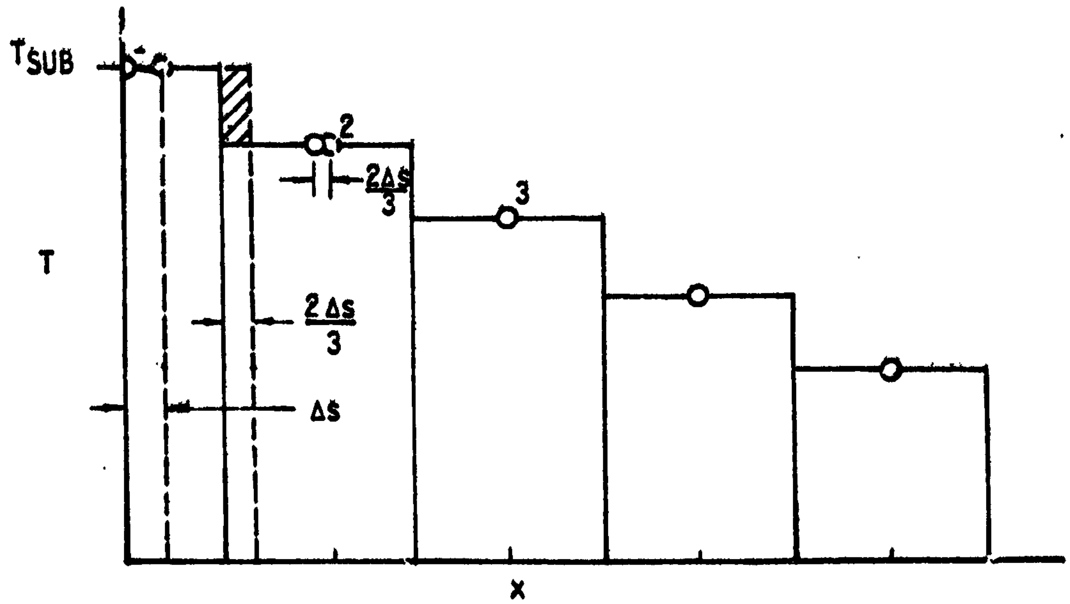


Fig. 2.5 Node Movement For Ablator-Sublimer

one time step is ΔS, we see that if the node boundary between 1 and 2 is moved 2/3 ΔS and node 2 is moved 1/3 ΔS, the material in node 1 and node 2 will be completely eliminated after a given number of steps. However, before we completely eliminate node 1 and 2, we stop when a prescribed amount of material is left in node 2 and raise its temperature to T_{SUB}. Node 3 now becomes node number 2, and the remaining nodes are renumbered. The process now continues until node 2 is eliminated again.

If we now consider the original numbering scheme, we see that the node boundary between node 1 and node 2 is a moving boundary or looking at it in another way, node 1 is fixed in space (Eulerian) and nodes 2 and greater are fixed (LaGrangian) to a moving material. In this sense, we see that energy is convected or advected into node 1 and this energy must be supplied by the aerodynamic heating environment. Referring to Fig. 2.5, we can see that this amounts to

$$\rho C_p \frac{2\Delta S}{3} (T_{SUB} - T_2).$$

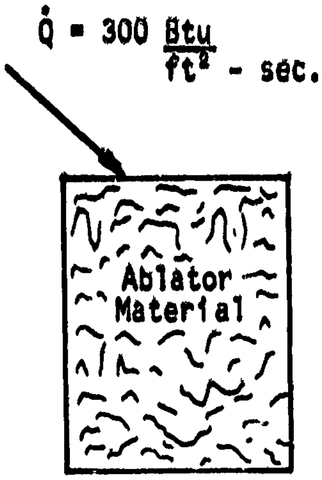
Since this energy must be supplied by the aerodynamic heating and is only required when ablation occurs, we adjust the latent heat of sublimation to account for this. We then compute an effective latent heat of ablation from the following expression

$$L_{eff}^{n+1} = \frac{\left(L_{eff}^{n} V_1^n + \frac{2}{3} \Delta S^{n+1} \left(L + C_p \left(T_{SUB} - T_2^n\right)\right)\right)}{V_1^n + \frac{2}{3}\Delta S^n}.$$

In the expresssion above, L is the actual heat of ablation L^n_{eff} is the effective heat of ablation from the last step and V_1^n is the volume of node 1 at the last time step.

In applying this method, heat conducted from node 1 to node 2 and 2 to 3 etc. is accounted for in the same manner as the slab described in Section 2.1.

An example of this procedure is shown in Figure 2.6 for a hypothetical ablator. Results are compared to a steady state analytical solution from Ref. 2.



ρ = 100 lbm./ft^3

C_p = .30 Btu/lbm. - ^oR

K = 1.0 x 10^{-4} Btu/ft. - sec. - ^oR

L = 1276 Btu/lbm.

T_{melt} = 5460 ^oR

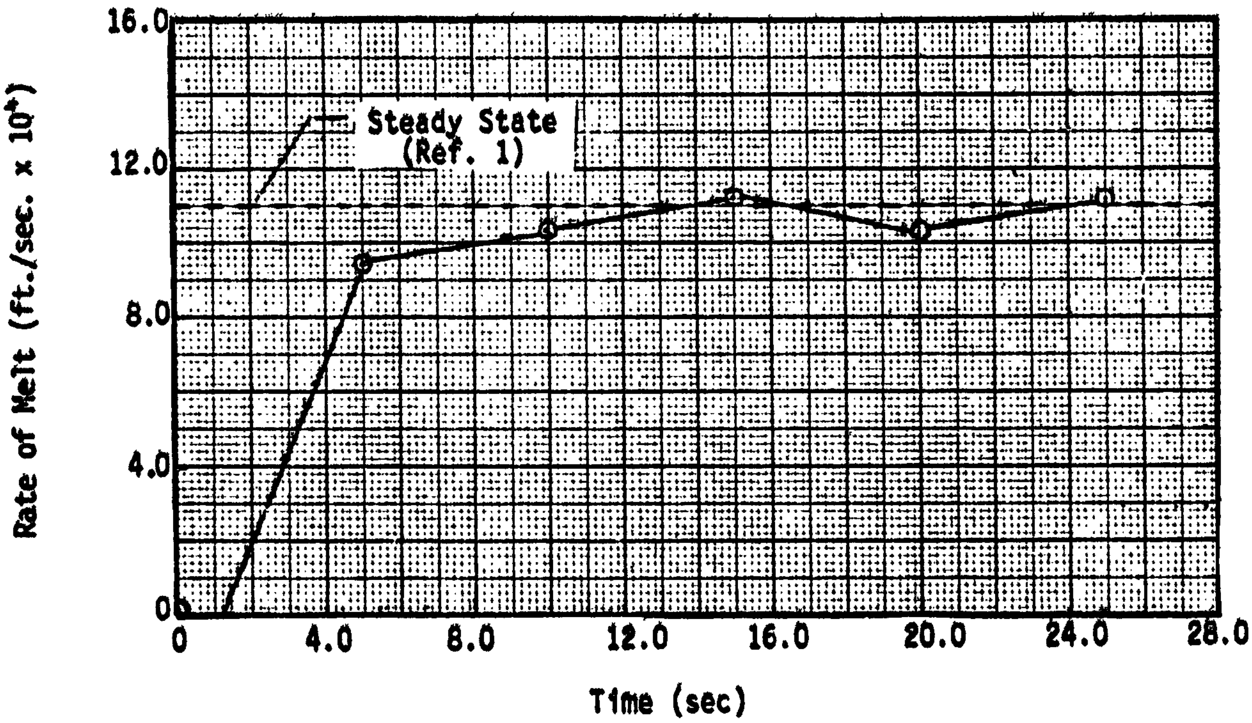


Fig. 2.6 Comparison of Results for the Recession Rate

Section 3.0

DESCRIPTION OF THE PROGRAM

An effort was made throughout the development of the EXITS code to keep the structure of the code as modular as possible and to define specific functions which could be broken off into subroutines. By in large, this has been accomplished, and as a result, the program capability can be expanded without extensive reprogramming.

The method of defining thermal structure types, i. e. slab, honeycomb, corrugated etc. facilitates the organization of the program since each structure type, with the exception of the slab and the ablator, consists of a conductor connecting two nodes located at the ends of the structure and capacitance, one half of which is assigned to each node. The slab and ablator are similarily defined with the exception being several nodes are placed within the structure.

The main driver contains calls to the primary functions or primary subroutines. These primary functions in turn call secondary routines which supply required information. The structure of the EXITS code is shown in Table 3.1. The routines are arranged so that the MAIN controls the program flow, calls input routines, contains the time marching iterative loop and creates the output file.

A more detailed flow chart and arrangment of the subroutines is shown in Figure 3.1. Each subroutine's calling structure is shown in Table 3.2. A full description of each subroutine is given in the next section.

No blank common is used, only named common and it's location is shown in Table 3.3.

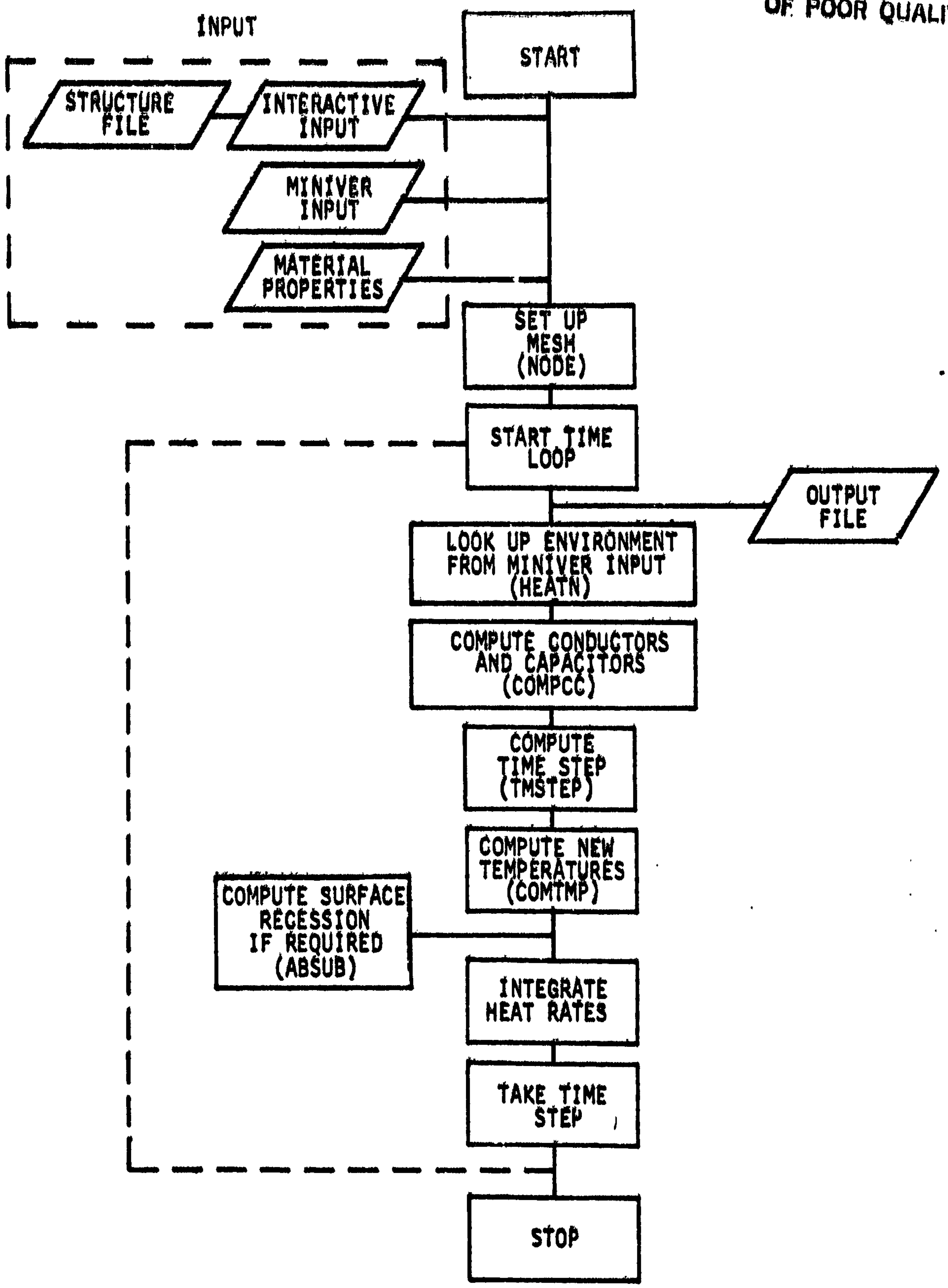


Table 3.1 Simplified Functional Structure

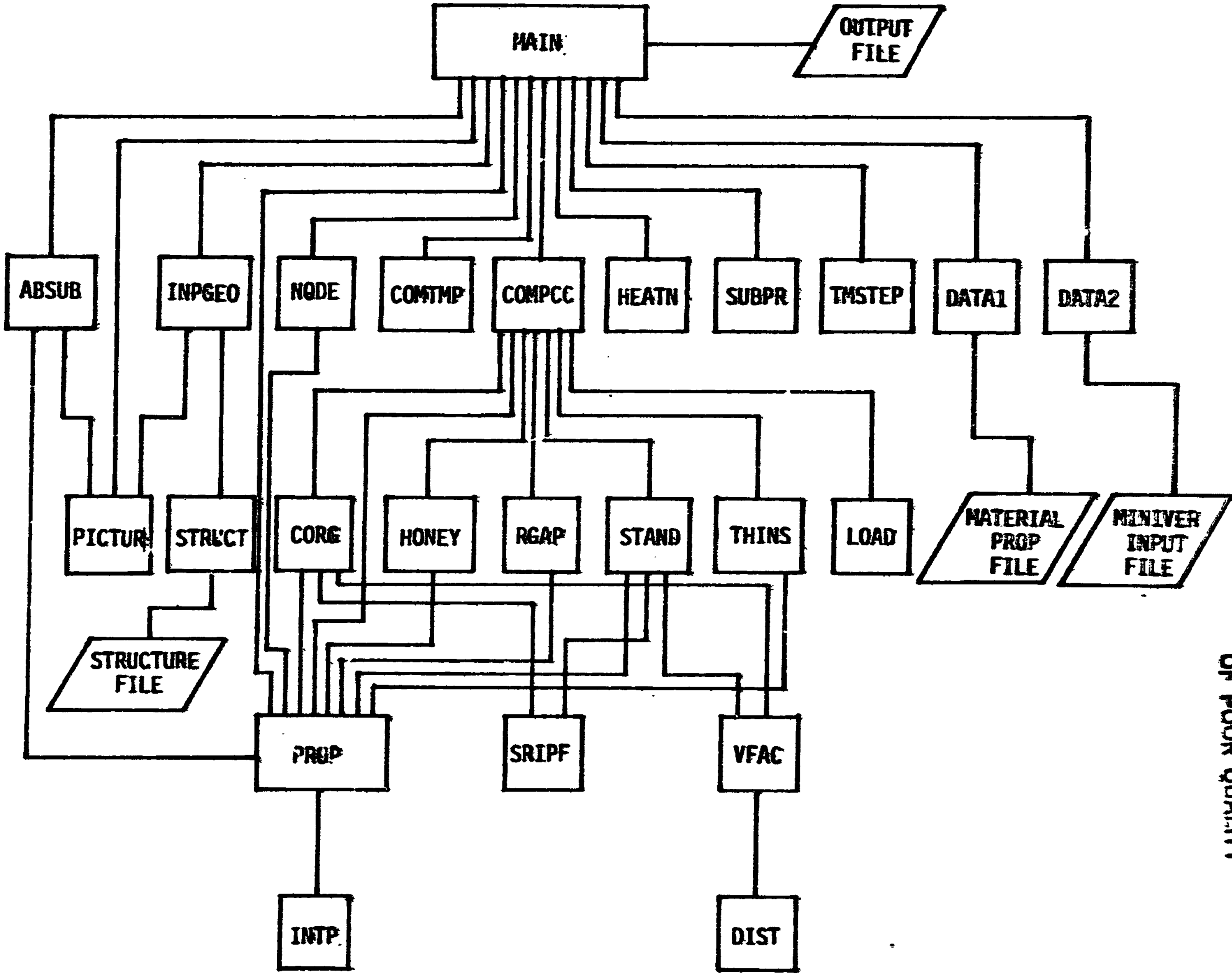


Fig. 3.1 EXITS Subroutine Flow Chart

CALLS / SUBROUTINE	MAIN	PROP	INTP	DATA1	COMPCC	STRUCT	LOAD	ABSUB	DATA2	PICTUR	COMTMP	NODE	HEATN	VFAC	DIST	TMSTEP	INPGEO	SUBPR	SRIPF	CORG	HONEY	RGAP	STAND	THINS
MAIN		X		X	X			X	X	X	X	X	X			X	X	X						
PROP			X																					
INTP																								
DATA1																								
COMPCC		X					X													X	X	X	X	X
STRUCT																								
LOAD																								
ABSUB		X								X														
DATA2																								
PICTUR																								
COMTMP																								
NODE		X																						
HEATN																								
VFAC															X									
DIST																								
TMSTEP																								
INPGEO						X				X														
SUBPR																								
SRIPF																								
CORG		X												X					X					
HONEY		X																						
RGAP		X																						
STAND		X												X					X					
THINS		X																						

TABLE 3.2 Subroutine Calling Structure

ROUTINE / COMMON	MAIN	PROP	INTP	DATA1	COMPCC	STRUCT	LOAD	ABSUB	DATA2	PICTUR	COMTMP	NODE	HEATN	VFAC	DIST	TMSTEP	INPGEO	SUBPR	SRIPF	CORG	HONEY	RGAP	STANB	THINS
ENVIR	X								X				X											
GAP	X				X		X					X					X			X	X	X	X	X
INIT	X			X		X		X	X	X		X					X							
TAX	X				X			X				X												
TIME	X				X			X			X	X				X	X							
ARA	X				X		X	X			X	X				X								
LD	X			X	X	X	X	X		X	X	X				X	X							
NODES	X			X	X			X			X	X												
CTMP	X										X													
CAC	X				X			X																
PICT	X							X		X		X					X							
SUBLM	X							X			X													
TITLE	X			X		X		X		X		X					X							
PRESS	X				X			X			X	X								X	X	X	X	X
SAVE	X							X																
DTA			X	X																				
CSUB				X														X						
TITL2										X							X							
FACT														X	X					X			X	
SF														X					X	X			X	

Subroutine PROP Contains No Common Statement.

TABLE 3.3 Named Common Statements And Subroutine Locations

Section 4.0

DESCRIPTION OF SUBROUTINES

This section describes the main driver and the twenty three subroutines that comprise the EXITS code. The description presented is an overall description which may include the subroutine function, method and program logic.

4.1 MAIN

The main driver of the EXITS code controls the major functions of the program and also contains the output calls. Logic for calling the major subroutines is found in this part of the program. Constants and control flags and initial values of integrated heat loads are first set to their prescribed values. The interactive input routine INPGEO is called. Then initial temperatures are set and subroutines DATA1 and DATA2 are called to obtain the material property and environment data. A call to subroutine NODE sets up the thermal network of nodes, capacitors and conductors for each body point. A call to PICTUR sends a depiction of the structure and node location to the line printer.

The temperature integration starts with the time loop after further initialization. Output and units conversion take place within the time loop which is controled by the print flag NPEG. The adiabatic wall enthalpy, film coefficient and pressure is found from a call to HEATN. If an ablator-sublimer is used, the ablator properties are found from two calls to SUBPR. Values for the conductors and capacitors are computed from COMPCC. The time step DTSM is calculated from stability criteria and the user supplied parameter STAB. Temperatures for all nodes in the structure are computed at the end of the time step by subroutine COMTMP. If an ablator is called for, the recession and renumbering of the node and conductor sequence is done in ABSUB. Finally, at the end of the time integration loop, the heat loads, sensible heat, advected heat, and sublimed heat are integrated and time is increased by the amount DTSM. A check is made to see if the number of steps or time has exceeded the input values and if not control is returned to the top of the integration loop.

4.2 SUBROUTINE PROP

This subroutine returns thermophysical properties for the material specified by the variable MAT as a function of temperature, T1, and pressure, P. Subroutine INTP is called with T1 and P as the independent arguments after the property table numbers are computed for the density, specific heat, conductivity and emissivity. Properties for ablator material, heat of ablation and temperature of ablation, are not computed by PROP. These properties are found by the subroutine SUBPR.

4.3 SUBROUTINE INTP

This subroutine linearly interpolates in either two or three dimensional arrays for material properties as a function of temperature or as a function of temperature and pressure. The arguments X, P, N, Y, are respectively, temperature, pressure, table number and the returned property. The subroutine interpolates in both monovariate and bivariate tables. Ablator-sublimer properties, sublimation temperature and heat of sublimation, are not found by INTP but are found by SUBPR. Data for the properties are stored in the array CC(N,J) for the monovariate arrays and CC(N,J) and BSV(N,JT,IL) arrays for the bivariate tables. The arrangement of data in the arrays for the two types of tables are shown in the following examples. Data for the monovariate tables are shown in Table 4.1.

CC(N,1) —	5.	NYLON PHEN CONDUCTIVITY	
CC(N,2) —	0.0	1.39E-5	— CC(N,3)
CC(N,4) —	460.0	1.39E-5	— CC(N,5)
⋮	660.0	1.94E-5	⋮
⋮	910.0	2.50E-5	⋮
CC(N,10) —	1000.0	2.50E-5	— CC(N,11)

TABLE 4.1 Arrangement of Data For Monovariate Properties

Data for the bivariate table are shown in Table 4.2.

Initially a check is made on the sign of CC(N,2) to determine if the data for table N is monovariate or bivariate. If the sign is positive, the data is searched to find the two temperatures to interpolate between and a straight line interpolation is used.

If the sign on the variable CC(N,2) is negative, then a bivariate table is assumed and the independent variable array, pressure stored in CC(N,3) to CC(N,(-CC(N,2)+2)), is searched to find the increment in the pressure direction. The temperatures are then searched to find the two temperatures between which the interpolation is to be performed and the pressure increment applied. Finally, with two interpolated values found in the pressure direction, the temperature increment is applied and the final value is computed and returned through Y in the argument.

4.4 SUBROUTINE DATA1

Subroutine DATA1 finds the material property data for the materials given, renumbers the material identifiers, MATS(I,LT,IN), and stores the material property data in arrays to be used later in the thermal analysis. This routine first reads through the data and picks out the data from the materials used in the model. Material identification numbers are then changed to the order in which they appear to minimize the storage requirement in the CC(I,J) and BSU(I,J) arrays.

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OF POOR QUALITY

		CC(N,3)	CC(N,4)	CC(N,5)	. . . .	. . .	CC(N,K*)
CC(N***,1)	15	LI-900	CONDUCTIVITY				
CC(N,2)	6.0	0.0	.21	2.12	21.16	211.6	2116.0
CC(N,K+1)	0.0	1.389E-6	1.389E-6 —J→	2.083E-6	4.166E-6	6.060E-6	6.472E-6
CC(N,K+2)	210.0	1.389E-6	1.389E-6	2.083E-6	4.166E-6	6.060E-6	6.472E-6
	460.0	2.083E-6	2.083E-6	2.777E-6	5.083E-6	6.944E-6	7.638E-6
	710.0	2.555E-6	2.555E-6	3.472E-6	6.250E-6	8.777E-6	9.472E-6
	960.0	3.472E-6	3.472E-6	4.638E-6	7.666E-6	1.111E-5	1.202E-5
	1210.0	4.861E-6	4.861E-6	6.000E-6	9.027E-6	1.366E-5	1.483E-5
	1460.0	I 6.472E-6	6.472E-6	7.639E-6	1.088E-5	1.667E-5	1.827E-5
	1710.0	↓ 8.555E-6	8.555E-6	9.722E-6	1.366E-5	2.014E-5	2.172E-5
	1960.0	1.155E-5	1.155E-5	1.275E-5	1.174E-5	2.430E-5	2.616E-5
	2210.0	1.575E-5	1.575E-5	1.694E-5	2.130E-5	2.944E-5	3.138E-5
	2460.0	2.039E-5	2.039E-5	2.172E-5	2.616E-5	3.527E-5	3.777E-5
	2760.0	2.683E-5	2.683E-5	2.833E-5	3.222E-5	4.305E-5	4.638E-5
	2960.0	3.222E-5	3.222E-5	3.416E-5	3.861E-5	4.972E-5	5.388E-5
	3260.0	4.277E-5	4.277E-5	4.500E-5	5.000E-5	6.111E-5	6.722E-5
CC(N,L**)	3460.0	5.277E-5	5.277E-5	5.444E-5	6.080E-5	7.277E-5	8.055E-5

BSV(N,I,J)

TABLE 4.2 Arrangement Of Data For Bivariate Properties

*K = -CC(N,1) + 2
**L = K + CC(N,1)
***N = TABLE NUMBER

CC(N,1) = NUMBER OF TEMPERATURE ENTRIES
CC(N,2) = NUMBER OF PRESSURE ENTRIES

When a material is found or matched to the material specified, MAT(I,LT,IM), this routine reads the title card and next set of data cards according to the number specified. The next three sets are then read for a total of four tables. If the first entry in the independent array of any table is negative, the table is assumed to be bivariate and a different set of logic is used to store the data. Data for the monovariate tables are stored in an array, CC(N,J), where N is the table number. If the data is found to be bivariate, then the independent variables are stored in CC(N,J) array and the dependent variables are stored in the array BSV(N,J,K), Table 4.6. Each material property set in the property file must appear in the prescribed order, density, specific heat, conductivity, and emissivity. Units for these properties must be entered in BTU's, feet, seconds, pounds mass, pounds force, and degrees Rankine.

For ablator-sublimer material, the material property number of the fifth and sixth property is entered on the title card. When the same material identifier number is found, the temperature of sublimation and the heat of sublimation as a function of pressure is given as the fifth and sixth property and stored in the array CCS(I,J).

4.5 SUBROUTINE COMPCC

Subroutine COMPCC computes the values of the conductors and capacitors for the network. The capacitor C(I) and conductor CD(I) values for the slab and ablator structure types are computed directly in COMPCC. Capacitor and conductor values for the other structures are found from routines called from COMPCC. Values for the conductors between the nodes for the slab and the ablator are found by calculating the distance between the nodes from the node position array, XX(I), and then finding the conductivity from the average temperature between the nodes. Conductor values are found from the expression

$$K_1 = \frac{k}{\Delta x}$$

In the same loop that the conductors are computed, the capacitors are found. The mass of the material between the nodes is computed and multiplied by the specific heat. Since one half the mass is associated with each node, the capacitance value is divided by two and half of it is summed at each node. Capacitance value for each node is found from

$$Ci = \sum_{j=1}^{2} \frac{\rho_j V_j C_{pj}}{2.0}$$

where the summation on j is on the thermal mass adjacent to the node i. At this time, the mass of the structure is also computed and stored in XMAS.

For structure other than slab type, JN = 1, or ablator, JN = 7, COMPCC branches off to the following routines, Table 4.3.

JN	Structure Type	Subroutine
2	RADIATION GAP	RGAP
3	HONEYCOMB	HONEY
4	CORRUGATED	CORG
5	Z-STANDOFF	STAND
6	''THIN'' SKIN	THINS

TABLE 4.3 Routines For Computing Effective Conductance

Before branching off however, subroutine LOAD is called. This routine takes information, (i.e. geometry, materials etc.) from named common, LD, and loads it into the named common, GAP. The subroutines called when JN = 2 through 6 compute the effective thermal conductance, XK, mass XM, and capacitance values CAP1 and CAP2 and returns these values through the named common LD. Subroutine COMPCC then sums the capacitor values in the C(I)s and the mass XMAS. The conductor is then defined in CD(I).

4.6 SUBROUTINE STRUCT

Subroutine STRUCT is the routine that handles the structure files.

STRUCT opens the structure file and either locates a specific structure that already exists in the file or adds an additional structure to the file. Every structure has a corresponding structure number, and a two line description, along with the structure variables.

4.7 SUBROUTINE LOAD

This routine takes data from the named common LD which describes the geometry and materials of the following structure types

RADIATION GAP
HONEYCOMB
CORRUGATED
Z-STANDOFF
THIN SKIN

and loads it into the named common GAP. In addition, the temperature of the upper and lower surfaces are set for the material property lookups and the radiation conductance. The material identifier numbers MATS(MP,IS,I) are loaded into the M(I) array and the six geometric parameters, XP(MP,IS,J), are loaded into the X(I) array.

4.8 SUBROUTINE ABSUB

Subroutine ABSUB provides the logic to predict ablator-sublimer recession, the node spacing and the effective heat of ablation. This routine is called by main after the sublimation temperature is reached. Ablator variables are passed through the named common SUBLM where the following variables are significant.

TSUB - Sublimation temperature
XL - Latent heat of sublimation
XLP - Effective heat of sublimation
EXCHT - Excess heat over time step
EXCHSV - Excess heat from last time step
QADVS - Advected heat from previous time step
TMSV - Time at last iteration

First, this routine computes the distance of the surface recession, ΔS, by the following expression

$$\Delta S = \frac{q_{excess}}{L' \ \rho}$$

From this value of ΔS the surface node is moved a distance of ΔS, the second node is moved $\Delta S/3.0$ and the boundary between the two nodes is moved $2\ \Delta S/3$. If the distance between the first and second node, XLTS, becomes less than XMIN, the second node is dropped from the network and nodes, capacitors, locations, and conductors for the rest of the network are renumbered. Figure 4.1 shown below describes some of the nomenclature used in this routine.

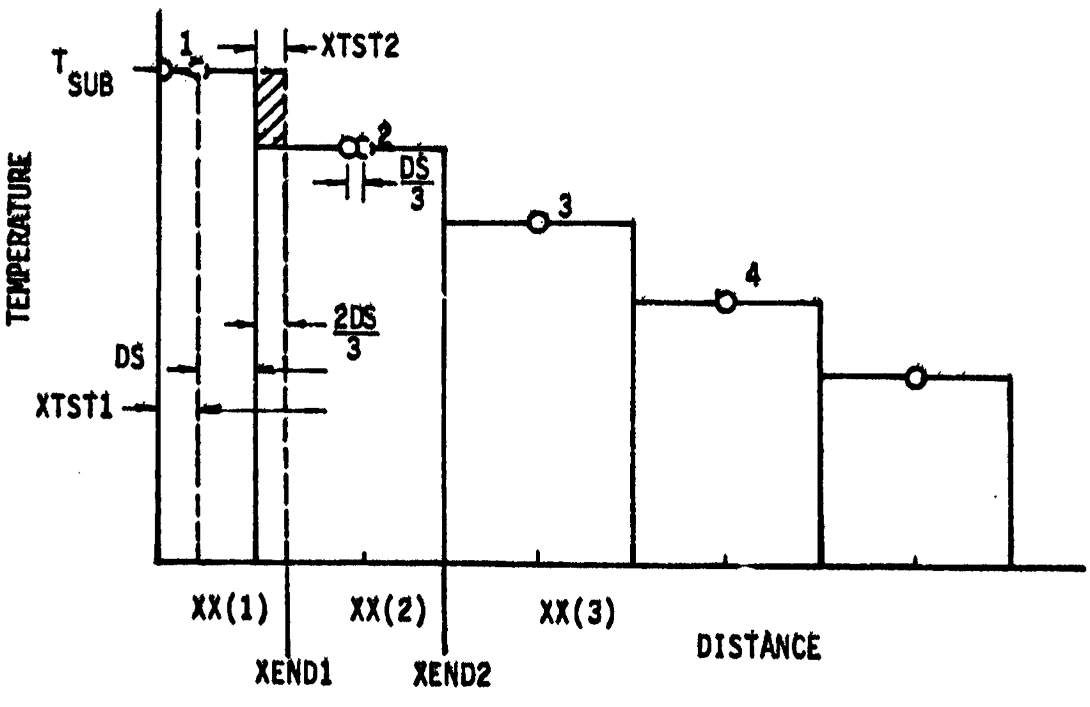


Fig. 4.1 Nomenclature For Ablation Logic

After the nodes and the node boundaries have been moved as shown in this figure, the total energy required to sublime the mass in node one is computed as follows

$$QMEL = \rho \cdot \left(L' \cdot XTST1 + L \cdot XTST2 + C_p \cdot XTST2\ (T_{SUB} - T_2)\right)$$

where L' is the effective heat of sublimation from the previous step and L is the physical heat of sublimation. The new effective heat of sublimation now is computed from the expression below

$$L' = \frac{QMEL}{\rho \cdot (XTST1 + XTST2)}.$$

The sensible heat added to node one by moving the melt line 2*DS/3 is the heat advected across the moving boundary and is compensated for by increasing the heat of sublimation to form an effective heat of sublimation. This increase amounts to

$$QADV = \rho\, C_p XTST2^* \ (T_{SUB} - T_2)$$

and is shown in the figure as the cross hatched area.

Dropping node two and renumbering the network is accomplished in the last part of the routine, after which subroutine PICTUR is called and a new schematic of the structure is printed on the line printer.

4.9 SUBROUTINE DATA2

Subroutine DATA2 reads data from Unit 7 which defines the environment and was created by LANMIN. Data on the LANMIN output file are shown in Section 5.1. The body point number for the particular point in question, LBP is passed to DATA2 through the argument. The file is then searched for the correct body point and, once found, the following quantities are read from the file and stored using the following variable names

TIME	TM1 (IC)
FILM COEFFICIENT	HC1 (IC)
ADIABATIC WALL ENTHALPY	HAW1 (IC)
PRESSURE	PRES1 (IC)

The largest number of entries in these tables is dimensioned by the common variable NMEN and currently set to 50. If a search of the file does not reveal a match of the body point number, a message is printed, CANNOT FIND BODY POINT.

4.10 SUBROUTINE PICTUR

Subroutine PICTUR displays a description of the structure for a specific Body Point in the form of a picture. PICTUR is called in the EXITS program in two ways. The first way is from INPGEO, right after the structure of a Body Point is defined. This is a quick look picture, that appears on the interactive device, and is used for determining if the structure defined is really the structure desired. If not, an opportunity is allowed to redefine the structure for the Body Point correctly.

The other way th PICTUR is called is from MAIN after the node structure has been defined. This picture is written to the Output file and corresponds to the specific body point that is being executed at that time.

If an ablator-sublimer structure is chosen, then additional calls of PICTUR will occur each time a node is dropped from the structure. For each node that is dropped, a picture will be written to the Output file that describes the structure of the body point after dropping the node. An example of a picture made by PICTUR is shown in Fig. 4.2. It includes a picture representation of the structure of each layer stacked together and also information like the materials used, the structure type and some of the dimensions.

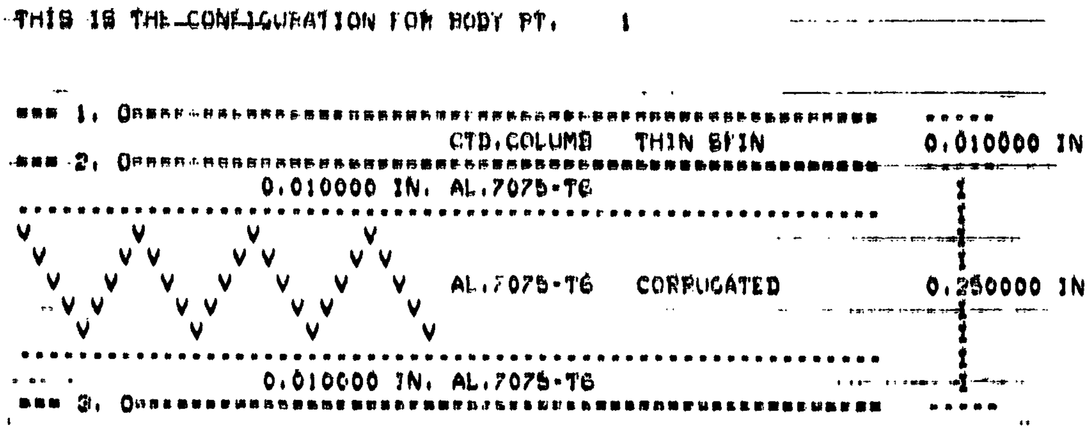


Fig. 4.2 Line Printer Representation Of Sample Structure From Subroutine PICTUR

4.11 SUBROUTINE COMTMP

Subroutine COMTMP is the subroutine which calculates the new temperatures T(I) at the end of the time step given the old temperatures TO(I), capacitors C(I), and conductors CD(I) using the heat balance, Section 2.0, at each of the nodes in the structure. Two types of logic are used to compute the temperatures. The first part of the subroutine is devoted to setting up the heat balances and the boundary conditions for the thin skin structure type if a thin skin section is adjacent to the node in question. The second part performs heat balances for all other structural types.

At the beginning of the routine a check on the flag ISBFG is made to determine if thin skin logic is to be used any within the structure. If not, the logic flow goes directly to the standard heat balance for each node. To determine if a node is adjacent to a thin skin element, a check is made on the conductors an either side of the node. If a conductor value is greater than 10^{9}, then the thin skin heat balance is to be used. (A conductor value of 10^{16} is set in subroutine THINS).

Logic is included to determine if the node is above or below the thin skin section or if the thin skin section lies on the surface or is the last structural type and requires the adiabatic boundary condition.

The standard heat balance, Section 2.0, is used for all nodes other than nodes adjacent to the thin skin sections. A check is made to see if the node in question is a surface node or if it is the last node. Finally, the temperature of the surface node is checked to see if it has exceeded the sublimation temperature for a ablator-sublimer structure. If this is the case, the excess heat is calculated.

$$EXCHT = \left(T(1) - T_{SUB}\right) \cdot C_1,$$

the flag NAB set equal to one and the surface temperature set to T_{SUB}.

4.12 SUBROUTINE NODE

Subroutine NODE is called from MAIN to set up the nodel network and to initialize temperatures.

The logic starts by taking one structure type at a time beginning at the surface and working down. A check is made on the structure type, IST, to see if it is a slab or ablator-sublimer. If a slab or ablator-sublimer is found, it is divided into layers and nodes assigned as follows. The layer thickness is controlled by the input parameter DTIM which divides the total thickness into layers to give a stable value of DTIM shown below

$$DX = \sqrt{\frac{DTIM \cdot 2 \cdot k}{\rho \, C_p}}$$

The number of layers, conductors, are found from

$$NX = \frac{H}{DX} + 1$$

where H is the thickness of the slab or ablator-sublimer. Finally, the length of each conductor in the slab is found from

$$TK = \frac{H}{NX} .$$

At each conductor, the node number at the upper and lower end of the conductor is stored in the L(IC,2) array, the initial temperatures T and TO are set and the node positions XX(IC) are assigned. Finally, at the end of this subroutine, the network information is written out which shows node spacing, structure type, material type, conductor number, and node numbers.

4.13 SUBROUTINE HEATN

This routine linearly interpolates the heating and pressure environment generated by LANMIN and stored in the named common ENVIR. Time (TIME), is the independent argument while the film coefficient (HC), adiabatic wall enthalpy (HAW), pressure (PRES), are returned to MAIN. The counter ISU allows the code to start the interpolation search at the same place in the arrays the last time this routine was called.

4.14 SUBROUTINE VFAC

Subroutine VFAC computes the geometric view factors of NN two dimensional surfaces using the crossed strings method. The named common SF contains the area, AR(I), emissivity, EPP(I), view factors F(I,J), and area view factor products ASF(I,J), of up to ten surfaces which may see each other within an enclosure. Coordinates of the end points of straight line surfaces are contained in the XX and YY arrays in the named common FACT. Two nested DO loops, I and J, cycle through each surface. The area of surface I is found from the subroutine

DIST which finds the distance between the end points assuming that the surface is a straight line surface.

The view factor using the crossed strings method is shown below, Ref. 5. Given two surfaces shown in Fig. 4.3.

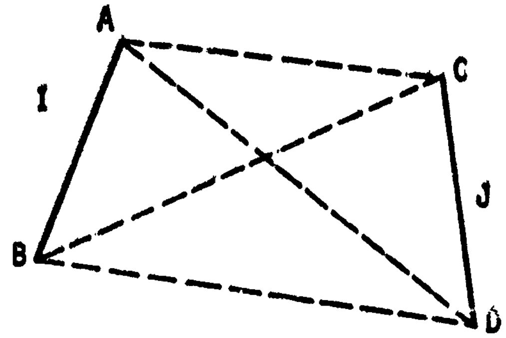


Fig. 4.3 Crossed Strings Nomenclature

$$F_{i-j} = \frac{\left(\overline{AD} + \overline{BC}\right) - \left(\overline{AC} + \overline{BD}\right)}{2\, A_i}$$

In other words, the view factor from surface I to J is equal to the lengths of the crossed strings minus the uncrossed strings divided by twice the area of surface I.

Subroutine DIST is called to find the lengths of the crossed and uncrossed strings. The variable SUMF is the sum of the view factors of one surface to all other surfaces which should equal 1 but is not now printed out.

4.15 SUBROUTINE DIST

Subroutine DIST finds the distance between two points given their two dimensional coordinates. The named common FACT contains the coordinates of the end points of the line segments which make up the radiation enclosure. The coordinates are contained in the XX(I,J) and YY(I,J) arrays where the I subscript is the surface number and J is equal to 1 or 2 depending upon which end of the surface is considered. The distance formula

$$D = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2}$$

is used to compute the distance.

4.16 SUBROUTINE TMSTEP

This subroutine determines the stable time step for the explicit time integration of the energy balance at each node. For the general case the maximum stable time step for the nodal network shown in Figure 4.4 is

$$\Delta\theta \leq \left. \frac{C\ (I)}{CD\ (J) + CD\ (J-1)} \right|_{MIN.}$$

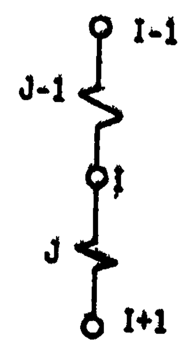


Fig. 4.4 Nomenclature For Slab Time Step Calculation

For the case where the node lies on the surface, the conductor CD(J-1) is replaced by CONV + CRAD, the sum of the convective and radiative conductors. For the adiabatic backwall, the conductor CD(J) is set to zero.

The thin skin stability requirement for the configuration shown in Figure 4.5

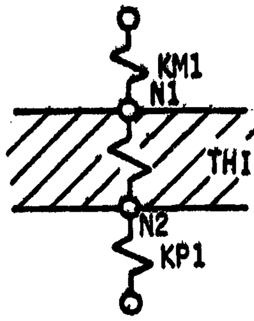


Fig. 4.5 Nomenclature For Thin Skin Time Step Calculation

is found by ignoring the very high conductor value of the thin skin section. In general, the stability requirement for node N1 or N2 is

$$\Delta\theta \leq \left. \frac{C\ (N1) + C\ (N2)}{CD\ (KM1) + CD\ (KP1)} \right|_{MIN}$$

For a thin skin surface node, the convection and radiation conductors are included in CD(KM1). For the adiabatic backwall CD(KP1) = 0.

After the minimum $\Delta\theta$ is found, the resulting time step is divided by the input parameter STAB to insure stability.

4.17 SUBROUTINE INPGEO

Subroutine INPGEO is the interactive routine that sets up the initial conditions and defines the structure for each Body Point to be run, asks for the FILE NAME of the file that contains the LANMIN (MINIVER) data for each body point, and asks for the FILE NAME of the file that contains all previously defined structures. (NOTE: Use of this file is optional). This subroutine also asks for the FILE NAME of the file that is to contain the EXITS output.

The initial, final and delta_times for the output print are also set here. The control parameters may also be changed at this point if the user desires. Otherwise, default values are used.

The number of body points to be run is then defined and the conditions for each body point are defined. For each body point, an initial and sink temperature is defined as well as the structure of that body point. The structure for a body point may be chosen from the structure file by structure number or by creating a new structure definition.

Creating a new structure is done by layers usi ` structure types, material numbers, and dimensions. After the structure of a body point is defined, a simple picture of that structure is displayed and the structure of the next body point is defined. After the structure and inital condition for all the body points are defined, INPGEO returns to MAIN.

4.18 SUBROUTINE SUBPR

Subroutine SUBPR interpolates in an array of data to find the temperature and latent heat of sublimation as a function of surface static pressure as supplied by LANMIN. These properties are stored in the CCS (N, NMB9) array found in the named common CSUB. The data is stored in the following manner

```
CCS (N,1) = Number of X-Y pairs in array
CCS (N,2) = First independent variable (Pressure)
CCS (N,3) = First dependent variable
CCS (N,4) = Second independent variable
CCS (N,5) = Second dependent variable
   etc.
    |
    |
    |
    ↓
```

The routine first checks to see if the value of the argument, X, is out of range of the independent variables in the table, and if so, assigns the correct subscripts to extrapolate off the end of the table. If the value is not out of range, a search is conducted to find the two independent variables which bound the value and a simple straight line interpolation is performed.

4.19 SUBROUTINE SRIPF

Subroutine SRIPF finds the radiation interchange factor, $\mathcal{F}$, in an enclosure given the areas, emissivities and the geometric view factors found in VFAC. The named common SF contains the information in AR(I) (areas), EPP(I) (emissivity), and F(I,J) (geometric view factors). The product of the area and radiant interchange factor is stored in ASF(I,J).

The method used in SRIPF is a network method which is solved by an iterative technique for the radiosity between each of the surfaces. If we consider the network in Figure 4.6 for an enclosure with three surfaces

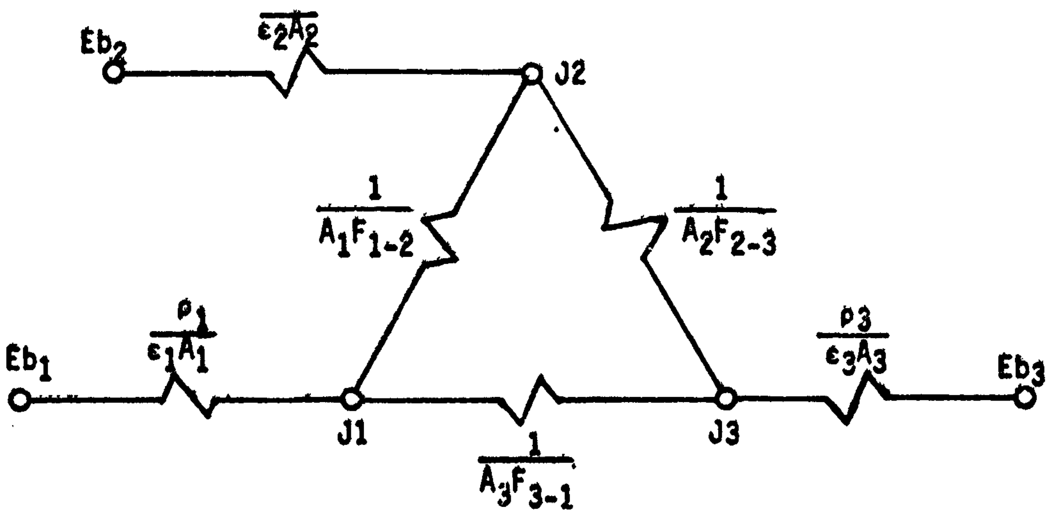


Fig. 4.6 Network for Typical Three Surface Enclosure

we see that

$$q_{NET\ j} = \sum_{k=1}^{n} F_{j\ k} A_j \left(J_k - J_j\right)$$

or

$$q_{NET-j} = \frac{\epsilon_j A_j}{\rho_j}(J_j - E_{bj}) .$$

Equating these two expressions and by use of some algebra, we see that

$$J_j = \left[\frac{\epsilon_j}{1 - \rho_j F_{jj}}\right] E_{bj} + \frac{\rho_j}{1 - \rho_j F_{jj}} \sum_{\substack{k=1 \\ k \neq j}}^{n} J_k F_{jk}$$

is the final expression for the radiosity at node j. Using the following iterative relaxation procedure

$$J_j^{n+1} = (1 - \beta) J_j^n + \beta J_j ,$$

where the relaxation parameter, β, is typically .5, convergence,

$$\left.\frac{J_j^n - J_j^{n-1}}{J_j^n}\right|_{GREATEST} \leq .001$$

is found within ten iterations for the structures described in this code. After the radiosities are found, the radiant interchange area factors are found from

$$ASF\ (I,J) = \mathcal{F}_{i-j} A_i = \frac{A_i F_{i-j} (J_i - J_j)}{(E_{bi} - E_{bj})}$$

where the black body emissive power E_b is assigned arbitrarily.

4.20 SUBROUTINE CORG

This routine determines the effective thermal conductivity, thermal capacity and mass of a corrugated panel section considering heat transfer by conduction and radiation through the panel. We first consider a small section of the corrugated panel shown in Figure 4.7

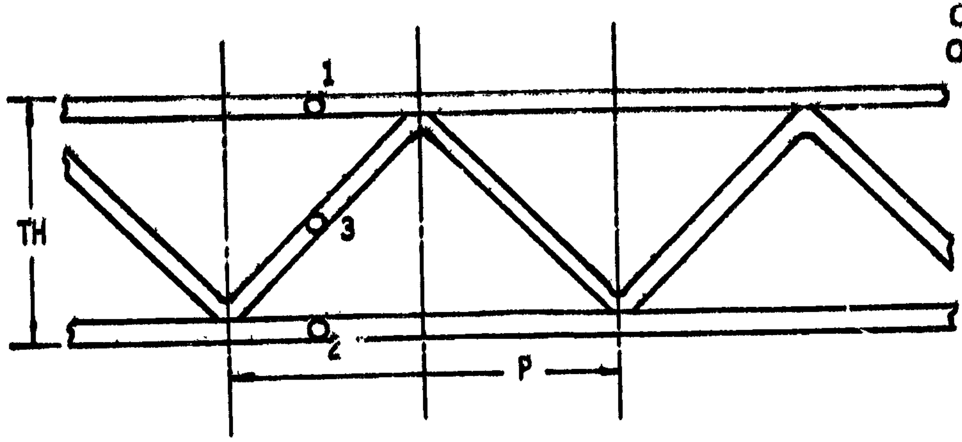


Fig. 4.7 Corrugated Panel Configuration

and choose two planes of symmetry and assign the three nodes 1, 2, and 3. The geometric and material parameters are contained in the named common GAP. The three material thicknesses are TH1, TH2, TH3, while material identifiers are contained in M1, M2, M3. Overall height is TH and the pitch is P. Temperatures at 1 and 2 are given as T1 and T2. These parameters are assigned their respective variable names in subroutine LOAD which is called immediately before CORG is called. The temperature at 3 is unknown, but given the temperatures at 1 and 2, geometric and thermophysical properties, the temperature at 3 can be solved by iteration. The equivalent network for this system consists of a conduction path from node 1 to node 2 passing through node 3. In addition, there is radiative heat transfer from node 1 to 3 and reradiative heat transfer from 3 to 1. The radiative enclosure for the upper, lower, and corrugated structure is modeled using three planes shown below

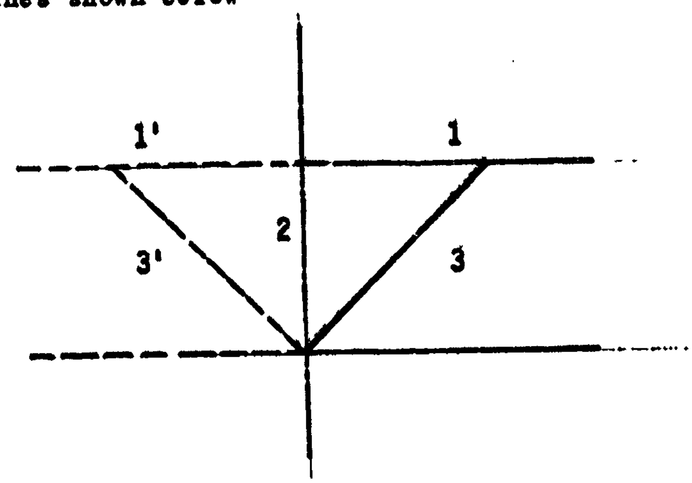


Fig. 4.8 Radiation Enclosure for Corrugated Panel

Plane 2 is a plane of symmetry in which the emissivity is zero and all incident radiation is reflected back into the enclosure which is the emitted and reflected radiation from the reflected enclosure 1', 3', 2. The coordinates of the planes 1, 2, 3 are set and stored in the XX (I,J) and YY (I,J) arrays where I is the plane number and J is 1 or 2 representing the end points. The subroutines VFAC and SRIPF are called to define geometric view factors and area-radiative interchange factors, ASF (I,J). From these factor adiation conductors are formed from the following expression

$$K_{ij} = A_i \mathscr{F}_{ij} \, \sigma \, (T_i^2 + T_j^2) \, (T_i + T_j) \; .$$

where σ = Stefan Boltzman Constant

The equivalent network for the total heat transfer from surface 1 to 2 is shown in Figure 4.9.

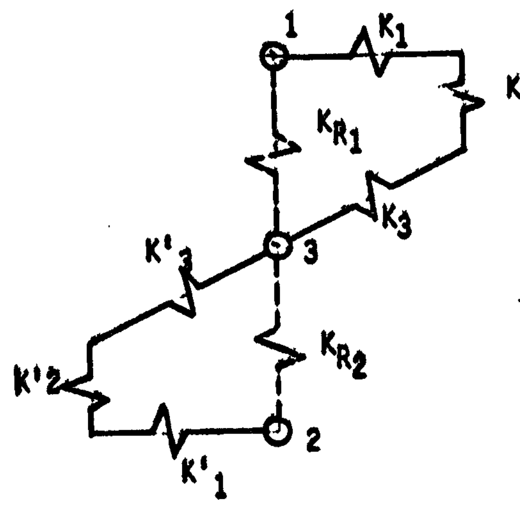


Fig. 4.9 Corrugated Panel Equivalent Network

The three conductors in series K_1 K_2 K_3 and K_1' K_2' K_3' represent the paths through the upper and lower surfaces, a contact conductance which for the present time is set to 10^8 times the area, and the conduction path through the corrugated section. The expression for the three conductors in series is used to form the conductors from node 1 to 3 and 2 to 3 as shown below

$$C1 = \frac{K_1K_2K_3}{K_1K_2 + K_1K_3 + K_2K_3}$$

and

$$C2 = \frac{K_1'K_2'K_3'}{K_1'K_2' + K_1'K_3' + K_2'K_3'} \; .$$

If we represent the radiation paths from 1 to 3 as

$$C4 = A_1\mathcal{F}_{1-3}\sigma\,(T_1^2 + T_3^2)\,(T_1 + T_3)$$

and 2 to 3 as

$$C5 = A_1\mathcal{F}_{1-3}\,\sigma\,(T_2^2 + T_3^2)\,(T_2 + T_3)$$

we can iterate on the temperature at 3 using the following expression.

$$T_3^{n+1} = (1 - \beta)\,T_3^n + \beta \cdot \left(\frac{T_1C1 + T_2C2 + T_1C4 + T_2C5}{C1 + C2 + C4 + C5}\right)$$

Convergence is obtained when

$$\frac{T_3^{n+1} - T_3^n}{T_3^{n+1}} < \varepsilon \sim .001$$

where ε is the input parameter TOL set to a default value of .001.

When the temperature T_3 is solved for the total heat transfer per unit area of panel is computed

$$Q = \frac{|T_1 - T_3| \cdot (C1 + C4)}{P2}$$

and the equivalent conductivity is found from

$$XK = \frac{Q}{T_1 - T_2} .$$

An example case for an aluminum corrugated panel and the equivalent thermal conductance is shown in Figure 4.10.

The thermal capacitance is computed from the mass of the structure and split in two equal parts assigned to CAP1 and CAP2. Total mass is found and stored in XM.

4.21 SUBROUTINE HONEY

Subroutine HONEY determines the effective thermal conductivity, capacity and mass of a honeycomb core sandwiched between two layers. The geometric definition and material identifiers are contained in the named common GAP. Temperatures of the outer layers T1 and T2 are also found in GAP. Cell dimensions are given by TH, the overall height, and H the distance from one flat side to the other for a hexagonal cell. The distance D is the pitch distance shown in Figure 4.11.

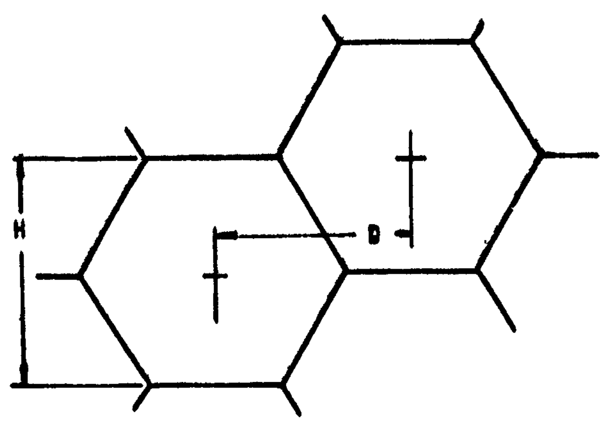
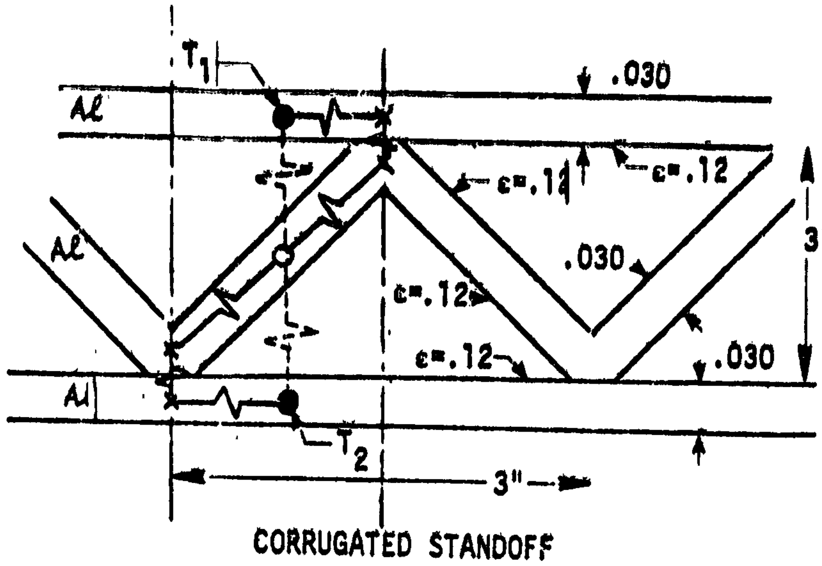


Fig. 4.11 Honeycomb Cell Dimensions



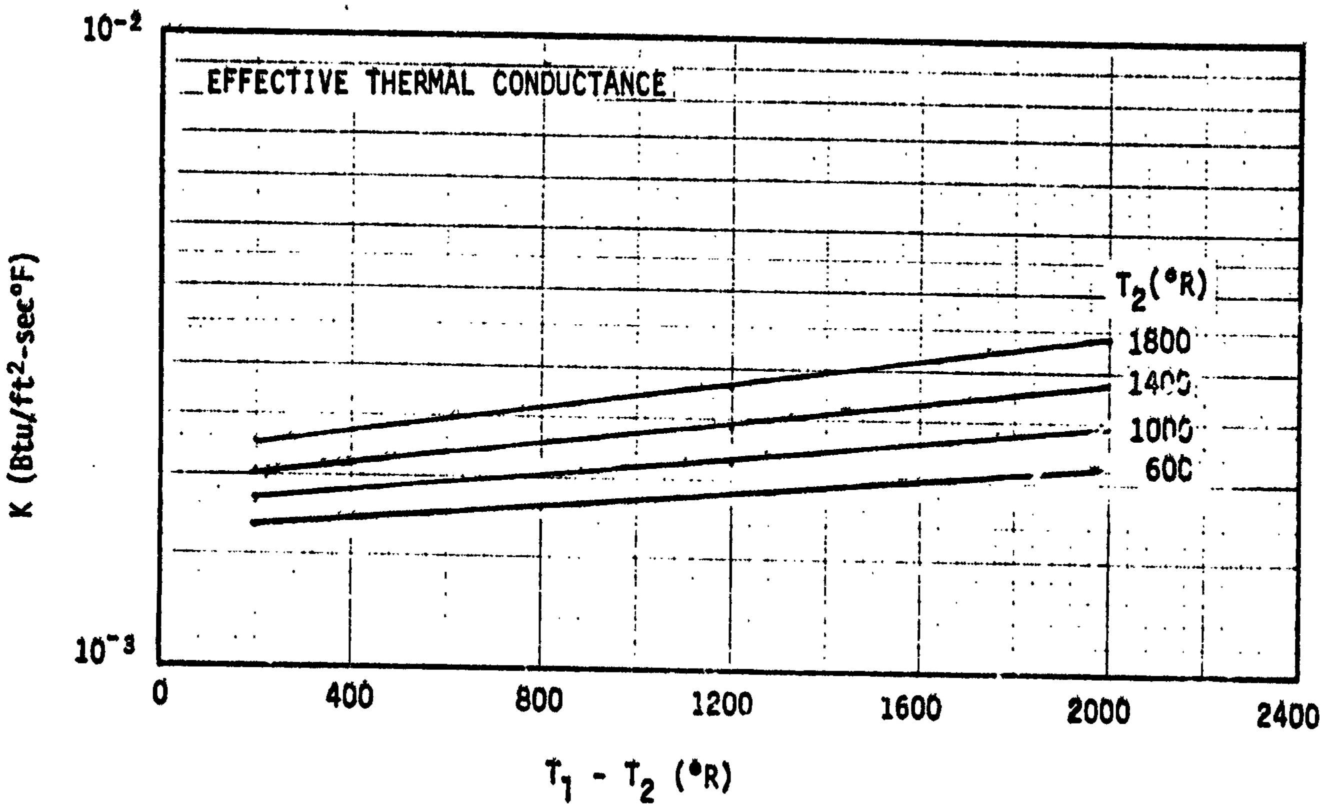


Fig. 4.10 Corrugated Structure Effective Thermal Conductance

The number of cells per unit area, the number of cell walls, and the volume of the material makin up the structure are computed.

Heat transfer through the honeycomb is assumed to be by conduction through the core and radiation within each cell. Each cell is assumed to have six equal walls which is shown in Figure 4.12.

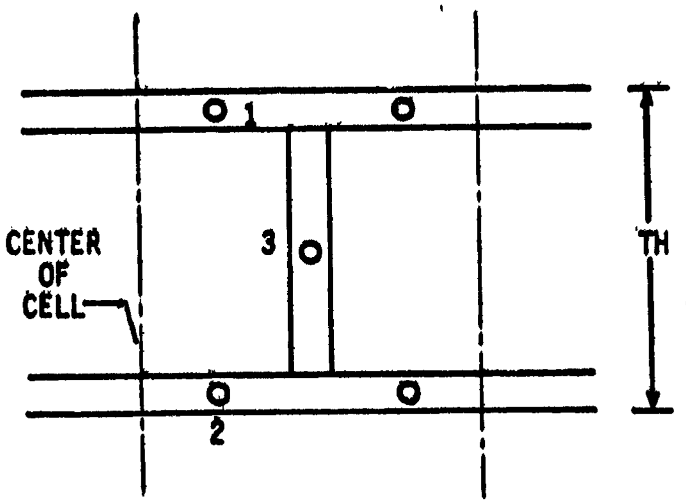
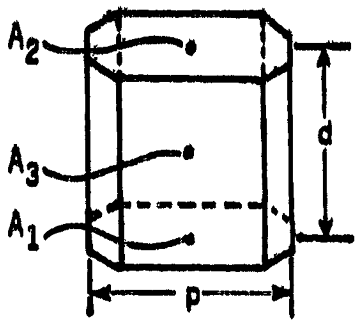


Fig. 4.12 Honeycomb Cell Model

Temperatures at 1 and 2, T1 and T2 respectively, are given. Temperatuare at 3 is solved by relaxation. Radiation from nodes 1 to 2, 1 to 3 and 3 to 2 is computed by assuming a view factor of .1 from surface 1 to 2 and .9 from 1 to 3. This is done in lieu of using the crossed string method (subroutine VFAC) since this is a three dimensional configuration. Changes in the view factors can be made eas'ly to reflect cell size and honeycomb thickness. Typical view factors as a function of cell size and honeycomb thickness are provided in Table 4.4.



VIEW FACTORS

F_{1-2} (Base To Top)
F_{1-3} (Base To Sides)

d \ p	.2	.3	.4	.5	.6	.8	1.0
.25	.130 .870	.230 .770	.300 .700	.380 .620	.450 .550	.540 .460	.610 .390
.50	.035 .965	.075 .925	.125 .875	.175 .825	.220 .780	.300 .700	.380 .620
1.0	.025 .975	.035 .965	.040 .960	.060 .940	.075 .925	.125 .875	.170 .830
2.0	.012 .988	.020 .980	.025 .975	.030 .970	.035 .965	.040 .960	.060 .940
3.0	.008 .992	.010 .990	.017 .983	.025 .975	.027 .973	.028 .972	.030 .970
4.0	.006 .994	.012 .908	.016 .984	.020 .980	.021 .979	.023 .977	.025 .975

Table 4.4 View Factors From Top And Sides To Bottom Of Honeycomb Cell For Use In Subroutine HONEY

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The equivalent electrical network is shown in Figure 4.13

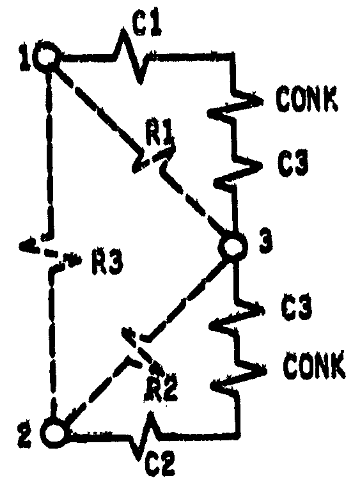

Fig. 4.13   Equivalent Network For Honeycomb

This network describes the heat transfer path between the upper and lower surfaces. Equivalent conductors for the conduction paths are determined from

$$XC1 = \frac{C1 \cdot CONK \cdot C3}{C1 \cdot CONK + C3 \cdot CONK + C1 \cdot C3}$$

and

$$XC2 = \frac{C2 \cdot CONK \cdot C3}{C2 \cdot CONK + C3 \cdot CONK + C2 \cdot C3}$$

where CONK is the contact conductance between the core and the outer surfaces, currently set to 10^8 BTU/Ft^2-Sec-°F. R1, R2, and R3 are computed using the three temperatures and the view factors. Finally, the temperature at 3 is found by relaxation using the formula

$$T_3^{n+1} = (1 - \beta)\, T_3^n + \beta \; \frac{\left(T1 \cdot (XC1 + R1) + T2 \cdot (XC2 + R2)\right)}{XC1 + R1 + XC2 + R2}$$

In the expression above, β is the relaxation factor usually set to .5 in the input. Convergence is rapid and occurs when

$$\frac{T_s^{n+1} - T_s^{n}}{T_s^{n+1}} < TOL \sim .001 \cdot$$

Total heat transfer is computed from the conductor values and three known temperatures. Equivalent conductance is then found by dividing by the temperature difference T_1-T_2. An example case is shown in Figure 4.14 for an all aluminum honeycomb structure. Capacitance CAP1 and CAP2 is found in addition to the mass of the structure and stored in XM.

4.22 SUBROUTINE RGAP

Subroutine RGAP computes the equivalent conductor value through a radiation gap. This model also includes the thermal conductance of the upper and lower surfaces. The thermal model of the radiation gap used is shown in Figure 4.15.

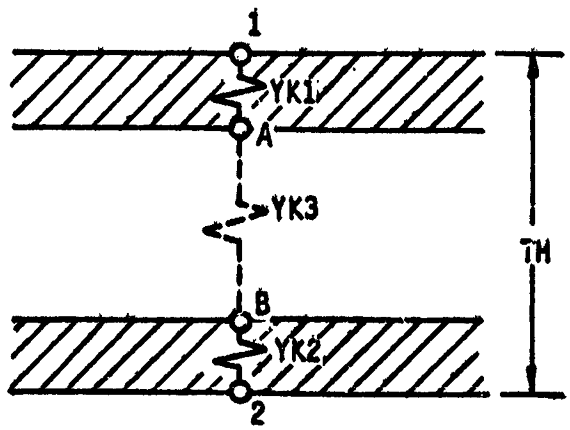

Fig. 4.15 Network For Radiation Gap Calculation

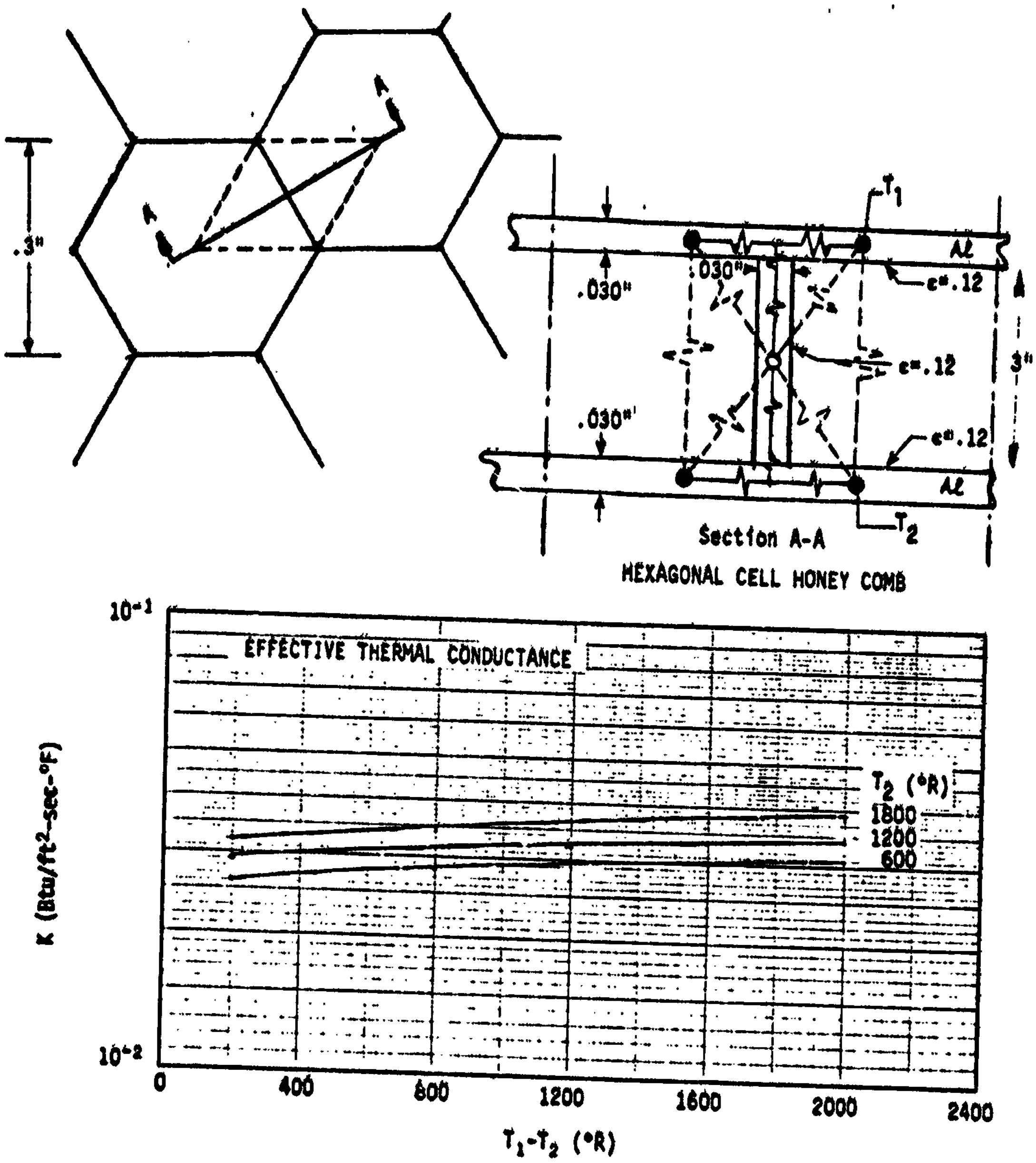

Fig. 4.14 Honeycomb Effective Thermal Conductance

The temperatures at A and B are computed from the known temperatures at 1 and 2. All geometric and material parameters are passed to RGAP through the named common GAP. The radiant interchange factor between the two surfaces is assumed to be that of two infinite plates and is found from the expression below

$$\mathcal{F}_{A-B} = \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} .$$

An iteration procedure is used to find the temperatures at A and B given the temperatures at 1 and 2, T1 and T2 respectively. The conductors YK1 and YK2 are found from the conductivity and the thicknesses TH1 and TH2. YK3 is a radiation conductor found from the following expression:

$$Yk3 = \sigma \mathcal{F}_{A-B} \; (TA^2 + TB^2) \; (TA + TB)$$

The relaxation algorithm used to find TA and TB is as follows

$$TA^{n+1} = (1 - \beta) \; TA^n + \beta \; \frac{T1 \cdot YK1 + TB^n \cdot YK3^n}{YK1 + YK3}$$

and

$$TB^{n+1} = (1 - \beta) \; TB^n + \beta \; \frac{T2 \cdot YK2 + TA^n \cdot YK3^n}{YK2 + YK3} .$$

Convergence is found after

$$\frac{TA^{n+1} - TA^n}{TA^n} \quad \text{AND} \quad \frac{TB^{n+1} - TB^n}{TB^n} < \varepsilon \approx .001$$

Equivalent thermal conductivity is found once TA and TB are solved by

$$XK = \frac{YK1 \cdot YK2 \cdot YK3}{YK1 \cdot YK2 + YK1 \cdot YK3 + YK2 \cdot YK3}.$$

An example case is shown in Figure 4.16.

Finally the mass, XM, and capacitance, CAP1 and CAP2, are computed.

4.23 SUBROUTINE STAND

This subroutine computes the equivalent thermal conductance, capacitance and mass of a structure consisting of a standoff section and two outer surfaces. Heat transfer is assumed to be by conduction and radiation through the panel. Consider the small section of the Z-standoff panel shown in Figure 4.17.

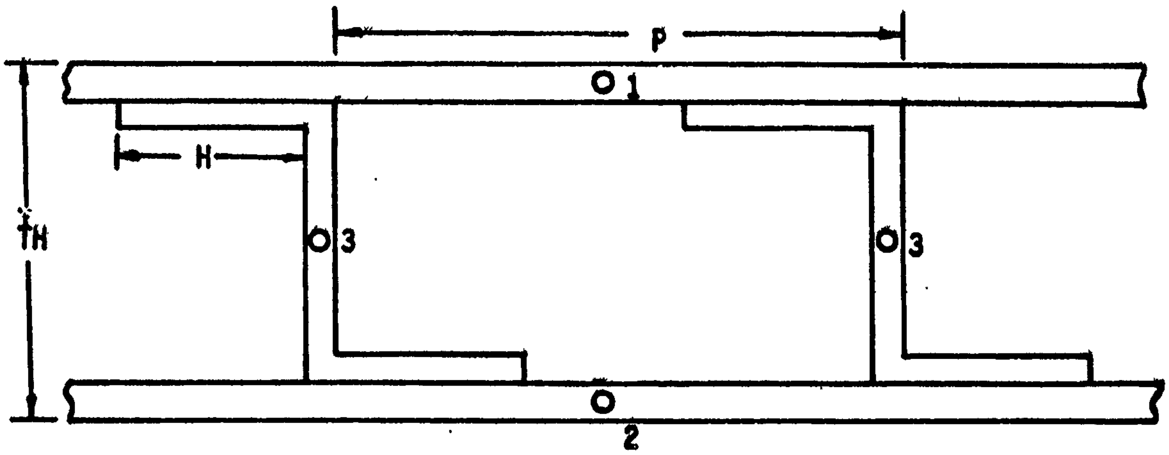

Fig. 4.17 Z-Standoff Configuration

We choose a single enclosure bounded by two standoffs' mid-plane and assign three nodes to the four surfaces, node 3 being common to the standoffs. The geometric and material parameters are contained in the named common, GAP. The three material thicknesses are TH1, TH2, and TH3 while the material identifiers are M1, M2, and M3. Overall height is TH, the pitch is P and the flange width

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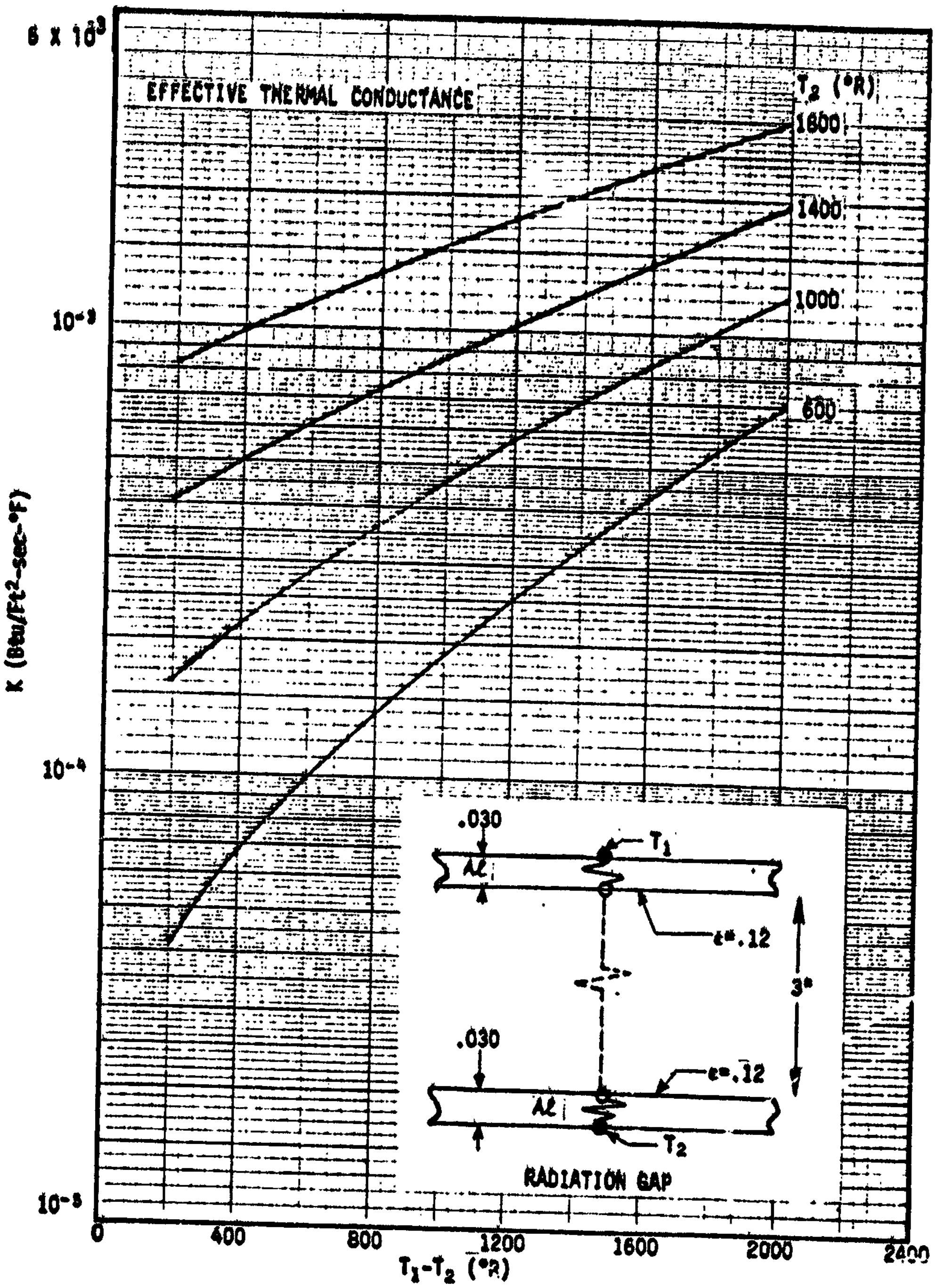

Fig. 4.16 Radiation Gap Effective Thermal Conductance

is H. Temperatures at 1 and 2 are T1 and T2. These parameters are assigned their respective variable names in subroutine LOAD which is called immediately before STAND is called. Temperature at 3 is unknown, but given the temperatures at 1 and 2, geometric and property data, the temperature at 3 can be solved for by iteration. The heat transfer paths are conduction from the upper and lower surfaces through each of the standoffs, since the model is asymmetrical about a midplane, and radiation from node 1 to 2, and from 1 to 3 to 2. The radiative enclosure for the upper lower surfaces, and standoffs consists of four planes shown in Figure 4.18.

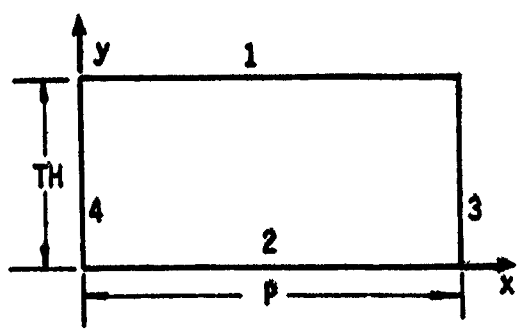

Fig. 4.18 Radiation Enclosure Model For Z-Standoff

The coordinates of the planes making up the enclosure are computed and stored in the XX(I,J) and YY(I,J) arrays where I is the plane number and J is 1 or 2 representing the end points. The subroutines VFAC and SRIPF are called to define geometric view factors and area-interchange factors ASF(I,J).

From these factors, radiation conductors are formed from the following expression

$$K_{ij} = A_i \mathscr{F}_{ij} \sigma (T_i^2 + T_j^2)(T_i + T_j)$$

The equivalent network for the total heat transfer from surface 1 to 2 is shown in Figure 4.19.

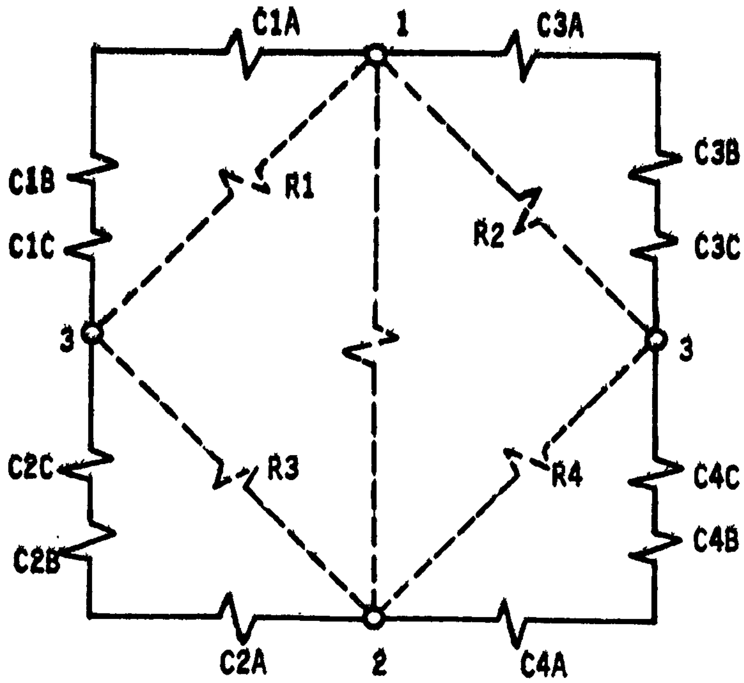

Fig. 4.19 Equivalent Network For Z-Standoff

Equivalent series conductors are formed, C1, C2, C3 and C4 which include a contact conductance and the conductance of the plate and standoffs. Radiation conductors R1, R2, R3, R4, and R5 complete the network. The expression for the equivalent conductor C1 is

$$C1 = \frac{C1A \cdot C1B \cdot C1C}{C1A \cdot C1B + C1B \cdot C1C + C1A \cdot C1C}$$

Similar expressions are used for C2, C3 and C4. The temperature at 3 is found by relaxation using the following expression

$$T_3^{n+1} = (1 - \beta)\, T_3^n + \beta \left(\frac{T1\,(R1 + R2 + C1 + C3) + T2\,(C2 + R3 + C4 + R4)}{R1 + R2 + R3 + R4 + C1 + C2 + C3 + C4} \right)$$

Convergence is obtained when

$$\frac{T_s^{n+1} - T_s^n}{T_s^{n+1}} < \varepsilon \sim .001$$

where is the input parameter TOL set to a default value of .001.

The total heat transfer per unit of panel is then found from

$$Q = \frac{(T1 - T2) \cdot R5 + (T1 - T3) \cdot (C2 + C4 + R3 + R4)}{P}$$

and the equivalent thermal conductance is found from

$$XK = \frac{Q}{T1 - T2} .$$

An example of the equivalent thermal conductance calculation is shown in Figure 4.20.

The thermal capacitance is found and stored in CAP1 and CAP2. Total mass is found and stored in XM.

4.24 SUBROUTINE THINS

Subroutine THINS computes the capacitance and mass of a material with infinite thermal conductance. CAP1 and CAP2 each contain one half the total thermal capacitance of the plate and XM contains the mass. The equivalent thermal conductance is set to 10^{16}, while never used in computing temperatures, it is used as a flag to indicate presence of infinitely conducting plate.

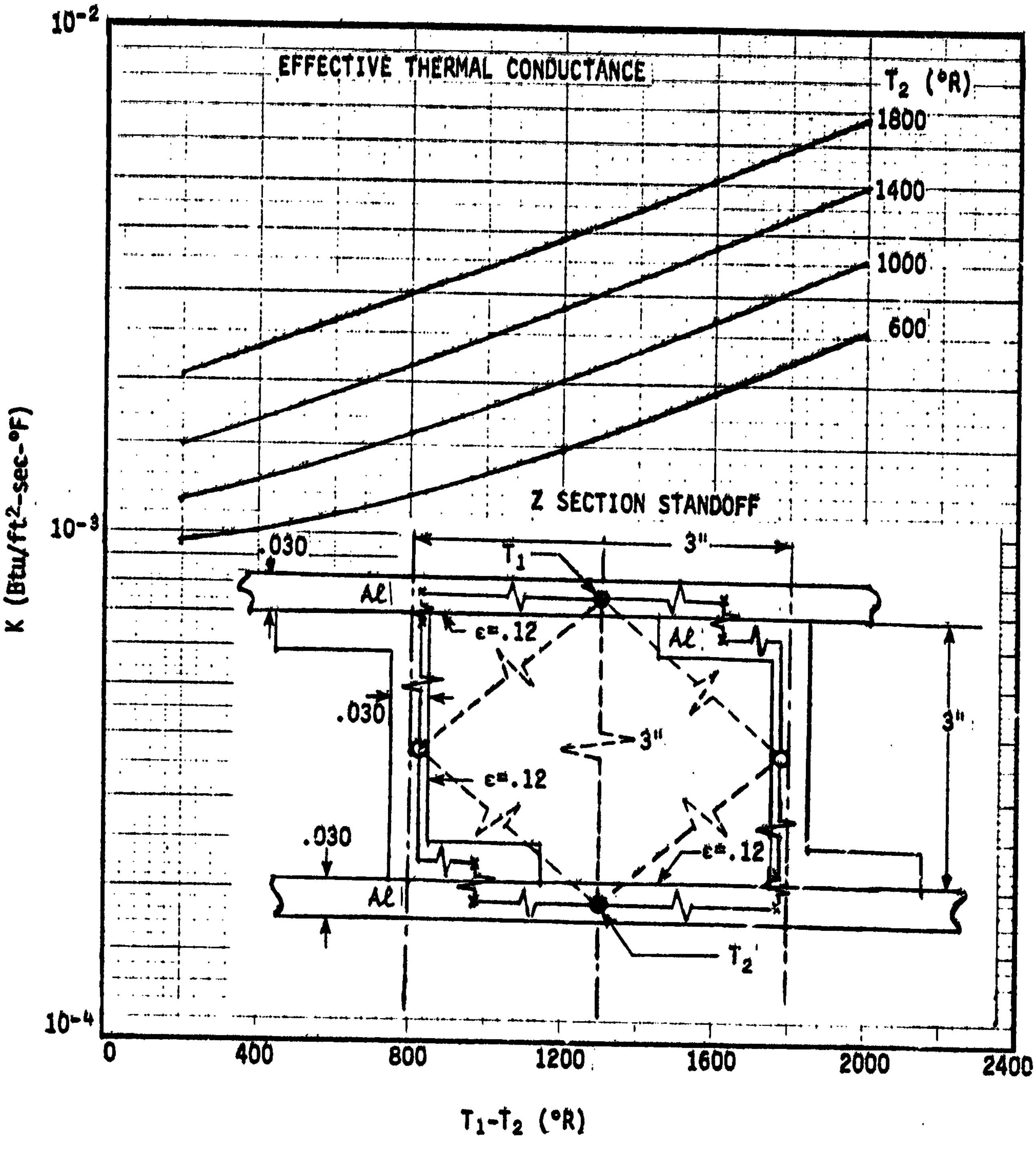

Fig. 4.20 Z-Standoff Effective Thermal Conductance

Section 5.0

INPUT

Data required for operation of EXITS comes from several sources. Data for the particular case, control parameters, geometry etc. comes from the interactive input. Material properties are on a property file and identified with a material number. The environment comes from a file created by LANMIN which is compatible with the EXITS input format. If the structural configuration has been modeled previously and saved on the structure file, the user can skip the structural modeling questions during the interactive input, and call in data from the structure file to describe the detail of the thermal protection system being investigated. A user may wish to study the effects of changing certain trajectory parameters, in such case he would create several LANMIN input files. He would then run the EXITS code at each body point being investigated saving the structure by assigning it a structure number and saving it on a structure file. The input for the subsequent trajectory cases would be greatly simplified since the geometry and materials have been defined and stored on a structures file. Several of these structures files may be created, each file defining the thermal protection system at selected body point locations on a particular vehicle. With these data defined, one can easily compare for thermal protection systems candidate vehicles'.

The following discussion presents examples and descriptions of the input data required for input in the EXITS code. First we have the data defining the environment generated and stored by LANMIN. Next the material properties file, which presently contains some twenty eight materials and can be added to or edited as the user chooses, is presented. Thirdly, an example of the file generated by EXITS which saves the thermal protection system structural and geometric definition and is called the structures file.

Two examples of the interactive input which demonstrates use of all of the options and the seven structure types now available in EXITS are presented. A description of the output for these cases is given in Section VI.

5.1 LANMIN GENERATED ENVIRONMENT FILE

The environment for the body point under investigation is generated by the LANMIN code and stored as a data file. The EXITS code reads this data from Unit 7 in subroutine DATA2 and stores it in arrays. A body point description and body point number is read from this file by the following statement

```
    READ(7,700,END=1000)DESCRP,IBP
700 FORMAT(A72,I5)
```

until the body point specified in the interactive input is found. The environment is then read immediately following this record by the read statement shown below

```
    READ(7,701)TM1(IC),HC1(IC),HAW1(IC),PRES1(IC)
701 FORMAT(2X,F6. 1,39X,E10.3,2X,E10.3,36X,E10.3).
```

An example of the LANMIN input file is shown in Table 5.1. As can be seen, only the time, enthalpy based heat transfer coefficient, adiabatic wall enthalpy, and pressure is read. Data may be read in either the English units or Metric units shown in Table 5.2. Trajectory points are read until a negative time point is encountered.

STS-1 REENTRY TRAJ. (ORBITER) VAND. REF. B.P. NO. 12

*TIME SEC	ALT KFT	VEL FT/SEC	MACH NO	ANGLE ATTACK	REYNOLDS NO./FT	HEAT COEF LBM/SFT-S	REC ENTHALPY BTU/LBM	RAD EQUIL DEG F	HEAT RATE BTU/SFT-S	HEAT LOAD BTU/SFT	PRESSURE LB/SFT	FLOW TYPE
.0	396.3	24566.1	19.24	41.13	.249+001	.645-005	.113+005	198.9	.694-001	.208+001	.125-001	RARE
25.0	384.0	24580.2	20.54	41.20	.444+001	.877-005	.113+005	251.1	.943-001	.444+001	.204-001	RARE
50.0	371.5	24595.5	21.85	41.25	.628+001	.122-004	.112+005	313.5	.131+000	.772+001	.345-001	RARE
75.0	359.1	24610.3	23.30	41.23	.164+002	.176-004	.112+005	385.2	.189+000	.124+002	.617-001	RARE
100.0	346.7	24624.4	24.21	41.05	.310+002	.250-004	.112+005	462.6	.269+000	.192+002	.109+000	RARE
125.0	334.5	24637.6	25.23	40.63	.614+002	.363-004	.112+005	554.2	.390+000	.289+002	.199+000	RARE
150.0	322.5	24646.1	26.14	40.54	.124+003	.537-004	.112+005	655.4	.576+000	.433+002	.378+000	RARE
175.0	310.5	24656.9	26.67	40.63	.251+003	.801-004	.112+005	771.5	.860+000	.648+002	.731+000	RARE
200.0	299.3	24658.3	27.62	41.20	.508+003	.120-003	.112+005	964.5	.129+001	.971+002	.144+001	RARE
225.0	286.1	24657.6	27.89	41.89	.980+003	.179-003	.113+005	1045.9	.193+001	.145+003	.280+001	RARE
250.0	277.9	24631.7	27.86	40.52	.174+004	.253-003	.112+005	1180.8	.271+001	.213+003	.471+001	RARE
275.0	268.3	24595.5	27.82	39.53	.298+004	.253-003	.111+005	1178.0	.269+001	.280+003	.775+001	LAM
300.0	263.9	24510.6	27.00	40.26	.402+004	.301-003	.111+005	1246.5	.319+001	.360+003	.113+002	LAM
325.0	255.0	24414.9	26.45	40.93	.511+004	.345-003	.110+005	1300.2	.363+001	.451+003	.151+002	LAM
350.0	251.0	24277.0	26.07	41.50	.586+004	.371-003	.109+005	1327.8	.387+001	.548+003	.178+002	LAM
375.0	249.2	24123.1	25.76	41.16	.645+004	.388-003	.108+005	1341.2	.399+001	.647+003	.194+002	LAM
400.0	247.4	23958.1	25.46	40.16	.690+004	.397-003	.106+005	1344.3	.402+001	.748+003	.204+002	LAM
425.0	245.5	23786.2	25.21	39.66	.726+004	.404-003	.104+005	1344.5	.402+001	.848+003	.206+002	LAM
450.0	244.6	23612.5	24.96	39.26	.764+004	.411-003	.103+005	1344.6	.402+001	.949+003	.212+002	LAM
475.0	243.4	23428.1	24.70	39.49	.795+004	.419-003	.101+005	1346.0	.403+001	.105+004	.222+002	LAM
500.0	242.3	23241.0	24.44	39.60	.827+004	.426-003	.997+004	1346.5	.403+001	.115+004	.231+002	LAM
514.0	241.0	23129.0	24.29	39.44	.847+004	.429-003	.987+004	1345.3	.402+001	.121+004	.235+002	LAM
528.0	240.9	23018.0	24.14	39.27	.867+004	.432-003	.977+004	1344.0	.401+001	.126+004	.238+002	LAM
542.0	240.2	22907.4	23.98	39.11	.887+004	.436-003	.967+004	1342.8	.400+001	.132+004	.241+002	LAM

Table 5.1 Example Of LANMIN Generated Environment For Body Point 12

* Headers are written for LANMIN printed output but are omitted in file generated for EXITS input.

QUANTITY	ENGLISH	METRIC
TIME	SECONDS	SECONDS
FILM COEFFICIENT	$\frac{LBM.}{FT^2-SEC}$	$\frac{Kg.}{M^2-SEC.}$
ADIABATIC WALL ENTHALPY	$\frac{BTU}{LBM.}$	$\frac{JOULES}{Kg.}$
PRESSURE	$\frac{LBF.}{FT^2.}$	$\frac{NEWTONS}{M^2}$

Table 5.2 LANMIN Generated Environment Units

5.2 MATERIAL PROPERTIES FILE

The thermophysical properties file is read by subroutine DATA1 which finds the specified material identification number, Table 5.3, and then reads the four or six property tables for a non-ablator or ablator respectively. The present set of property data are contained in the file INP1.DAT and read by Unit 8 and are shown in Table 5.4. Property data are usually a function of temperature only, however, the option exits for density, specific heat, thermal conductivity, and emissivity to be a function of both temperature and pressure. Two additional properties, sublimation temperture, and heat of ablation are added for the ablation materials. Both of these properties are input as a function of pressure.

Referring to Table 5.4, we see that the present property file contains twenty eight materials used in thermal protection system design. Material identification numbers are given as the first entry of the header card for the density table. The header card to each table is read by the following statement

```
    READ(8,701)KD,JD,TEST1,TEST2,TMPMXA
701 FORMAT(I3,2X,I5,4X,A10,1X,A13,E10.0)
```

MATERIAL LIST

1. Aluminum 7075-T6
2. Cork
3. LRSI Coating
4. HRSI Coating
5. LI-900 (Bivariate)
6. FRSI Coating
7. FRSI Nomex Felt (Bivariate)
8. SIP RTV 560
9. Titanium
10. Coated Columbium
11. Copper
12. Beryllium
13. Zirconia
14. Molybdenum
15. RENE 41
16. Micro Quartz Felt Insulation
17. INCONEL 617
18. RCC
19. Q-Felt 108 (Bivariate)
20. Tantalum
21. Tungsten
22. INCONEL X 750
23. L 605 Cobalt
24. HAYNES 25
25. MIN-K 1301
26. LI 2200 (Bivariate)
27. Nylon Phenolic (ABLATOR)
28. B-Stage Cork (ABLATOR)
29. MSA-1 (ABLATOR)

Table 5.3 Material Identifier Numbers

```
1     2    AL.7075-T6 DENSITY      660.0
    0.0       175.
 10000.       175.
      7    AL.7075-T6 SPECIFIC HEAT
    0.0       .170
  310.0       .170
  460.0       .195
  660.0       .210
 1320.0       .275
 1460.0       .275
 10000.       .275
      6    AL.7075-T6 CONDUCTIVITY
    0.0     1.400E-2
  260.0     1.400E-2
  460.0     2.000E-2
  760.0     2.500E-2
  860.0     2.700E-2
  960.0     2.900E-2
      2    AL.7075-T6 EMISSIVITY
    0.0       .12
 10000.       .12
2     2    CORK        DENSITY     860.0
    0.0      10.
 10000.      10.
      2    CORK        SPECIFIC HEAT
    0.0       .04
 10000.       .04
      2    CORK        CONDUCTIVITY
    0.0     6.90E-6
 10000.     6.90E-6
      2    CORK        EMISSIVITY
    0.0       .8
 10000.       .8
3     2    LRSI COAT  DENSITY      1660.0
    0.0     104.0
 10000.     104.0
      9    LRSI COAT  SPECIFIC HEAT
    0.0       .15
  210.0       .15
  310.0       .17
  460.0       .19
  710.0       .215
  960.0       .240
 1460.0       .285
 2460.0       .345
 3460.0       .390
      9    LRSI COAT  CONDUCTIVITY
    0.0     1.181E-4
  210.0     1.181E-4
  310.0     1.250E-4
  460.0     1.353E-4
  710.0     1.528E-4
  960.0     1.678E-4
 1450.0     1.956E-4
 2460.0     2.453E-4
 3460.0     3.278E-4
```

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Table 5.4 Thermophysical Material Properties File

```
         2   LRSI COAT  EMISSIVITY
       0.0        .80
    10000.        .80
4        2   HRSI COAT  DENSITY       2760.0
       0.0      104.0
    10000.      104.0
         9   HRSI COAT  SPECIFIC HEAT
       0.0        .15
     210.0        .15
     310.0        .17
     460.0        .19
     710.0        .215
     960.0        .240
    1460.0        .285
    2460.0        .345
    3460.0        .390
         9   HRSI COAT  CONDUCTIVITY
       0.0     1.181E-4
     210.0     1.181E-4
     310.0     1.290E-4
     460.0     1.353E-4
     710.0     1.528E-4
     960.0     1.678E-4
    1460.0     1.956E-4
    2460.0     2.493E-4
    3460.0     3.278E-4
         2   HRSI COAT  EMISSIVITY
       0.0        .85
    10000.        .85
5        2   LI-900     DENSITY       2760.0
       0.0        9.0
    10000.        9.0
        10   LI-900     SPECIFIC HEAT
       0.0        .070
     210.0        .070
     310.0        .105
     460.0        .150
     710.0        .210
     960.0        .252
    1460.0        .288
    1960.0        .300
    2210.0        .303
    3460.0        .303
```

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Table 5.4 (Continued)

```
        15    LI-900      CONDUCTIVITY
      -6.0        0.0        .21        2.12       21.16      211.6      2116.0
       0.0     1.389E-6   1.389E-6   2.083E-6   4.166E-6   6.060E-6   6.472E-6
     210.0     1.389E-6   1.389E-6   2.083E-6   4.166E-6   6.060E-6   6.472E-6
     460.0     2.083E-6   2.083E-6   2.777E-6   5.083E-6   6.944E-6   7.638E-6
     710.0     2.555E-6   2.555E-6   3.472E-6   6.250E-6   8.777E-6   9.472E-6
     960.0     3.472E-6   3.472E-6   4.638E-6   7.666E-6   1.111E-5   1.202E-5
    1210.0     4.861E-6   4.861E-6   6.000E-6   9.027E-6   1.366E-5   1.483E-5
    1460.0     6.472E-6   6.472E-6   7.639E-6   1.088E-5   1.667E-5   1.827E-5
    1710.0     8.555E-6   8.555E-6   9.722E-6   1.366E-5   2.014E-5   2.172E-5
    1960.0     1.155E-5   1.155E-5   1.275E-5   1.714E-5   2.430E-5   2.616E-5
    2210.0     1.575E-5   1.575E-5   1.694E-5   2.130E-5   2.944E-5   3.138E-5
    2460.0     2.039E-5   2.039E-5   2.172E-5   2.616E-5   3.527E-5   3.777E-5
    2760.0     2.683E-5   2.683E-5   2.833E-5   3.222E-5   4.305E-5   4.638E-5
    2960.0     3.222E-5   3.222E-5   3.416E-5   3.861E-5   4.972E-5   5.388E-5
    3260.0     4.277E-5   4.277E-5   4.500E-5   5.000E-5   6.111E-5   6.722E-5
    3460.0     5.277E-5   5.277E-5   5.444E-5   6.080E-5   7.277E-5   8.055E-5
         2    LI-900      EMISSIVITY
       0.0        1.0
    10000.        1.0
  6      2    FRSI COAT   DENSITY       1160.0
       0.0       97.0
    10000.       97.0
         2    FRSI COAT   SPECIFIC HEAT
       0.0        .35
    10000.        .35
         2    FRSI COAT   CONDUCTIVITY
       0.0     5.000E-5
    10000.     5.000E-5
         2    FRSI COAT   EMISSIVITY
       0.0        .80
    10000.        .80
  7      2    FRSI NOMEX  DENSITY       1160.0
       0.0        5.4
    10000.        5.4
         8    FRSI NOMEX  SPECIFIC HEAT
       0.0        .300
     210.0        .300
     460.0        .312
     660.0        .320
     760.0        .335
    1060.0        .345
    1260.0        .360
    1460.0        .380
```


Table 5.4 (Continued)

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```
    10     FRSI NOMEX CONDUCTIVITY
  -7.0       0.0       .021       .212      2.116      21.16      211.6      2116.0
   0.0    1.805E-6  1.805E-6  1.944E-6  2.222E-6  2.555E-6  2.833E-6  3.055E-6
 210.0    1.805E-6  1.805E-6  1.944E-6  2.222E-6  2.555E-6  2.833E-6  3.055E-6
 460.0    2.222E-6  2.222E-6  2.916E-6  3.888E-6  4.750E-6  5.550E-6  5.722E-6
 560.0    2.388E-6  2.388E-6  3.333E-6  4.611E-6  5.694E-6  6.611E-6  6.944E-6
 660.0    2.638E-6  2.638E-6  3.833E-6  5.388E-6  6.666E-6  7.638E-6  8.055E-6
 760.0    2.833E-6  2.833E-6  4.305E-6  6.111E-6  7.638E-6  8.944E-6  9.861E-6
 860.0    3.055E-6  3.055E-6  4.722E-6  6.944E-6  8.777E-6  1.027E-5  1.061E-5
1060.0    3.611E-6  3.611E-6  5.750E-6  8.750E-6  1.130E-5  1.319E-5  1.358E-5
1260.0    4.166E-6  4.166E-6  6.944E-6  1.055E-5  1.388E-5  1.688E-5  1.722E-5
1460.0    4.861E-6  4.861E-6  8.333E-6  1.283E-5  1.708E-5  2.152E-5  2.208E-5
     2     FRSI NOMEX EMISSIVITY
   0.0       1.0
10000.       1.0
8    2     SIP-RTV560 DENSITY       960.0
   0.0     88.0
10000.     88.0
     9     SIP-RTV560 SPECIFIC HEAT
   0.0      .273
 320.0      .273
 360.0      .270
 410.0      .260
 460.0      .265
 560.0      .285
 660.0      .300
 860.0      .340
1000.0      .340
     7     SIP-RTV560 CONDUCTIVITY
   0.0     6.472E-5
 260.0     6.472E-5
 360.0     6.944E-5
 460.0     6.805E-5
 660.0     5.555E-5
 860.0     4.528E-5
 960.0     4.055E-5
     2     SIP-RTV560 EMISSIVITY
   0.0       1.0
10000.       1.0
9    2     TITANIUM   DENSITY       1260.0
   0.0     512.0
10000.     512.0
```

Table 5.4 (Continued)

	6	TITANIUM	SPECIFIC HEAT	
	0.0	.096		
	260.0	.096		
	460.0	.125		
	860.0	.146		
	1660.0	.160		
	10000.	.160		
	5	TITANIUM	CONDUCTIVITY	
	0.0	1.200E-3		
	530.0	1.200E-3		
	960.0	1.500E-3		
	1460.0	2.800E-3		
	10000.	2.800E-3		
	2	TITANIUM	EMISSIVITY	
	0.0	.12		
	10000.	.12		
10	2	CTD.COLUMB	DENSITY	2960.0
	0.0	562.0		
	10000.	562.0		
	6	CTD.COLUMB	SPECIFIC HEAT	
	0.0	.059		
	460.0	.059		
	660.0	.061		
	1060.0	.065		
	1460.0	.065		
	10000.	.065		
	6	CTD.COLUMB	CONDUCTIVITY	
	0.0	4.40E-3		
	530.0	4.40E-3		
	960.0	6.10E-3		
	1460.0	7.30E-3		
	2460.0	8.00E-3		
	10000.	8.00E-3		
	4	CTD.COLUMB	EMISSIVITY	
	0.0	.19		
	3160.0	.19		
	4060.0	.24		
	10000.	.24		
11	2	COPPER	DENSITY	1560.0
	0.0	555.0		
	10000.	555.0		
	8	COPPER	SPECIFIC HEAT	
	0.0	.0001		
	60.0	.0400		
	460.0	.088		
	960.0	.100		
	1460.0	.110		
	1960.0	.120		
	2460.0	.130		
	10000.	.130		

Table 5.4 (Continued)

```
    8   COPPER     CONDUCTIVITY
   0.0      .070
  60.0      .070
 460.0      .066
 960.0      .061
1460.0      .058
1960.0      .057
2460.0      .051
10000.      .051
    2   COPPER     EMISSIVITY
   0.0      .78
10000.      .78
12   2   BERYLLIUM  DENSITY      1660.0
   0.0    116.0
10000.    116.0
   10   BERYLLIUM  SPECIFIC HEAT
   0.0      .000
 160.0      .001
 360.0      .20
 460.0      .35
 960.0      .58
1460.0      .68
1960.0      .75
2460.0      .84
2960.0      .86
3460.0      .86
    9   BERYLLIUM  CONDUCTIVITY
   0.0    38.88E-3
 400.0    38.88E-3
 460.0    35.00E-3
 960.0    22.22E-3
1460.0    17.00E-3
1960.0    14.00E-3
2460.0    12.50E-3
2960.0    12.00E-3
3460.0    12.00E-3
    2   BERYLLIUM  EMISSIVITY
   0.0      .15
10000.      .15
13   2   ZIRCONIA   DENSITY      3360.0
   0.0    349.4
10000.    349.4
    6   ZIRCONIA   SPECIFIC HEAT
   0.0      .115
 460.0      .115
 960.0      .140
1460.0      .148
2460.0      .153
3960.0      .155
    6   ZIRCONIA   CONDUCTIVITY
   0.0    2.360E-4
 460.0    2.360E-4
 960.0    2.560E-4
1460.0    2.790E-4
2460.0    3.470E-4
3960.0    3.610E-4
```


Table 5.4 (Continued)

```
      2    ZIRCONIA   EMISSIVITY
    0.0      .20
 10000.      .20
14    2    MOLYBDENUM DENSITY      2860.0
    0.0     640.0
 10000.     640.0
      7    MOLYBDENUM SPECIFIC HEAT
    0.0     .052
  260.0     .052
  460.0     .060
 1460.0     .067
 2460.0     .080
 4960.0     .110
 7460.0     .110
      7    MOLYBDENUM CONDUCTIVITY
    0.0     .0244
  260.0     .0244
  460.0     .0218
 1460.0     .0200
 2460.0     .0160
 4960.0     .0160
 7460.0     .0119
      2    MOLYBDENUM EMISSIVITY
    0.0      .20
 10000.      .20
15    2    RENE 41    DENSITY      2060.0
    0.0     512.0
 10000.     512.0
      5    RENE 41    SPECIFIC HEAT
    0.0     .059
   60.0     .059
  460.0     .059
 2860.0     .230
 10000.     .230
      5    RENE 41    CONDUCTIVITY
    0.0     .0014
  530.0     .0014
  960.0     .0022
 1460.0     .0029
 2460.0     .0042
      2    RENE 41    EMISSIVITY
    0.0      .20
 10000.      .20
16    2    MICRO QRTZ DENSITY      1460.0
    0.0      3.5
 10000.      3.5
      9    MICRO QRTZ SPECIFIC HEAT
    0.0     .186
  535.0     .186
  760.0     .2173
  860.0     .2312
  880.0     .2340
 1260.0     .26136
 1380.0     .270
 1460.0     .27227
 2260.0     .2950
```


Table 5.4 (Continued)

```
          9    MICRO QRTZ CONDUCTIVITY
        0.0      7.220E-6
      535.0      7.220E-6
      760.0      7.639E-6
      860.0      9.028E-6
      880.0      9.352E-6
     1260.0      1.551E-5
     1380.0      1.773E-5
     1460.0      1.921E-5
     2260.0      3.970E-5
          2    MICRO QRTZ EMISSIVITY
        0.0       .85
     10000.       .85
 17       2    INCONL 617 DENSITY        2260.0
        0.0      521.86
     10000.      521.86
         12    INCONL 617 SPECIFIC HEAT
        0.0       .100
      538.0       .100
      660.0       .104
      860.0       .111
     1060.0       .117
     1460.0       .131
     1660.0       .137
     1860.0       .144
     2060.0       .150
     2260.0       .157
     2460.0       .163
     10000.       .163
         12    INCONL 617 CONDUCTIVITY
        0.0      2.176E-3
      538.0      2.176E-3
      660.0      2.338E-3
      860.0      2.616E-3
     1060.0      2.894E-3
     1460.0      3.449E-3
     1660.0      3.727E-3
     1860.0      4.005E-3
     2060.0      4.282E-3
     2260.0      4.560E-3
     2460.0      4.838E-3
     10000.      4.838E-3
          2    INCONL 617 EMISSIVITY
        0.0       .15
     10000.       .15
 18       2    RCC         DENSITY       3000.0
        0.0      103.7
     10000.      103.7
```

Table 5.4   (Continued)

```
        11    RCC        SPECIFIC HEAT
       0.0       .080
     160.0       .080
     360.0       .150
     460.0       .170
     960.0       .242
    1460.0       .295
    1960.0       .330
    2460.0       .360
    2960.0       .390
    3460.0       .420
    10000.       .420
        11    RCC        CONDUCTIVITY
       0.0     1.852E-4
     160.0     1.852E-4
     460.0     5.324E-4
     660.0     7.176E-4
     860.0     8.102E-4
    1060.0     8.796E-4
    1460.0     9.259E-4
    2160.0     9.722E-4
    2660.0     9.722E-4
    3360.0     9.491E-4
    10000.     9.491E-4
         8    RCC        EMISSIVITY
       0.0     .8
     860.0     .8
    1260.0     .86
    1760.0     .88
    2260.0     .885
    2560.0     .88
    3460.0     .84
    10000.     .84
19       2    G-FELT 108 DENSITY       1160.0

       0.0     6.0
    10000.     6.0
        10    G-FELT 108 SPECIFIC HEAT
       0.0     .20
     660.0     .20
     760.0     .21
     960.0     .24
    1160.0     .26
    1460.0     .27
    1660.0     .28
    1860.0     .29
    2060.0     .30
    10000.     .30
```

Table 5.4 (Continued)

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	10	G-FELT 108	CONDUCTIVITY	
	-2.0	21.16	2116.0	
	0.0	3.700E-6	6.018E-6	
	660.0	3.700E-6	6.018E-6	
	760.0	4.600E-6	6.944E-6	
	960.0	6.700E-6	9.028E-6	
	1160.0	9.020E-6	1.197E-5	
	1460.0	1.203E-5	1.574E-5	
	1660.0	1.435E-5	1.852E-5	
	1860.0	1.713E-5	2.129E-5	
	2060.0	1.713E-5	2.407E-5	
	10000.	1.713E-5	2.407E-5	
	6	G-FELT 108	EMISSIVITY	
	0.0	.88		
	660.0	.88		
	1160.0	.70		
	1460.0	.65		
	1660.0	.60		
	10000.	.60		
20	2	TANTALUM	DENSITY	4460.0
	0.0	1036.8		
	10000.	1036.8		
	6	TANTALUM	SPECIFIC HEAT	
	0.0	.0326		
	260.0	.0326		
	460.0	.0331		
	1460.0	.0356		
	2960.0	.0396		
	3460.0	.0410		
	10000.	.0410		
	10	TANTALUM	CONDUCTIVITY	
	0.0	8.750E-3		
	260.0	8.750E-3		
	1080.0	1.027E-2		
	1440.0	1.067E-2		
	2160.0	1.170E-2		
	2520.0	1.210E-2		
	2820.0	1.230E-2		
	3180.0	1.270E-2		
	3600.0	1.295E-2		
	10000.	1.295E-2		
	2	TANTALUM	EMISSIVITY	
	0.0	.20		
	10000.	.20		
21	2	TUNGSTEN	DENSITY	4460.0
	0.0	1204.4		
	10000.	1204.4		
	5	TUNGSTEN	SPECIFIC HEAT	
	0.0	.0325		
	460.0	.0325		
	5460.0	.0440		
	7460.0	.0470		
	10000.	.0470		

Table 5.4 (Continued)

```
      7   TUNGSTEN   CONDUCTIVITY
    0.0      1.60E-2
  460.0      1.60E-2
 2460.0      1.25E-2
 3460.0      1.10E-2
 4460.0      9.50E-3
 4960.0      9.40E-3
 10000.      9.40E-3
      2   TUNGSTEN   EMISSIVITY
    0.0      .066
 10000.      .066
22    2   INCONLX750 DENSITY        2260.0
    0.0      531.3
 10000.      531.3
      6   INCONLX750 SPECIFIC HEAT
    0.0      .080
  260.0      .080
  460.0      .095
 1460.0      .136
 2460.0      .170
 10000.      .170
      6   INCONLX750 CONDUCTIVITY
    0.0      1.900E-3
  530.0      1.900E-3
  960.0      2.600E-3
 1460.0      3.400E-3
 2460.0      4.800E-3
 10000.      4.800E-3
      4   INCONLX750 EMISSIVITY
    0.0      .60
 1010.0      .60
 2035.0      .75
 10000.      .75
23    2   L605 COBLT DENSITY        2260.0
    0.0      569.0
 10000.      569.0
      4   L605 COBLT SPECIFIC HEAT
    0.0      .0965
  160.0      .0965
 2960.0      .1640
 10000.      .1640
      6   L605 COBLT CONDUCTIVITY
    0.0      1.50E-3
  530.0      1.50E-3
  960.0      2.30E-3
 1460.0      3.10E-3
 2460.0      4.90E-3
 10000.      4.90E-3
      2   L605 COBLT EMISSIVITY
    0.0      .20
 10000.      .20
24    2   HAYNES 25  DENSITY        2460.0
    0.0      570.0
 10000.      570.0
```

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Table 5.4 (Continued)

```
         2   HAYNES 25  SPECIFIC HEAT
       0.0      .12
     10000.     .12
         5   HAYNES 25  CONDUCTIVITY
       0.0      1.38E-2
     460.0      1.38E-2
    1460.0      3.75E-2
    2260.0      5.55E-2
    10000.      5.55E-2
         2   HAYNES 25  EMISSIVITY
       0.0      .78
    10000.      .78
25       2   MIN-K 1301 DENSITY       1260.0
       0.0      20.0
    10000.      20.0
         2   MIN-K 1301 SPECIFIC HEAT
       0.0      .212
    10000.      .212
         7   MIN-K 1301 CONDUCTIVITY
       0.0    4.638E-6
     160.0    4.638E-6
     860.0    4.861E-6
    1060.0    5.333E-6
    1260.0    5.777E-6
    1460.0    6.250E-6
    10000.    6.250E-6
         2   MIN-K 1301 EMISSIVITY
       0.0    .93
    10000.    .93
26       2   LI-2200    DENSITY       2760.0
       0.0    22.0
    10000.    22.0
         2   LI-2200    SPECIFIC HEAT
       0.0    .19
    10000.    .30
        15   LI-2200    CONDUCTIVITY
      -6.0      0.0       .21       2.12      21.16     211.6     2116.
       0.0    3.88E-6   3.88E-6   4.44E-6   7.22E-6   8.33E-6   8.88E-6
     210.0    3.88E-6   3.88E-6   4.44E-6   7.22E-6   8.33E-6   8.88E-6
     460.0    4.72E-6   4.72E-6   6.11E-6   8.61E-6   9.16E-6   1.19E-5
     710.0    6.11E-6   6.11E-6   7.22E-6   1.05E-5   1.30E-5   1.50E-5
     960.0    6.66E-6   6.66E-6   8.88E-6   1.11E-5   1.55E-5   1.80E-5
    1210.0    8.05E-6   8.05E-6   1.02E-5   1.25E-5   1.77E-5   2.11E-5
    1460.0    9.44E-6   9.44E-6   1.19E-5   1.44E-5   2.08E-5   2.44E-5
    1710.0    1.13E-5   1.13E-5   1.38E-5   1.66E-5   2.55E-5   2.88E-5
    1960.0    1.38E-5   1.38E-5   1.63E-5   1.97E-5   2.94E-5   3.30E-5
    2210.0    1.66E-5   1.66E-5   1.94E-5   2.33E-5   3.41E-5   3.86E-5
    2460.0    1.94E-5   1.94E-5   2.30E-5   2.77E-5   3.94E-5   4.44E-5
    2760.0    2.36E-5   2.36E-5   2.77E-5   3.33E-5   4.63E-5   5.25E-5
    2960.0    2.66E-5   2.66E-5   3.13E-5   3.75E-5   5.16E-5   5.88E-5
    3260.0    3.22E-5   3.22E-5   3.75E-5   4.55E-5   6.08E-5   6.94E-5
    3460.0    3.63E-5   3.63E-5   4.25E-5   5.25E-5   6.80E-5   7.77E-5
```

Table 5.4 (Continued)

	2	LI-2200 EMISSIVITY	
	0.0	.80	
	10000.	.80	
27	2	NYLON PHEN DENSITY	6210.0
	0.0	94.0	
	10000.	94.0	
	5	NYLON PHEN SPECIFIC HEAT	
	0.0	.20	
	560.0	.21	
	660.0	.25	
	960.0	.275	
	10000.	.275	
	5	NYLON PHEN CONDUCTIVITY	
	0.0	1.39E-5	
	460.0	1.39E-5	
	660.0	1.94E-5	
	910.0	2.50E-5	
	10000.	2.50E-5	
	2	NYLON PHEN EMISSIVITY	
	0.0	.85	
	10000.	.85	
27	5	NYLON PHEN SUBLIM. TEMP	
	0.0	5670.0	
	21.16	5670.0	
	211.6	5880.0	
	2116.	6210.0	
	21160.0	6210.0	
27	5	NYLON PHEN HEAT-ABLATION	
	0.0	11000.0	
	21.16	11000.0	
	211.6	10600.0	
	2116.	9200.0	
	21160.	9200.0	
28	2	B-STG.CORK DENSITY	1220.0
	0.0	31.0	
	10000.	31.	
	2	B-STG.CORK SPECIFIC HT.	
	0.0	.46	
	10000.	.46	
	4	B-STG.CORK CONDUCTIVITY	
	0.0	1.11 E-5	
	860.0	1.11 E-5	
	1310.0	3.33 E-6	
	10000.0	3.33 E-6	
	2	B-STG.CORK EMISSIVITY	
	0.0	.8	
	10000.	.8	
28	2	B-STG.CORK SUB.TEMP	

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Table 5.4 (Continued)

```
     0.0       1220.
     5000.     1220.
28       2    B-STD.CORK HEAT ABL.  .
     0.0       7000.
     5000.     7000.
2V       2    MSA-1      DENSITY      1080.0
   0.0       16.0
   10000.     16.
         4    MSA-1      SPECIFIC HT.
   0.0       .28
   550.0__.__ _.28
   1080.      .56
   10000.     .56
         4    MSA-1      CONDUCTIVITY
   0.0           8.30 E-6
   510.          8.30 E-6
   1100.         1.39 E-6
   10000.        1.39 E-6
         2    MSA-1      EMISSIV:TY
   0.0        .8
   10000.      .8
29       2    MSA-1      SUB.TEMP
   0.0       1080.
   3000.      1080.
29       2    MSA-1      HEAT-ABL.
   0.0       3000.
   5000.      3000.
-1            END OF FILE
```


Table 5.4 (Continued)

where

KD = Material Identifier Number

JD = Number of entries in Table (down the page)

TEST1 = Material Name

TEST2 = Property (Density, specific heat, etc.)

TMPMXA = Maximum allowable temperature for material.
(Read on density header card)

The next JD records are then read to load the property into arrays using the following read statement and format.

```
     READ(8,702) (ARD(MR),MR=1,8)
702 FORMAT(5X,8E10.0).
```

For a monovariate table, the independent variable is ARD(1) and the dependent variable is ARD(2). For a bivariate table, ARD(1) is the negative of the number of pressure entries, going across the page. The pressure values are stored in ARD(2) through ARD(8).

The next JD records are read by the same read statement. ARD(1) will then be the temperature while ARD(2) through ARD(8) are the properties i. e. conductivity or specific heat.

All property tables must be arranged in a particular order. The first property must be density followed by specific heat, conductivity and emissivity. For a ablator-sublimer material, sublimation temperature, and heat of ablation are added as the fifth and sixth properties. To flag a material as being an ablator sublimer, the material identification number is included on the header card for the sublimation temperature table. Units for the various properties are given in Table 5.5 and are always used regardless of the units set used in the input.

PROPERTY	UNITS
DENSITY	LBM./FT.^{3}
MAXIMUM ALLOWABLE TEMPERATURE	DEGREES-R
SPECIFIC HEAT	BTU/LBM.- R
THERMAL CONDUCTIVITY	BTU/Ft-SEC- R
EMISSIVITY	DIMENSIONLESS
SUBLIMATION TEMPERATURE	DEGREES-R
HEIGHT OF ABLATION	BTU/LBM.

TABLE 5.5 Material Property Units

5.3 STRUCTURES FILE

The EXITS program will create a file which saves the geometric and material definition of the thermal protection system being analyzed. The user assigns this definition a structure number which is used to identify the structure for later use. By doing this, the user can reevaluate the same thermal protection system under different environment conditions with a much reduced interactive input. The name of the structure file is input during the interactive portion of the input. Structures are added to the file at the bottom or below any structure which already exist in the file. If any of the existing structures have the structure number the user is using to identify the new structure, a message will appear during the interactive input asking for a new identification number. Therefore, each structure in the file will have a distinct structure identification number.

An example of a structure definition is given in Table 5.6 for the demonstration cases presented in Section 5.4 and 5.6. No format specifications need to be discussed here since EXITS creates and reads this file exclusively.

The first record gives the identification number, the number of layers, the number of materials per layer and the number of dimensions per layer to define the geometry. The next two lines are a description typed in during the interactive input. The next four lines describe each layer. The first entry gives the layer type. Material types are given in the next three locations. Finally, the next six floating point values define the layer geometry dimensions in feet.

```
 1       4       3       6
  TEST CASE STRUCTURE FOR LANGLEY CENTER
  ABLATOR SUBLIMER - RADIATION GAP - THIN SKIN - Z STANDOFF
         7  28   0   0  0.8333334E-01  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
         2  10   1   0  0.1041667E-01  0.8333334E-02  0.0000000E+00  0.1250000E+00  0.0000000E+00  0.0000000E+00
         6   1   0   0  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.2500000E-01  0.0000000E+00  0.0000000E+00
         5  17  10   1  0.1166667E-01  0.1500000E-01  0.7916667E-02  0.1666667E+00  0.6666667E+00  0.6250000E-01
 2       4       3       6
  TEST CASE STRUCTURE FOR LANGLEY CENTER
  SLAB - SLAB - HONEY COMB - CORRUGATED
         1   4   0   0  0.8333334E-02  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
         1   5   0   0  0.4166667E-01  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
         3   1   1   1  0.1000000E-01  0.9166666E-02  0.7916667E-02  0.6250000E-01  0.0000000E+00  0.2500000E-01
         4  17  17   9  0.6666666E-02  0.6666666E-02  0.1000000E-01  0.8333334E-01  0.6666667E-01  0.0000000E+00
 3       1       3       6
  ABLATOR SUBLIMER
  HALF INCH OF CORK
         7  27   0   0  0.4166667E-01  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
-9999
```

TABLE 5.6 Structure File For Sample Case Given In Section 5.4 And 5.6

5.4 EXAMPLE CASE ONE (ABLATOR, RADIATION GAP, THIN SKIN, Z-STANDOFF)

This first example case configuration is not representative of an actual thermal protection system structure but serves to illustrate the interactive input requirements for four of the structural types. The configuration for this case is shown in Figure 5.1.

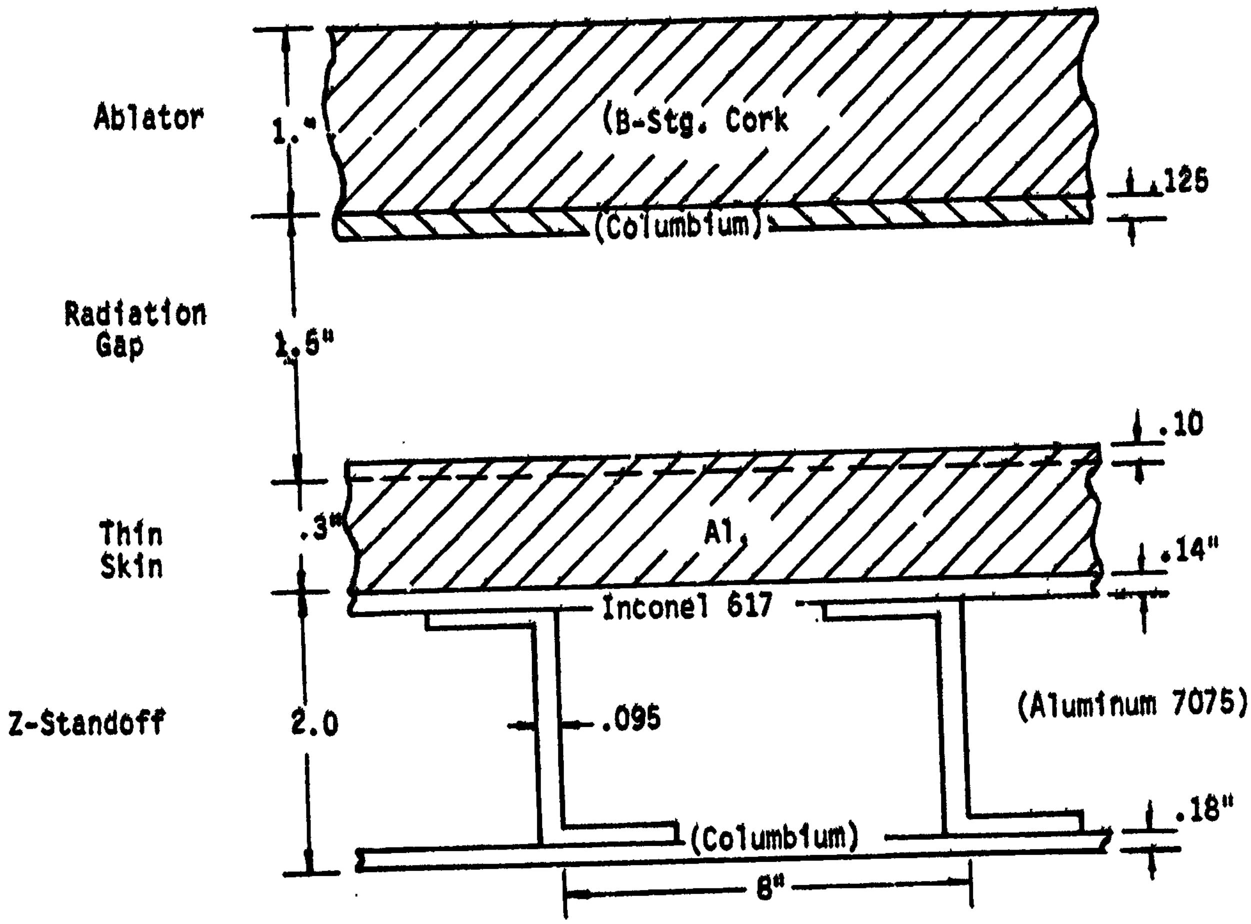

Fig. 5.1 Configuration for Test Case Number One

As shown in Figure 5.1, an ablator 1.0 inch thick is placed on top of a columbium sheet .125 inches in thickness. Next we have an aluminum plate .4 inches thick placed over an Inconel 617 sheet .14 inches thick. An aluminum Z-standoff structure separates the Inconel 617 sheet from a columbium backface sheet .18 inches thick. We see that the .4 inch aluminum plate is divided at a depth of .1 inches from the top surface. This is required to define the radiation gap model since a lower surface plate is needed. The thermal resistance in the .1 inch aluminum is included in the radiation gap model and does not effect the time step. The aerothermodynamic environment is located on the file MINIVER.DAT and identified by body point number 3. The structure was saved on the structure file STRUCTURE.FIL which is shown in Table 5.6. Also included in this example is the input required to rerun this case using the structural definition saved on STRUCTURE.FIL. The interactive input is shown in Table 5.7. For the case where this example is rerun using the saved structure, the interactive input is shown in Table 5.8.

LINE NO.	
	RUN EXITS
1	WHAT IS THE MINIVER INPUT DATA FILE NAME ? MINIVER.DAT
2	WHAT IS THE STRUCTURE FILE NAME ? STRUCTURE.FIL
3	WHAT IS THE NAME OF THE OUTPUT FILE ? OUTPUT.DAT
4	WHAT IS THE INITIAL TIME(SEC) ? 0.0
5	WHAT IS THE FINAL TIME(SEC) ? 1410.0
6	WHAT IS THE TIME(SEC) BETWEEN PRINTOUTS ? 100.0
7	DO YOU WANT TO RESET CONTROL PARAMETERS ? N
8	WHAT IS THE TOTAL NUMBER OF BODY POINTS ? 1
9	WHAT IS THE BODY POINT NUMBER ? 1
10	DO YOU WANT TO RESET THE TIME OR CONTROL PARAMETERS ? T
11	WHAT IS THE INITIAL TIME(SEC) ? 0.0
12	WHAT IS THE FINAL TIME(SEC) ? 1410.0
13	WHAT IS THE TIME(SEC) BETWEEN PRINTOUTS ? 100.0
14	DO YOU WANT TO RESET CONTROL PARAMETERS ? Y
15	RESOLUTION: DEFAULT = 10.0 NEW VALUE =
16	STABILITY: DEFAULT = 2.0 NEW VALUE =
17	ITERATION TOLERENCE: DEFAULT = .001 NEW VALUE =
18	RELAXATION FACTOR: DEFAULT = 0.5 NEW VALUE =
19	NUMBER OF STEPS BETWEEN PARAMETER CALC.: DEFAULT = 20 NEW VALUE =
20	MAXIMUM NUMBER OF ITERATIONS: DEFAULT = 3000 NEW VALUE =

LINE NO.	EXPLANATION
1.	Name of input file created by LANIN code.
2.	File name where structure definitions are stored.
3.	File name where output data is stored.
4.	Time at which thermal response analysis begins.
5.	Time at which thermal response analysis ends.
6.	Time in seconds between printout.
7.	Y = Yes, N = No: Control parameters are given in lines 15 through 20 and will be explained there.
8.	Number of body points to be run using this set of initial parameters.
9.	Body point number for first body point (Later changed on Line 26)
10.	T = Time, C = Control, N = No, Y = Yes. The answer T (Time) or Y (Yes) will ask questions 4 through 7. The answer C (Control) will ask questions 15 through 24.
11-13	Since the answer to 10 was T, lines 4 through 6 reappear.
14.	Y = Yes, N = No An answer Y (YES) will ask questions 15 through 24.
15.	Resolution parameter controls number of nodes in slab and ablator layers. Parameter is defined as DTIN in description of subroutine NODE.
16.	Maximum allowable time step is divided by this value. Defined as STAB in description of instabity occurs from strongly nonlinear radiation conductors.
17.	Tolerance for convergence in equivalent conductor network calculations.
18.	Relaxation factor for calculating midpoint temperature in equivalent conductor routine.
19.	Parameter calculation computes new conductor and capacitor values increased accuracy and run times result from decreasing this value.
20.	Program will stop (normal exit when maximum number of steps is reached).

*If no response, return key will advance code to next question and default value will be used.

Table 5.7 Interactive Input for Configuration Shown in Figure 5.1

	ENGLISH(DEFAULT)	METRIC
TEMPERATURE	DEG F	DEG K
LENGTH	INCHES	CM
ENERGY	BTU	JOULES
MASS	LBM	KGM

LINE NO.		LINE NO.	EXPLANATION
21	ARE THE UNITS OF MINIVER.DAT IN ENGLISH OR METRIC ? E	21.	Units of thermoenviorment E = English, M = Metric (See Table 5.2).
22	DO YOU WANT OUTPUT DATA IN ENGLISH OR METRIC ? E	22.	E = English, M = Metric.
23	DO YOU WANT INPUT DATA IN ENGLISH OR METRIC ? E	23.	E = English, M = Metric.
24	DO YOU WANT ADDITIONAL PRINTOUT ? N	24.	N = No, Y = Yes. If yes the values of the capacitors and conductors will be printed.
25	WHAT IS THE TOTAL NUMBER OF BODY POINTS ? 1	25-27	At this point, questions 8-10 are repeated and quantities can be changed.
26	WHAT IS THE BODY POINT NUMBER ? 3		
27	DO YOU WANT TO RESET THE TIME OR CONTROL PARAMETERS ? N		
28	WHAT IS THE INITIAL TEMPERATURE OF BODY PT. 3 ? 100.0	28.	Initial temperature of structure is degrees F if answer to questions 23 is E or degrees K if answer to 23 is M.
29	WHAT IS THE SINK TEMPERATURE OF BODY PT. 3 ? 0.0	29.	Temperature of sink which structure reradiates to in degrees F if answer to question 23 is E or degrees K if answer is M.
30	WHAT IS THE VIEW FACTOR FOR BODY PT. 3 ? 1.0	30.	View factor between surface of structure and sink.
31	DOES THE STRUCTURE FOR BODY PT. 3 EXIST IN THE STRUCTURE FILE ? N	31.	Y = Yes, N = No. If the answer is Y = Yes, then questions defining the structure are omitted. See Table 5.7 for input previously defined using structures file.
32	DO YOU WANT TO ADD THE STRUCTURE FOR BODY PT. 3 TO THE STRUCTURE FILE ? Y	32.	Y = Yes, N = No. If the answer is Yes, then structure definition will be added to structures file.
33	HOW MANY LAYERS AT BODY PT. 3 ? 4	33.	Number of layers of structure. For this case we have four, ablator, radiation gap, thin skin, and Z-standoff.

Table 5.7 (Continued)

```
STRUCTURE TYPE  - - -  NUMBER

SLAB                   1
RADIATION GAP          2
HONEYCOMB              3
CORRUGATED             4
Z STANDOFF             5
THIN SKIN              6
ABLATOR SUBLIMER       7

LINE
NO.
34  WHAT IS THE STRUCTURE TYPE NUMBER FOR LAYER  1 OF BODY PT.     3 ?
    7
35  WHAT IS THE MAT. IDENTIFIER AND THE MAT. THICKNESS
    FOR LAYER  1 OF BODY PT.     3 ?
    28 1.0
36  ARE THERE ANY CORRECTIONS FOR LAYER  1 OF BODY POINT     3 ?
    N

STRUCTURE TYPE  - - -  NUMBER

SLAB                   1
RADIATION GA           2
HONEYCOMB              3
CORRUGATED             4
Z STANDOFF             5
THIN SKIN              6
ABLATOR SUBLIMER       7

37  WHAT IS THE STRUCTURE TYPE NUMBER FOR LAYER  2 OF BODY PT.     3 ?
    2
38  WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  1
    FOR LAYER  2 OF BODY PT.     3 ?
    10 0.125
39  WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  2
    FOR LAYER  2 OF BODY PT.     3 ?
    1 .10
40  WHAT IS THE STRUCTURE HEIGHT FOR LAYER  2 OF BODY PT.     3 ?
    1.5
41  ARE THERE ANY CORRECTIONS FOR LAYER  2 OF BODY POINT     3 ?
    N
```

LINE NO.	EXPLANATION
34.	Number of structure type for first layer. Answer 1 through 7 according to table.
35.	Material identifier (Table 5.3) and thickness of ablator.
36.	Y = Yes, N = No. If answer is yes, will return to line 34.
37.	Number of structure type for second layer. Answer 1 through 7 according to table.
38.	Material identifier (Table 5.3) and thickness for the top material of the radiation gap. For this example columbium (10) .125 inches thick.
39.	Material identifier (Table 5.3) and thickness of bottom material of the radiation gap.
40.	Overall height of radiation gap.
41.	Y = Yes, N = No. If answer is yes, will return to line 37.

Table 5.7 (Continued)

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```
                    STRUCTURE TYPE  - - -   NUMBER

                    SLAB                       1
                    RADIATION GAP              2
                    HONEYCOMB                  3
                    CORRUGATED                 4
                    Z STANDOFF                 5
                    THIN SKIN                  6
                    ABLATOR SUBLIMER           7
LINE
NO.

42  WHAT IS THE STRUCTURE TYPE NUMBER FOR LAYER  3 OF BODY PT.     3 ?
    6
43  WHAT IS THE MAT. IDENTIFIER AND THE MAT. THICKNESS
    FOR LAYER  3 OF BODY PT.     3 ?
    1 .3
44  ARE THERE ANY CORRECTIONS FOR LAYER  3 OF BODY POINT     3 ?
    N

                    STRUCTURE TYPE  - - -   NUMBER

                    SLAB                       1
                    RADIATION GAP              2
                    HONEYCOMB                  3
                    CORRUGATED                 4
                    Z STANDOFF                 5
                    THIN SKIN                  6
                    ABLATOR SUBLIMER           7

45  WHAT IS THE STRUCTURE TYPE NUMBER FOR LAYER  4 OF BODY PT.     3 ?
    5
46  WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  1
    FOR LAYER  4 OF BODY PT.     3 ?
    17 .14
47  WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  2
    FOR LAYER  4 OF BODY PT.     3 ?
    10 .18
48  WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  3
    FOR LAYER  4 OF BODY PT.     3 ?
    1 .005
49  WHAT IS THE STRUCTURE HEIGHT,PITCH,AND FLANGE WIDTH FOR LAYER  4 OF BODY PT.     3 ?
    2.0 8.0 .75
50  ARE THERE ANY CORRECTIONS FOR LAYER  4 OF BODY POINT     3 ?
    N
```

LINE NO.	EXPLANATION
42.	Number of structure type for third layer. Answer 1 through 7 according to table.
43.	Material identifier (Table 5.3) and thickness. (.3 for this example).
44.	Y = Yes, N = No. If yes, will return to line 42.
45.	Number of structure type for fourth layer. Answer 1 through 7 according to table.
46.	Material identifier (Table 5.3) and thickness of top of Z-standoff structure.
47.	Material identifier (Table 5.3) and thickness for bottom of Z-standoff structure.
48.	Material identifier (Table 5.3) and thickness for middle or Z part of structure.
49.	Overall height of Z-standoff structure (2.0 inches), pitch or distance between Z structures (8.0 inches), and flange width (.75 inches) of Z-standoff.
50.	Y = Yes, N = No. If yes then will return to line 45.

Table 5.7 (Continued)

```
THIS IS THE CONFIGURATION FOR BODY PT.    3

=================================================================    -----
                                                                       I
                          B-STG. CORK      ABLATOR SUBLIMER         1.000000 IN.
                                                                       I
=================================================================    -----
                0.125000 IN. CTD.COLUMB                                I
-----------------------------------------------------------------      I
                                                                       I
                                           RADIATION GAP            1.500000 IN.
                                                                       I
-----------------------------------------------------------------      I
                0.100000 IN. AL.7075-T6                                I
=================================================================    -----
                            AL.7075-T6     THIN SKIN                0.300000 IN.
=================================================================    -----
                0.140000 IN. INCONL 617                                I
-----------------------------------------------------------------      I
 ZZZZZZ          ZZZZZZ                                                I
      Z               Z                                                I
      Z               Z     AL.7075-T6     Z STANDOFF               2.000000 IN.
      Z               Z                                                I
      ZZZZZZ          ZZZZZZ                                           I
-----------------------------------------------------------------      I
                0.180700 IN. CTD.COLUMB                                I
=================================================================    -----
```

Picture Of Structure And Materials Appears On Screen

```
LINE
NO.

51 ARE THERE ANY CORRECTIONS FOR BODY PT.      3 ?
   N
52 WHAT IS THE STRUCTURE NUMBER FOR BODY PT.      3
   1
53 GIVE A TWO LINE DESCRIPTION OF THE STRUCTURE FOR BODY PT.      3
   TEST CASE STRUCTURE FOR LANGLEY CENTER
   ABLATOR SUBLIMER - RADIATION GAP - THIN SKIN - Z STANDOFF

        MODEL COMPLETE - - - - - - GONE TO EXECUTE

              - - - EXECUTION  COMPLETE - - -

OUTPUT FILENAME = OUTPUT.DAT

>
```

51. Y = Yes, N = No. If answer is yes will return to line number 10.

52. Answer assigns a structure identification number to the thermal protection system definition for storage in the structures file.

53. Reply is two line description of structure which is included in the structure file.

Name Of Output File Appears When Execution Is Complete

Table 5.7 (Concluded)

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5.5 EXAMPLE CASE ONE RERUN FROM STRUCTURES FILE

Here we have rerun the case previously described using the data stored on the structures file which defines the thermal protection system. Table 5.8 shows the input for this case. As can be seen, the interactive input has been greatly simplified. The description of lines one to thirteen has been previously given. At line 14, the response is Y (yes) since we have already described the structure. Line 15 asks for the structure identifier number which was assigned previously. If the answer at line 16 is Y (yes) then control is returned to line 7, if N (no) we have completed the interactive input and EXITS goes into execution.

```
LINE
NO.
    RUN EXITS
 1  WHAT IS THE MINIVER INPUT DATA FILE NAME ?
    MINIVER.DAT
 2  WHAT IS THE STRUCTURE FILE NAME ?
    STRUCTURE.FIL
 3  WHAT IS THE NAME OF THE OUTPUT FILE ?
    OUTPUT.DAT
 4  WHAT IS THE INITIAL TIME(SEC) ?
    0.0
 5  WHAT IS THE FINAL TIME(SEC) ?
    1410.0
 6  WHAT IS THE TIME(SEC) BETWEEN PRINTOUTS ?
    100.0
 7  DO YOU WANT TO RESET CONTROL PARAMETERS ?
    N
 8  WHAT IS THE TOTAL NUMBER OF BODY POINTS ?
    1
 9  WHAT IS THE BODY POINT NUMBER ?
    3
10  DO YOU WANT TO RESET THE TIME OR CONTROL PARAMETERS ?
    N
11  WHAT IS THE INITIAL TEMPERATURE OF BODY PT.     3 ?
    100.0
12  WHAT IS THE SINK TEMPERATURE OF BODY PT.     3 ?
    0.0
13  WHAT IS THE VIEW FACTOR FOR BODY PT.     3 ?
    1.0
14  DOES THE STRUCTURE FOR BODY PT.     3 EXIST IN THE STRUCTURE FILE ?
    Y
15  WHAT IS THE STRUCTURE NUMBER FOR BODY PT.     3 ?
    1

          STRUCTURE NUMBER =     1
    TEST CASE STRUCTURE FOR LANGLEY CENTER
    ABLATOR SUBLIMER - RADIATION GAP - THIN SKIN - Z STANDOFF
```

```
THIS IS THE CONFIGURATION FOR BODY PT.    3

==========================================================  ----
                                                              1
                    B-STG. CORK          ABLATOR SUBLIMER     1.000000 IN.
                                                              1
==========================================================  ----
               0.125000 IN. CTD.COLUMB                        1
----------------------------------------------------------    1
                                                              1
                                         RADIATION GAP        1.500000 IN.
                                                              1
----------------------------------------------------------    1
               0.100000 IN. AL.7075-T6                        1
==========================================================  ----
                          AL.7075-T6     THIN SKIN            0.300000 IN.
==========================================================  ----
               0.140000 IN. INCONL 617                        1
----------------------------------------------------------    1
ZZZZZZ         ZZZZZZ                                         1
     Z              Z                                         1
     Z              Z     AL.7075-T6     Z STANDOFF           2.000000 IN.
     Z              Z                                         1
     ZZZZZZ         ZZZZZZ                                    1
----------------------------------------------------------    1
               0.188000 IN. CTD.COLUMB                        1
==========================================================  ----

LINE
NO.
16  ARE THERE ANY CORRECTIONS FOR BODY PT.     3 ?
    N

        MODEL COMPLETE - - - - - - GONE TO EXECUTE

             - - - EXECUTION  COMPLETE - - -

OUTPUT FILENAME = OUTPUT.DAT

>
```

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Table 5.8 Example of Sample Case One Rerun From Structures File

5.6 EXAMPLE CASE TWO (SLAB, SLAB, HONEYCOMB AND CORRUGATED)

In this example the input requirements for the remaining three structures (Slab, Honeycomb, Corrugated) are demonstrated. Again, this case is not representative of a thermal protection system but serves to illustrate the input requirements for the remaining three structures. The configuration for this example case is shown in Figure 5.2.

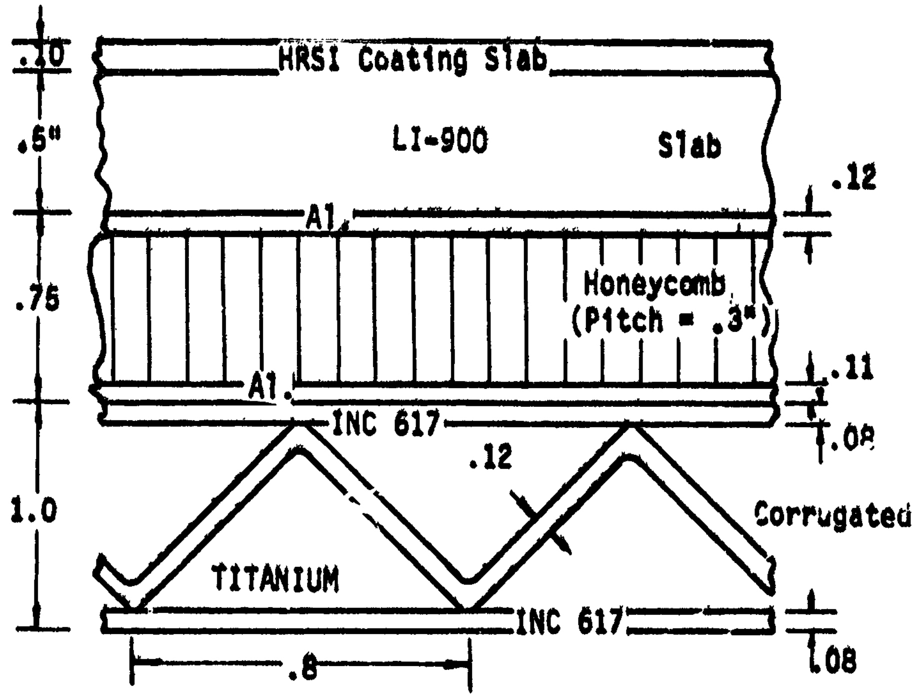

Fig. 5.2 Configuration for Test Case Number Two

As shown in Figure 5.2 a LI-900 insulation .5 inch thick with a .10 inch coating of HRSI coating material is backed up by a honeycomb structure .75 inches thick and a corrugated structure. Different materials are used in the honeycomb and corrugated layers to illustrate their input. The aerothermodynamic environment is defined on the file MINIVER.DAT and identified by body point 5. The structure was saved on the structure file STRUCTURE.FIL and is included in the example shown in Table 5.6. The interactive input for this case is presented in Table 5.9.

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```
LINE
NO.
     RUN EXITS
 1  WHAT IS THE MINIVER INPUT DATA FILE NAME ?
    MINIVER.DAT
 2  WHAT IS THE STRUCTURE FILE NAME ?
    STRUCTURE.FIL
 3  WHAT IS THE NAME OF THE OUTPUT FILE ?
    OUTPUT.FIL
 4  WHAT IS THE INITIAL TIME(SEC) ?
    0.0
 5  WHAT IS THE FINAL TIME(SEC) ?
    1410.0
 6  WHAT IS THE TIME(SEC) BETWEEN PRINTOUTS ?
    100.0
 7  DO YOU WANT TO RESET CONTROL PARAMETERS ?
    N
 8  WHAT IS THE TOTAL NUMBER OF BODY POINTS ?
    1
 9  WHAT IS THE BODY POINT NUMBER ?
    3
10  DO YOU WANT TO RESET THE TIME OR CONTROL PARAMETERS ?
    N
11  WHAT IS THE INITIAL TEMPERATURE OF BODY PT.     3 ?
    100.0
12  WHAT IS THE SINK TEMPERATURE OF BODY PT.     3 ?
    0.0
13  WHAT IS THE VIEW FACTOR FOR BODY PT.     3 ?
    1.0
14  DOES THE STRUCTURE FOR BODY PT.     3 EXIST IN THE STRUCTURE FILE ?
    N
15  DO YOU WANT TO ADD THE STRUCTURE FOR BODY PT.     3 TO THE STRUCTURE FILE ?
    Y
16  HOW MANY LAYERS AT BODY PT.     3 ?
    4
```

LINE NO.	EXPLANATION
1-16	Same as shown in Example Case One, Table 5.7.

Table 5.9 Interactive Input for Configuration Shown in Figure 5.2

C-2

```
              STRUCTURE TYPE  - - -   NUMBER

              SLAB                       1
              RADIATION GAP              2
              HONEYCOMB                  3
              CORRUGATED                 4
              Z STANDOFF                 5
              THIN SKIN                  6
              ABLATOR SUBLIMER           7
LINE
NO.
17  WHAT IS THE STRUCTURE TYPE NUMBER FOR LAYER  1 OF BODY PT.     3 ?
    :
18  WHAT IS THE MAT. IDENTIFIER AND THE MAT. THICKNESS
    FOR LAYER  1 OF BODY PT.      3 ?
    4 .10
19  ARE THERE ANY CORRECTIONS FOR LAYER  1 OF BODY POINT     3 ?
    N

              STRUCTURE TYPE  - - -   NUMBER

              SLAB                       1
              RADIATION GAP              2
              HONEYCOMB                  3
              CORRUGATED                 4
              Z STANDOFF                 5
              THIN SKIN                  6
              ABLATOR SUBLIMER           7

20 WHAT IS THE STRUCTURE TYPE NUMBER FOR LAYER  2 OF BODY PT.     3 ?
   1
21 WHAT IS THE MAT. IDENTIFIER AND THE MAT. THICKNESS
   FOR LAYER  2 OF BODY PT.      3 ?
   5 .5
22 ARE THERE ANY CORRECTIONS FOR LAYER  2 OF BODY POINT     3 ?
   N
```

LINE NO.	EXPLANATION
17.	Number of structure type for first layer.
18.	Material identifier (Table 5.3) and thickness of slab.
19.	Y = Yes, N = No. If answer is yes, return to line 17.
20.	Number of structure type for second layer.
21.	Material identifier (Table 5.3) and thickness of second slab.
22.	Y = Yes, N = No. If answer is yes, return to line 20.

Table 5.9 (Continued)

```
            STRUCTURE TYPE  - - -   NUMBER

            SLAB                       1
            RADIATION GAP              2
            HONEYCOMB                  3
            CORRUGATED                 4
            Z STANDOFF                 5
            THIN SKIN                  6
            ABLATOR SUBLIMER           7
LINE
NO.
23 WHAT IS THE STRUCTURE TYPE NUMBER FOR LAYER  3 OF BODY PT.     3 ?
   3
24 WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  1
   FOR LAYER  3 OF BODY PT.      3 ?
   1 .12
25 WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  2
   FOR LAYER  3 OF BODY PT.      3 ?
   1 .11
26 WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  3
   FOR LAYER  3 OF BODY PT.      3 ?
   1 .095
27 WHAT IS THE STRUCTURE HEIGHT AND CELL DIMENSIONS OF LAYER  3 OF BODY PT.     3 ?
   .75 .30
28 ARE THERE ANY CORRECTIONS FOR LAYER  3 OF BODY POINT     3 ?
   N

            STRUCTURE TYPE  - - -   NUMBER

            SLAB                       1
            RADIATION GAP              2
            HONEYCOMB                  3
            CORRUGATED                 4
            Z STANDOFF                 5
            THIN SKIN                  6
            ABLATOR SUBLIMER           7

29 WHAT IS THE STRUCTURE TYPE NUMBER FOR LAYER  4 OF BODY PT.     3 ?
   4
30 WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  1
   FOR LAYER  4 OF BODY PT.      3 ?
   17 .08
31 WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  2
   FOR LAYER  4 OF BODY PT.      3 ?
   17 .08
32 WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT.  3
   FOR LAYER  4 OF BODY PT.      3 ?
   9 .12
33 WHAT IS THE STRUCTURE HEIGHT AND PITCH FOR LAYER  4 OF BODY PT.     3 ?
   1.0 .8
34 ARE THERE ANY CORRECTIONS FOR LAYER  4 OF BODY POINT     3 ?
   N
```

LINE NO.	EXPLANATION
23.	Number of structure type for third layer.
24.	Material identifier (Table 5.3) and thickness of top of honeycomb.
25.	Material identifier (Table 5.3) and thickness of bottom of honeycomb.
26.	Material identifier (Table 5.3) and thickness of honeycomb core.
27.	Overall height of honeycomb and honeycomb and pitch.
28.	Y = Yes, N = No. If answer is yes, return to line 23.
29.	Number of structure type of fourth layer.
30.	Material identifier (Table 5.3) and thickness of top of corrugated structure.
31.	Material identifier (Table 5.3) and thickness of bottom of corrugated structure.
32.	Material identifier (Table 5.3) and thickness of corrugated material.
33.	Overall height of corrugated structure and pitch of corrugations.
34.	Y = Yes, N = No. If answer is yes, return to line 29.

Table 5.9 (Continued)

```
THIS IS THE CONFIGURATION FOR BODY PT.    3

============================================================   -----
                                                                 I
                        HRSI COAT    SLAB                    0.100000 IN.
                                                                 I
============================================================   -----
                                                                 I
                        LI-900       SLAB                    0.500000 IN.
                                                                 I
============================================================   -----
              0.120000 IN. AL.7075-T6                            I
------------------------------------------------------------     I
 I    I    I    I    I                                           I
 I    I    I    I    I                                           I
 I    I    I    I    I  AL.7075-T6   HONEY COMB              0.750000 IN.
 I    I    I    I    I                                           I
 I    I    I    I    I                                           I
------------------------------------------------------------     I
              0.110000 IN. AL.7075-T6                            I
============================================================   -----
              0.080000 IN. INCONL 617                            I
------------------------------------------------------------     I
V      V      V      V                                           I
 V    V V    V V    V V                                          I
  V  V   V  V   V  V   V   TITANIUM     CORRUGATED           1.000000 IN.
   VV     VV     VV     V                                        I
    V      V      V      V                                       I
------------------------------------------------------------     I
              0.080000 IN. INCONL 617                            I
============================================================   -----
```

Picture Of Structure And Materials Appears On Screen

LINE NO.	
35	ARE THERE ANY CORRECTIONS FOR BODY PT. 3 ? N
36	WHAT IS THE STRUCTURE NUMBER FOR BODY PT. 3 2
37	GIVE A TWO LINE DESCRIPTION OF THE STRUCTURE FOR BODY PT. 3 TEST CASE STRUCTURE FOR LANGLEY CENTER SLAB - SLAB - HONEY COMB - CORRUGATED

MODEL COMPLETE - - - - - - GONE TO EXECUTE

- - - EXECUTION COMPLETE - - -

OUTPUT FILENAME = OUTPUT.FIL

LINE NO.	EXPLANATION
35-37	Same as Example Case One, Table 5.7.

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Table 5.9 (Concluded)

Section 6.0

OUTPUT

This section presents the results of the two sample cases used as examples of the input requirements in Section 5.0. Input for the first case is presented in Section 5.4 while Section 5.6 contains input requirements for the second case. Output for these examples is shown here for a typical Shuttle reentry trajectory. These structures shown in Figs. 5.1 and 5.2 are not examples of a TPS design but are only presented here to exhibit the EXITS code capabilities.

The first case is the ablator-radiation gap-thin skin- Z standoff structure shown in Fig. 5.1. Results are presented in Table 6.1 for this case. The output is divided into Sections A, B, C . . . H for description purposes.

Section A in Table 6.1 shows the parameters, flags, and time controls for this case. These values are either set during the interactive input or default values are used. A description of these variables is given below:

- TSTART - Initial time
- TSTOP - End time
- TIMPT - Time between printouts
- DTIM - Parameter which controls node spacing for slab or ablator structures
- STAB - Maximum allowable time step is divided by this number to assure stability
- TOL - Convergence criteria for equivalent conductivity calculations
- BET - Relaxation factor for iteration scheme used to compute equivalent conductivity
- NBP - Number of body points
- NEXT - Number of time steps between calculation of new conductor and capacitor values
- NSTP - Maximum number of time steps
- IPFLAG - Flag for printing conductor and capacitor values.

Section B presents the thermophysical property values used in the analysis. Only the properties for the materials used are shown here. Values for density, specific heat, conductivity, emissivity, and for an ablator material, sublimation temperature and heat of ablation are given.

Section C presents the LANMIN generated environment for the body point specified. Values for film coefficient, recovery enthalpy, and pressure are given.

Section D shows the node positions and numbering sequence, structure type, material and conductor number of the network. Initial temperature, sink temperature and the view factor to the sink is also shown.

Section E depicts a graphic representation of the model including the node spacing and materials. A double horizontal dashed line separates the structure types. Node locations are represented by an ''O'' on the left hand side.

Section F presents the temperature and load histories of the structure beginning at initial time. At each output, the total number of time steps and the value of the last time step taken are shown. Next, the integrated heat loads and heat rates are presented along with the net heat into and out of the structure. Surface recession and recession rates are shown. The temperature at each node within the structure and the node location, XX = 0.0 being the initial surface, is given.

Section G is presented each time a node is dropped from the network as the surface recedes. The same information is contained here as in Section E.

Section H gives the unit mass of the TPS and a message if a temperature has exceeded a material limit as specified in the material property tables.

Output for the second example is presented in Table 6.2. A description of this case is not necessary due to its similarity to the first example.

```
1    TSTART =      0.000   TSTOP =   1410.000   TINPT =    100.000
     DTIM   =     10.000   STAB  =      2.000   TOL   =      0.001   BET    =      0.500
     NBP    =  .       1   NEXT  =         20   NSTP  =       3000   IPFLAG =          1
```

(A)

```
1       T A B L E S
```

(B)

```
     B-BTG.CORK  -  MAT NO. 28

  MAXIMUM TEMPERATURE  .       760.40 DEG F

     TEMP.        DENSITY
    (DEG F)     (LBM/CU.FT)

  -0.4596E+03    0.3100E+02
   0.9540E+04    0.3100E+02

     TEMP.      SPECIFIC HT.
    (DEG F)    (BTU/LBM-DEG F)

  -0.4596E+03    0.4600E+00
   0.9540E+04    0.4600E+00

     TEMP.      CONDUCTIVITY
    (DEG F)   (BTU/FT-S-DEG F)

  -0.4596E+03    0.1110E-04
   0.4004E+03    0.1110E-04
   0.8504E+03    0.3330E-05
   0.9540E+04    0.3330E-05

     TEMP.       EMISSIVITY
    (DEG F)   (DIMENSIONLESS)

  -0.4596E+03    0.8000E+00
   0.9540E+04    0.8000E+00

    PRESSURE      SUB.TEMP
   (LB/SQ.FT)      (DEG F)

   0.0000E+00    0.7604E+03
   0.5000E+04    0.7604E+03

    PRESSURE      HEAT ABL.
   (LB/SQ.FT)     (BTU/LBM)

   0.0000E+00    0.7000E+04
   0.5000E+04    0.7000E+04
```


Table 6.1 Output For Example Case One (Table 5.7)

CTD.COLUMB - MAT NO. 10

MAXIMUM TEMPERATURE 2500.40 DEG F

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TEMP. (DEG F)	DENSITY (LBM/CU.FT)
-0.4596E+03	0.5620E+03
0.9540E+04	0.5620E+03

TEMP. (DEG F)	SPECIFIC HEAT (BTU/LBM-DEG F)
-0.4596E+03	0.5900E-01
0.4000E+00	0.5900E-01
0.2004E+03	0.6100E-01
0.6004E+03	0.6500E-01
0.1000E+04	0.6500E-01
0.9540E+04	0.6900E-01

TEMP. (DEG F)	CONDUCTIVITY (BTU/FT-S-DEG F)
-0.4596E+03	0.4400E-02
0.7040E+02	0.4400E-02
0.5004E+03	0.6100E-02
0.1000E+04	0.7300E-02
0.2000E+04	0.8000E-02
0.9540E+04	0.8000E-02

TEMP. (DEG F)	EMISSIVITY (DIMENSIONLESS)
-0.4596E+03	0.1900E+00
0.2700E+04	0.1900E+00
0.3600E+04	0.2400E+00
0.9540E+04	0.2400E+00

AL.7075-T6 - MAT NO. 1

MAXIMUM TEMPERATURE 200.40 DEG F

TEMP. (DEG F)	DENSITY (LBM/CU.FT)
-0.4596E+03	0.1750E+03
0.9540E+04	0.1750E+03

Table 6.1 (Continued)

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TEMP. (DEG F)	SPECIFIC HEAT (BTU/LBM-DEG F)
-0.4596E+03	0.1700E+00
-0.1496E+03	0.1700E+00
0.4000E+00	0.1950E+00
0.2004E+03	0.2100E+00
0.8604E+03	0.2750E+00
0.1000E+04	0.2750E+00
0.9540E+04	0.2750E+00

TEMP. (DEG F)	CONDUCTIVITY (BTU/FT-S-DEG F)
-0.4596E+03	0.1400E-01
-0.1996E+03	0.1400E-01
0.4000E+00	0.2000E-01
0.3004E+03	0.2500E-01
0.4004E+03	0.2700E-01
0.5004E+03	0.2900E-01

TEMP. (DEG F)	EMISSIVITY (DIMENSIONLESS)
-0.4596E+03	0.1200E+00
0.9540E+04	0.1200E+00

INCONL 617 - MAT NO. 17

MAXIMUM TEMPERATURE 1800.40 DEG F

TEMP. (DEG F)	DENSITY (LBM/CU.FT)
-0.4596E+03	0.5219E+03
0.9540E+04	0.5219E+03

TEMP. (DEG F)	SPECIFIC HEAT (BTU/LBM-DEG F)
-0.4596E+03	0.1000E+00
0.7840E+02	0.1000E+00
0.2004E+03	0.1040E+00
0.4004E+03	0.1110E+00
0.6004E+03	0.1170E+00
0.1000E+04	0.1310E+00
0.1200E+04	0.1370E+00
0.1400E+04	0.1440E+00
0.1600E+04	0.1500E+00
0.1800E+04	0.1570E+00
0.2000E+04	0.1630E+00
0.9540E+04	0.1630E+00

Table 6.1 (Continued)

TEMP. (DEG F)	CONDUCTIVITY (BTU/FT-S-DEG F)
-0.4596E+03	0.2176E-02
0.7840E+02	0.2176E-02
0.2004E+03	0.2338E-02
0.4004E+03	0.2616E-02
0.6004E+03	0.2894E-02
0.1000E+04	0.3449E-02
0.1200E+04	0.3727E-02
0.1400E+04	0.4005E-02
0.1600E+04	0.4282E-02
0.1800E+04	0.4560E-02
0.2000E+04	0.4838E-02
0.9940E+04	0.4838E-02

TEMP. (DEG F)	EMISSIVITY (DIMENSIONLESS)
-0.4596E+03	0.1500E+00
0.9540E+04	0.1900E+00

Table 6.1 (Continued)

1

BODY POINT NUMBER = 3 SAMPLE MINIVER INPUT TABLE

TIME (SEC)	FILM COEF. (LBM/SQ.FT-SEC)	REC ENTHALPY (BTU/LBM)	PRESSURE (LBF/SQ.FT)
0.0000E+00	0.6450E-05	0.1126E+05	0.1252E-01
0.5000E+02	0.1221E-04	0.1124E+05	0.3449E-01
0.1000E+03	0.2502E-04	0.1123E+05	0.1090E+00
0.1250E+03	0.3631E-04	0.1123E+05	0.1992E+00
0.1500E+03	0.5367E-04	0.1122E+05	0.3777E+00
0.1750E+03	0.8009E-04	0.1123E+05	0.7313E+00
0.2000E+03	0.1203E-03	0.1124E+05	0.1440E+01
0.2250E+03	0.1795E-03	0.1127E+05	0.2802E+01
0.2750E+03	0.2528E-03	0.1113E+05	0.7749E+01
0.3000E+03	0.3015E-03	0.1109E+05	0.1126E+02
0.3500E+03	0.3710E-03	0.1092E+05	0.1779E+02
0.4000E+03	0.3974E-03	0.1060E+05	0.2004E+02
0.4500E+03	0.4108E-03	0.1027E+05	0.2121E+02
0.5000E+03	0.4259E-03	0.9966E+04	0.2314E+02
0.5280E+03	0.4325E-03	0.9769E+04	0.2379E+02
0.5560E+03	0.4402E-03	0.9577E+04	0.2470E+02
0.5980E+03	0.4519E-03	0.9270E+04	0.2599E+02
0.6400E+03	0.4661E-03	0.8966E+04	0.2806E+02
0.6540E+03	0.5320E-03	0.8876E+04	0.2915E+02
0.6820E+03	0.6853E-03	0.8680E+04	0.3124E+02
0.7100E+03	0.7182E-03	0.8450E+04	0.3105E+02
0.7380E+03	0.8937E-03	0.8228E+04	0.3303E+02
0.7520E+03	0.1013E-02	0.8106E+04	0.3425E+02
0.7660E+03	0.1148E-02	0.7984E+04	0.3565E+02
0.7800E+03	0.1328E-02	0.7863E+04	0.3738E+02
0.7940E+03	0.1540E-02	0.7738E+04	0.3927E+02
0.8080E+03	0.1784E-02	0.7610E+04	0.4128E+02
0.8220E+03	0.2090E-02	0.7476E+04	0.4368E+02
0.8500E+03	0.2389E-02	0.7149E+04	0.4938E+02
0.8780E+03	0.2615E-02	0.6779E+04	0.5542E+02
0.9060E+03	0.2896E-02	0.6385E+04	0.6202E+02
0.9760E+03	0.3470E-02	0.5284E+04	0.7639E+02
0.1004E+04	0.3900E-02	0.4800E+04	0.8486E+02
0.1032E+04	0.4267E-02	0.4291E+04	0.8986E+02
0.1060E+04	0.4461E-02	0.3797E+04	0.9285E+02
0.1074E+04	0.4484E-02	0.3562E+04	0.9301E+02
0.1102E+04	0.4499E-02	0.3117E+04	0.9302E+02
0.1116E+04	0.4557E-02	0.2903E+04	0.9263E+02
0.1144E+04	0.4844E-02	0.2496E+04	0.9407E+02
0.1172E+04	0.5133E-02	0.2125E+04	0.9565E+02
0.1200E+04	0.5153E-02	0.1813E+04	0.9244E+02
0.1260E+04	0.5462E-02	0.1253E+04	0.8645E+02
0.1290E+04	0.5814E-02	0.1034E+04	0.8521E+02
0.1350E+04	0.6301E-02	0.6930E+03	0.8369E+02
0.1380E+04	0.6169E-02	0.5627E+03	0.8032E+02
0.1410E+04	0.5844E-02	0.4545E+03	0.7643E+02

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Table 6.1 (Continued)

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```
1                    STRUCTURE DEFINITION
                         BODY POINT     3
      TINIT  =  100.00 DEG F    TSINK =    0.00 DEG F    FIJ   =      1.000

            NODE NUMBER =     1        DISTANCE FROM SURFACE =   0.000000E+00 IN.
                 CONDUCTOR NUMBER =     1
                 STRUCTURE TYPE   =     7      ABLATOR SUBLIMER
                 MATERIAL  1 = B-STD.CORK
            NODE NUMBER =     2        DISTANCE FROM SURFACE =   0.416667E-01 IN.

            NODE NUMBER =     2        DISTANCE FROM SURFACE =   0.416667E-01 IN.
                 CONDUCTOR NUMBER =     2
                 STRUCTURE TYPE   =     7      ABLATOR SUBLIMER
                 MATERIAL  1 = B-STD.CORK
            NODE NUMBER =     3        DISTANCE FROM SURFACE =   0.833333E-01 IN.

            NODE NUMBER =     3        DISTANCE FROM SURFACE =   0.833333E-01 IN.
                 CONDUCTOR NUMBER =     3
                 STRUCTURE TYPE   =     7      ABLATOR SUBLIMER
                 MATERIAL  1 = B-STD.CORK
            NODE NUMBER =     4        DISTANCE FROM SURFACE =   0.125000E+00 IN.

            NODE NUMBER =     4        DISTANCE FROM SURFACE =   0.125000E+00 IN.
                 CONDUCTOR NUMBER =     4
                 STRUCTURE TYPE   =     7      ABLATOR SUBLIMER
                 MATERIAL  1 = B-STD.CORK
            NODE NUMBER =     5        DISTANCE FROM SURFACE =   0.166667E+00 IN.

            NODE NUMBER =     5        DISTANCE FROM SURFACE =   0.166667E+00 IN.
                 CONDUCTOR NUMBER =     5

                 STRUCTURE TYPE   =     7      ABLATOR SUBLIMER
                 MATERIAL  1 = B-STD.CORK
            NODE NUMBER =     6        DISTANCE FROM SURFACE =   0.208333E+00 IN.

            NODE NUMBER =     6        DISTANCE FROM SURFACE =   0.208333E+00 IN.
                 CONDUCTOR NUMBER =     6
                 STRUCTURE TYPE   =     7      ABLATOR SUBLIMER
                 MATERIAL  1 = B-STD.CORK
            NODE NUMBER =     7        DISTANCE FROM SURFACE =   0.250000E+00 IN.

            NODE NUMBER =     7        DISTANCE FROM SURFACE =   0.250000E+00 IN.
                 CONDUCTOR NUMBER =     7
                 STRUCTURE TYPE   =     7      ABLATOR SUBLIMER
                 MATERIAL  1 = B-STD.CORK
            NODE NUMBER =     8        DISTANCE FROM SURFACE =   0.291667E+00 IN.
```

Table 6.1 (Continued)

NODE NUMBER = 8 DISTANCE FROM SURFACE = 0.291667E+00 IN.
CONDUCTOR NUMBER = 8
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STD.CORK
NODE NUMBER = 9 DISTANCE FROM SURFACE = 0.333333E+00 IN.

NODE NUMBER = 9 DISTANCE FROM SURFACE = 0.333333E+00 IN.
CONDUCTOR NUMBER = 9
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STD.CORK
NODE NUMBER = 10 DISTANCE FROM SURFACE = 0.375000E+00 IN.

NODE NUMBER = 10 DISTANCE FROM SURFACE = 0.375000E+00 IN.
CONDUCTOR NUMBER = 10
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STD.CORK
NODE NUMBER = 11 DISTANCE FROM SURFACE = 0.416667E+00 IN.

NODE NUMBER = 11 DISTANCE FROM SURFACE = 0.416667E+00 IN.
CONDUCTOR NUMBER = 11
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STD.CORK
NODE NUMBER = 12 DISTANCE FROM SURFACE = 0.458333E+00 IN.

NODE NUMBER = 12 DISTANCE FROM SURFACE = 0.458333E+00 IN.
CONDUCTOR NUMBER = 12
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STD.CORK
NODE NUMBER = 13 DISTANCE FROM SURFACE = 0.500000E+00 IN.

NODE NUMBER = 13 DISTANCE FROM SURFACE = 0.500000E+00 IN.

CONDUCTOR NUMBER = 13
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STD.CORK
NODE NUMBER = 14 DISTANCE FROM SURFACE = 0.541667E+00 IN.

NODE NUMBER = 14 DISTANCE FROM SURFACE = 0.541667E+00 IN.
CONDUCTOR NUMBER = 14
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STD.CORK
NODE NUMBER = 15 DISTANCE FROM SURFACE = 0.583333E+00 IN.

NODE NUMBER = 15 DISTANCE FROM SURFACE = 0.583333E+00 IN.
CONDUCTOR NUMBER = 15
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STD.CORK
NODE NUMBER = 16 DISTANCE FROM SURFACE = 0.625000E+00 IN.

Table 6.1 (Continued)

NODE NUMBER = 16 DISTANCE FROM SURFACE = 0.625000E+00 IN.
CONDUCTOR NUMBER = 16
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STG.CORK
NODE NUMBER = 17 DISTANCE FROM SURFACE = 0.666667E+00 IN.

NODE NUMBER = 17 DISTANCE FROM SURFACE = 0.666667E+00 IN.
CONDUCTOR NUMBER = 17
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STG.CORK
NODE NUMBER = 18 DISTANCE FROM SURFACE = 0.708334E+00 IN.

NODE NUMBER = 18 DISTANCE FROM SURFACE = 0.708334E+00 IN.
CONDUCTOR NUMBER = 18
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STG.CORK
NODE NUMBER = 19 DISTANCE FROM SURFACE = 0.750000E+00 IN.

NODE NUMBER = 19 DISTANCE FROM SURFACE = 0.750000E+00 IN.
CONDUCTOR NUMBER = 19
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STG.CORK
NODE NUMBER = 20 DISTANCE FROM SURFACE = 0.791667E+00 IN.

NODE NUMBER = 20 DISTANCE FROM SURFACE = 0.791667E+00 IN.
CONDUCTOR NUMBER = 20
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STG.CORK
NODE NUMBER = 21 DISTANCE FROM SURFACE = 0.833334E+00 IN.

NODE NUMBER = 21 DISTANCE FROM SURFACE = 0.833334E+00 IN.
CONDUCTOR NUMBER = 21
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STG.CORK
NODE NUMBER = 22 DISTANCE FROM SURFACE = 0.875000E+00 IN.

NODE NUMBER = 22 DISTANCE FROM SURFACE = 0.875000E+00 IN.
CONDUCTOR NUMBER = 22
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STG.CORK
NODE NUMBER = 23 DISTANCE FROM SURFACE = 0.916667E+00 IN.

NODE NUMBER = 23 DISTANCE FROM SURFACE = 0.916667E+00 IN.
CONDUCTOR NUMBER = 23
STRUCTURE TYPE = 7 ABLATOR SUBLIMER
MATERIAL 1 = B-STG.CORK
NODE NUMBER = 24 DISTANCE FROM SURFACE = 0.958334E+00 IN.

Table 6.1 (Continued)

```
NODE NUMBER =    24      DISTANCE FROM SURFACE =   0.758334E+00 IN.
     CONDUCTOR NUMBER =    24
     STRUCTURE TYPE   =     7     ABLATOR SUBLIMER
     MATERIAL  1 = B-STD.CORK
NODE NUMBER =    25      DISTANCE FROM SURFACE =   0.100000E+01 IN.

NODE NUMBER =    25      DISTANCE FROM SURFACE =   0.100000E+01 IN.
     CONDUCTOR NUMBER =    25
     STRUCTURE TYPE   =     2     RADIATION GAP
     MATERIAL  1 = CTD.COLUMB
     MATERIAL  2 = AL.7075-T6
NODE NUMBER =    26      DISTANCE FROM SURFACE =   0.250000E+01 IN.

NODE NUMBER =    26      DISTANCE FROM SURFACE =   0.250000E+01 IN.
     CONDUCTOR NUMBER =    26
     STRUCTURE TYPE   =     6     THIN SKIN
     MATERIAL  1 = AL.7075-T6
NODE NUMBER =    27      DISTANCE FROM SURFACE =   0.280000E+01 IN.

NODE NUMBER =    27      DISTANCE FROM SURFACE =   0.280000E+01 IN.
     CONDUCTOR NUMBER =    27
     STRUCTURE TYPE   =     5     Z STANDOFF
     MATERIAL  1 = INCONL 617
     MATERIAL  2 = CTD.COLUMB
     MATERIAL  3 = AL.7075-T6
NODE NUMBER =    28      DISTANCE FROM SURFACE =   0.480000E+01 IN.
```

Table 6.1 (Continued)

```
1THIS IS THE CONFIGURATION FOR BODY PT.    3

=== 1. 0=================================================    ----
    2. 0                                                      I
    3. 0                                                      I
    4. 0                                                      I
    5. 0                                                      I
    6. 0                                                      I
    7. 0                                                      I
    8. 0                                                      I
    9. 0                                                      I
   10. 0                                                      I
   11. 0                                                      I
   12. 0                                                      I
   13. 0                    B-STG.CORK   ABLATOR SUBLIMER    1.000000 IN.
   14. 0                                                      I
   15. 0                                                      I
   16. 0                                                      I
   17. 0                                                      I
   18. 0                                                      I
   19. 0                                                      I
   20. 0                                                      I
   21. 0                                                      I
   22. 0                                                      I
   23. 0                                                      I
   24. 0                                                      I
===25. 0=================================================    ----
             0.125000 IN. CTD.COLUMB                          I
 ---------------------------------------------------------    I
                                                              I
                                         RADIATION GAP       1.500000 IN.
                                                              I
 ---------------------------------------------------------    I
             0.100000 IN. AL.7075-T6                          I
===26. 0=================================================    ----
                            AL.7075-T6   THIN SKIN           0.300000 IN.
===27. 0=================================================    ----
             0.140000 IN. INCONL 617                          I
 ---------------------------------------------------------    I
  ZZZZZZ            ZZZZZZ                                    I
       Z                 Z                                    I
       Z                 Z  AL.7075-T6   Z STANDOFF          2.000000 IN.
       Z                 Z                                    I
       ZZZZZZ            ZZZZZZ                               I
 ---------------------------------------------------------    I
             0.180000 IN. CTD.COLUMB                          I
===28. 0=================================================    ----
1
```

Table 6.1   (Continued)

```
TIME =      0.00000     TIME STEP =      0.00000     NO. OF STEPS =         0

INTEGRATED HEAT                                  HEAT RATES
BTU/SQ.FT                                        BTU/SQ.FT-SEC

CONVECTED           0.0                          CONVECTED        0.0
RADIATED            0.0                          RADIATED         0.0
NET LOAD                      0.0                NET LOAD                   0.0
STORED              0.0                          STORED           0.0
SUBLIMED            0.0                          SUBLIMED         0.0
ADVECTED            0.0                          ADVECTED         0.0
TPS NET                       0.0                TPS NET                    0.0

SURFACE RECESSION
DISTANCE     0.00000 IN.                         RECESSION RATE     0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)= 100.000    T(  2)= 100.000    T(  3)= 100.000    T(  4)= 100.000    T(  5)= 100.000
T(  6)= 100.000    T(  7)= 100.000    T(  8)= 100.000    T(  9)= 100.000    T( 10)= 100.000
T( 11)= 100.000    T( 12)= 100.000    T( 13)= 100.000    T( 14)= 100.000    T( 15)= 100.000
T( 16)= 100.000    T( 17)= 100.000    T( 18)= 100.000    T( 19)= 100.000    T( 20)= 100.000
T( 21)= 100.000    T( 22)= 100.000    T( 23)= 100.000    T( 24)= 100.000    T( 25)= 100.000
T( 26)= 100.000    T( 27)= 100.000    T( 28)= 100.000
NODE POSITION INCHES
XX(  1)=   0.000   XX(  2)=   0.042   XX(  3)=   0.083   XX(  4)=   0.125   XX(  5)=   0.167
XX(  6)=   0.208   XX(  7)=   0.250   XX(  8)=   0.292   XX(  9)=   0.333   XX( 10)=   0.375
XX( 11)=   0.417   XX( 12)=   0.458   XX( 13)=   0.500   XX( 14)=   0.542   XX( 15)=   0.583
XX( 16)=   0.625   XX( 17)=   0.667   XX( 18)=   0.708   XX( 19)=   0.750   XX( 20)=   0.792
XX( 21)=   0.833   XX( 22)=   0.875   XX( 23)=   0.917   XX( 24)=   0.958   XX( 25)=   1.000
XX( 26)=   2.500   XX( 27)=   2.800   XX( 28)=   4.800


TIME =    100.00000     TIME STEP =      2.84209     NO. OF STEPS =        28

INTEGRATED HEAT                                  HEAT RATES
BTU/SQ.FT                                        BTU/SQ.FT-SEC

CONVECTED          15.1                          CONVECTED        0.3
RADIATED            3.8                          RADIATED         0.1
NET LOAD                     11.3                NET LOAD                   0.2
STORED             11.3                          STORED           0.2
SUBLIMED            0.0                          SUBLIMED         0.0
ADVECTED            0.0                          ADVECTED         0.0
TPS NET                      11.3                TPS NET                    0.2

SURFACE RECESSION
DISTANCE     0.00000 IN.                         RECESSION RATE     0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)= 226.226    T(  2)= 174.707    T(  3)= 142.714    T(  4)= 123.583    T(  5)= 112.544
T(  6)= 106.400    T(  7)= 103.114    T(  8)= 101.435    T(  9)= 100.623    T( 10)= 100.253
T( 11)= 100.096    T( 12)= 100.034    T( 13)= 100.011    T( 14)= 100.003    T( 15)= 100.001
T( 16)= 100.000    T( 17)= 100.000    T( 18)= 100.000    T( 19)= 100.000    T( 20)= 100.000
T( 21)= 100.000    T( 22)= 100.000    T( 23)= 100.000    T( 24)= 100.000    T( 25)= 100.000
T( 26)= 100.000    T( 27)= 100.000    T( 28)= 100.000
```

Table 6.1 (Continued)

NODE POSITION INCHES

XX(1)= 0.000	XX(2)= 0.042	XX(3)= 0.083	XX(4)= 0.125	XX(5)= 0.167
XX(6)= 0.208	XX(7)= 0.250	XX(8)= 0.292	XX(9)= 0.333	XX(10)= 0.375
XX(11)= 0.417	XX(12)= 0.458	XX(13)= 0.500	XX(14)= 0.542	XX(15)= 0.583
XX(16)= 0.625	XX(17)= 0.667	XX(18)= 0.708	XX(19)= 0.750	XX(20)= 0.792
XX(21)= 0.833	XX(22)= 0.875	XX(23)= 0.917	XX(24)= 0.958	XX(25)= 1.000
XX(26)= 2.500	XX(27)= 2.800	XX(28)= 4.800		

TIME = 200.00000 TIME STEP = 0.47696 NO. OF STEPS = 58

ORIGINAL PAGE IS
OF POOR QUALITY

INTEGRATED HEAT BTU/SQ.FT			HEAT RATES BTU/SQ.FT-SEC		
CONVECTED	80.2		CONVECTED	1.3	
RADIATED	24.0		RADIATED	0.6	
NET LOAD		56.2	NET LOAD		0.7
STORED	56.2		STORED	0.7	
SUBLIMED	0.0		SUBLIMED	0.0	
ADVECTED	0.0		ADVECTED	0.0	
TPS NET		56.2	TPS NET		0.7

SURFACE RECESSION
DISTANCE 0.00000 IN. RECESSION RATE 0.00000 IN/SEC

TEMPERATURE DEG F

T(1)= 655.963	T(2)= 428.034	T(3)= 307.611	T(4)= 229.010	T(5)= 178.921
T(6)= 147.577	T(7)= 128.266	T(8)= 116.533	T(9)= 109.504	T(10)= 105.358
T(11)= 102.956	T(12)= 101.593	T(13)= 100.837	T(14)= 100.428	T(15)= 100.212
T(16)= 100.102	T(17)= 100.048	T(18)= 100.022	T(19)= 100.009	T(20)= 100.004
T(21)= 100.002	T(22)= 100.001	T(23)= 100.000	T(24)= 100.000	T(25)= 100.000
T(26)= 100.000	T(27)= 100.000	T(28)= 100.000		

NODE POSITION INCHES

XX(1)= 0.000	XX(2)= 0.042	XX(3)= 0.083	XX(4)= 0.125	XX(5)= 0.167
XX(6)= 0.208	XX(7)= 0.250	XX(8)= 0.292	XX(9)= 0.333	XX(10)= 0.375
XX(11)= 0.417	XX(12)= 0.458	XX(13)= 0.500	XX(14)= 0.542	XX(15)= 0.583
XX(16)= 0.625	XX(17)= 0.667	XX(18)= 0.708	XX(19)= 0.750	XX(20)= 0.792
XX(21)= 0.833	XX(22)= 0.875	XX(23)= 0.917	XX(24)= 0.958	XX(25)= 1.000
XX(26)= 2.500	XX(27)= 2.800	XX(28)= 4.800		

TIME = 300.00000 TIME STEP = 1.47916 NO. OF STEPS = 83

INTEGRATED HEAT BTU/SQ.FT			HEAT RATES BTU/SQ.FT-SEC		
CONVECTED	310.4		CONVECTED	3.2	
RADIATED	104.4		RADIATED	0.8	
NET LOAD		206.0	NET LOAD		2.4
STORED	103.8		STORED	0.4	
SUBLIMED	101.3		SUBLIMED	2.0	
ADVECTED	0.9		ADVECTED	0.0	
TPS NET		206.0	TPS NET		2.4

Table 6.1 (Continued)

SURFACE RECESSION

DISTANCE 0.00564 IN. RECESSION RATE 0.00006 IN/SEC

TEMPERATURE DEG F

T(1)= 760.400	T( )= 587.613	T(3)= 468.664	T(4)= 378.480	T(5)= 305.101
T(6)= 246.081	T(7)= 200.785	T(8)= 167.511	T(9)= 144.023	T(10)= 128.021
T(11)= 117.454	T(12)= 110.662	T(13)= 106.399	T(14)= 103.777	T(15)= 102.194
T(16)= 101.254	T(17)= 100.705	T(18)= 100.390	T(19)= 100.212	T(20)= 100.113
T(21)= 100.059	T(22)= 100.030	T(23)= 100.015	T(24)= 100.006	T(25)= 100.001
T(26)= 100.000	T(27)= 100.000	T(28)= 100.000		

NODE POSITION INCHES

XX(1)= 0.006	XX(2)= 0.044	XX(3)= 0.083	XX(4)= 0.125	XX(5)= 0.167
XX(6)= 0.208	XX(7)= 0.250	XX(8)= 0.292	XX(9)= 0.333	XX(10)= 0.375
XX(11)= 0.417	XX(12)= 0.458	XX(13)= 0.500	XX(14)= 0.542	XX(15)= 0.583
XX(16)= 0.625	XX(17)= 0.667	XX(18)= 0.708	XX(19)= 0.750	XX(20)= 0.792
XX(21)= 0.833	XX(22)= 0.875	XX(23)= 0.917	XX(24)= 0.958	XX(25)= 1.000
XX(26)= 2.500	XX(27)= 2.800	XX(28)= 4.800		

TIME = 400.00000 TIME STEP = 1.03531 NO. OF STEPS = 120

INTEGRATED HEAT BTU/SQ.FT			HEAT RATES BTU/SQ.FT-SEC		
CONVECTED	690.2		CONVECTED	4.1	
RADIATED	187.1		RADIATED	0.8	
NET LOAD		503.1	NET LOAD		3.3
STORED	135.7		STORED	0.3	
SUBLIMED	364.8		SUBLIMED	3.0	
ADVECTED	2.6		ADVECTED	0.0	
TPS NET		503.1	TPS NET		3.3

SURFACE RECESSION

DISTANCE 0.02025 IN. RECESSION RATE 0.00015 IN/SEC

TEMPERATURE DEG F

T(1)= 760.400	T(2)= 642.650	T(3)= 539.294	T(4)= 448.191	T(5)= 378.192
T(6)= 318.522	T(7)= 268.019	T(8)= 226.433	T(9)= 193.107	T(10)= 167.105
T(11)= 147.345	T(12)= 132.713	T(13)= 122.146	T(14)= 114.700	T(15)= 109.573
T(16)= 106.122	T(17)= 103.847	T(18)= 102.377	T(19)= 101.445	T(20)= 100.864
T(21)= 100.508	T(22)= 100.291	T(23)= 100.160	T(24)= 100.078	T(25)= 100.020
T(26)= 100.000	T(27)= 100.000	T(28)= 100.000		

NODE POSITION INCHES

XX(1)= 0.020	XX(2)= 0.048	XX(3)= 0.083	XX(4)= 0.125	XX(5)= 0.167
XX(6)= 0.208	XX(7)= 0.250	XX(8)= 0.292	XX(9)= 0.333	XX(10)= 0.375
XX(11)= 0.417	XX(12)= 0.458	XX(13)= 0.500	XX(14)= 0.542	XX(15)= 0.583
XX(16)= 0.625	XX(17)= 0.667	XX(18)= 0.708	XX(19)= 0.750	XX(20)= 0.792
XX(21)= 0.833	XX(22)= 0.875	XX(23)= 0.917	XX(24)= 0.958	XX(25)= 1.000
XX(26)= 2.500	XX(27)= 2.800	XX(28)= 4.800		

Table 6.1 (Continued)

ORIGINAL PAGE IS
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```
TIME =    500.00000    TIME STEP =      0.73596     NO. OF STEPS =        185

INTEGRATED HEAT                                    HEAT RATES
BTU/SQ.FT                                          BTU/SQ.FT-SEC

CONVECTED          1100.6                          CONVECTED        4.1
RADIATED            269.8                          RADIATED         0.8
NET LOAD                        830.8              NET LOAD                   3.3
STORED              163.9                          STORED           0.3
SUBLIMED            663.1                          SUBLIMED         3.0
ADVECTED              3.8                          ADVECTED         0.0
TPS NET                         830.8              TPS NET                    3.3


SURFACE RECESSION
DISTANCE     0.03672 IN.                           RECESSION RATE     0.00016 IN/SEC
TEMPERATURE DEG F
T(  1)= 760.400     T(  2)= 689.840     T(  3)= 598.048     T(  4)= 502.372     T(  5)= 429.213
T(  6)= 370.571     T(  7)= 319.121     T(  8)= 274.774     T(  9)= 237.242     T( 10)= 206.067
T( 11)= 180.663     T( 12)= 160.353     T( 13)= 144.426     T( 14)= 132.173     T( 15)= 122.924
T( 16)= 116.072     T( 17)= 111.089     T( 18)= 107.530     T( 19)= 105.032     T( 20)= 103.307
T( 21)= 102.131     T( 22)= 101.338     T( 23)= 100.800     T( 24)= 100.426     T( 25)= 100.144
T( 26)= 100.000     T( 27)= 100.000     T( 28)= 100.000
NODE POSITION INCHES
XX(  1)=    0.037   XX(  2)=    0.054   XX(  3)=    0.083   XX(  4)=    0.125   XX(  5)=    0.167
XX(  6)=    0.208   XX(  7)=    0.250   XX(  8)=    0.292   XX(  9)=    0.333   XX( 10)=    0.375
XX( 11)=    0.417   XX( 12)=    0.458   XX( 13)=    0.500   XX( 14)=    0.542   XX( 15)=    0.583
XX( 16)=    0.625   XX( 17)=    0.667   XX( 18)=    0.708   XX( 19)=    0.750   XX( 20)=    0.792
XX( 21)=    0.833   XX( 22)=    0.875   XX( 23)=    0.917   XX( 24)=    0.958   XX( 25)=    1.000
XX( 26)=    2.500   XX( 27)=    2.800   XX( 28)=    4.800


TIME =    600.00000    TIME STEP =      0.14777     NO. OF STEPS =        421

INTEGRATED HEAT                                    HEAT RATES
BTU/SQ.FT                                          BTU/SQ.FT-SEC

CONVECTED          1509.3                          CONVECTED        4.1
RADIATED            352.4                          RADIATED         0.8
NET LOAD                       1156.9              NET LOAD                   3.2
STORED              190.2                          STORED           0.3
SUBLIMED            962.3                          SUBLIMED         3.0
ADVECTED              4.4                          ADVECTED         0.0
TPS NET                        1156.9              TPS NET                    3.2

SURFACE RECESSION
DISTANCE     0.05322 IN.                           RECESSION RATE     0.00017 IN/SEC
TEMPERATURE DEG F
T(  1)= 760.400     T(  2)= 734.636     T(  3)= 652.931     T(  4)= 550.040     T(  5)= 473.121
T(  6)= 411.893     T(  7)= 360.579     T(  8)= 315.170     T(  9)= 275.544     T( 10)= 241.459
T( 11)= 212.566     T( 12)= 188.438     T( 13)= 168.590     T( 14)= 152.507     T( 15)= 139.670
T( 16)= 129.577     T( 17)= 121.758     T( 18)= 115.788     T( 19)= 111.293     T( 20)= 107.951
T( 21)= 105.492     T( 22)= 103.691     T( 23)= 102.366     T( 24)= 101.368     T( 25)= 100.575
T( 26)= 100.000     T( 27)= 100.000     T( 28)= 100.000
```

Table 6.1   (Continued)

NODE POSITION INCHES

XX(1)= 0.053	XX(2)= 0.039	XX(3)= 0.083	XX(4)= 0.125	XX(5)= 0.167
XX(6)= 0.208	XX(7)= 0.250	XX(8)= 0.292	XX(9)= 0.333	XX(10)= 0.375
XX(11)= 0.417	XX(12)= 0.458	XX(13)= 0.500	XX(14)= 0.542	XX(15)= 0.583
XX(16)= 0.625	XX(17)= 0.667	XX(18)= 0.708	XX(19)= 0.750	XX(20)= 0.792
XX(21)= 0.833	XX(22)= 0.875	XX(23)= 0.917	XX(24)= 0.958	XX(25)= 1.000
XX(26)= 2.500	XX(27)= 2.800	XX(28)= 4.800		

NODE DROPPED FROM SUBLIMER-ABLATOR MODEL

ORIGINAL PAGE IS
OF POOR QUALITY

1THIS IS THE CONFIGURATION FOR BODY PT. 3

```
===1. 0===============================================   ----
    2. 0                                                    I
    3. 0                                                    I
    4. 0                                                    I
    5. 0                                                    I
    6. 0                                                    I
    7. 0                                                    I
    8. 0                                                    I
    9. 0                                                    I
   10. 0                                                    I
   11. 0                                                    I
   12. 0                                                    I
   13. 0                 6 STD.CORK   ABLATOR SUBLIMER    0.945296 IN.
   14. 0                                                    I
   15. 0                                                    I
   16. 0                                                    I
   17. 0                                                    I
   18. 0                                                    I
   19. 0                                                    I
   20. 0                                                    I
   21. 0                                                    I
   22. 0                                                    I
   23. 0                                                    I
===24. 0===============================================   ----
          0.125000 IN. CTD.COLUMB                           I
------------------------------------------------------      I
                                                            I
                                RADIATION GAP         1.500000 IN.
                                                            I
------------------------------------------------------      I
          0.100000 IN. AL.7075-T6                           I
===25. 0===============================================   ----
                        AL.7075-T6   THIN SKIN        0.300000 IN.
===26. 0===============================================   ----
          0.140000 IN. INCONL 617                           I
------------------------------------------------------      I
  ZZZZZZ         ZZZZZZ                                     I
       Z              Z                                     I
       Z              Z   AL.7075-T6   Z STANDOFF     2.000000 IN.
       Z              Z                                     I
       ZZZZZZ         ZZZZZZ                                I
------------------------------------------------------      I
          0.180000 IN. CTD.COLUMB                           I
===27. 0===============================================   ----
```

Table 6.1 (Continued)

```
TIME =    700.00000    TIME STEP =      0.46820    NO. OF STEPS =        543

INTEGRATED HEAT                                  HEAT RATES
BTU/SQ.FT                                        BTU/SQ.FT-SEC


CONVECTED          1978.8                        CONVECTED        5.8
RADIATED            435.1                        RADIATED         0.8
NET LOAD                      1543.7             NET LOAD                  5.0
STORED              214.5                        STORED           0.2
SUBLIMED           1323.4                        SUBLIMED         4.7
ADVECTED              5.8                        ADVECTED         0.0
TPS NET                       1543.7             TPS NET                   5.0

SURFACE RECESSION
DISTANCE     0.07319 IN.                         RECESSION RATE     0.00020 IN/SEC
TEMPERATURE DEG F
T(  1)= 760.400    T(  2)= 698.392    T(  3)= 598.511    T(  4)= 514.310    T(  5)= 449.099
T(  6)= 396.113    T(  7)= 350.169    T(  8)= 309.324    T(  9)= 273.413    T( 10)= 242.208
T( 11)= 215.415    T( 12)= 192.687    T( 13)= `73.642    T( 14)= 157.877    T( 15)= 144.984
T( 16)= 134.567    T( 17)= 126.247    T( 18)= 119.674    T( 19)= 114.532    T( 20)= 110.537
T( 21)= 107.441    T( 22)= 105.029    T( 23)= 103.118    T( 24)= 101.547    T( 25)= 100.000
T( 26)= 100.000    T( 27)= 100.000
NODE POSITION INCHES
XX(  1)=   0.073    XX(  2)=   0.089    XX(  3)=   0.125    XX(  4)=   0.167    XX(  5)=   0.208
XX(  6)=   0.250    XX(  7)=   0.292    XX(  8)=   0.333    XX(  9)=   0.375    XX( 10)=   0.417
XX( 11)=   0.458    XX( 12)=   0.500    XX( 13)=   0.542    XX( 14)=   0.583    XX( 15)=   0.625
XX( 16)=   0.667    XX( 17)=   0.708    XX( 18)=   0.750    XX( 19)=   0.792    XX( 20)=   0.833
XX( 21)=   0.875    XX( 22)=   0.917    XX( 23)=   0.958    XX( 24)=   1.000    XX( 25)=   2.500
XX( 26)=   2.800    XX( 27)=   4.800

NODE DROPPED FROM SUBLIMER-ABLATOR MODEL
```

Table 6.1   (Continued)

```
1THIS IS THE CONFIGURATION FOR BODY PT.    3

=== 1. 0=================================================     -----
    2. 0
    3. 0                                                         I
    4. 0                                                         I
    5. 0                                                         I
    6. 0                                                         I
    7. 0                                                         I
    8. 0                                                         I
    9. 0                                                         I
   10. 0                                                         I
   11. 0                                                         I
   12. 0                   B-STD.CORK   ABLATOR SUBLIMER     0.910157 IN.
   13. 0                                                         I
   14. 0                                                         I
   15. 0                                                         I
   16. 0                                                         I
   17. 0                                                         I
   18. 0                                                         I
   19. 0                                                         I
   20. 0                                                         I
   21. 0                                                         I
   22. 0                                                         I

===23. 0=================================================     -----
            0.125000 IN. CTD.COLUMB                              I
---------------------------------------------------------        I
                                                                 I
                                      RADIATION GAP      1.500000 IN.
                                                                 I
---------------------------------------------------------        I
            0.100000 IN. AL.7075-T6                              I
===24. 0=================================================     -----
                            AL.7075-T6   THIN SKIN       0.300000 IN.
===25. 0=================================================     -----
            0.140000 IN. INCONL 617                              I
---------------------------------------------------------        I
 ZZZZZZ          ZZZZZZ                                          I
      Z               Z                                          I
      Z               Z     AL.7075-T6   Z STANDOFF      2.000000 IN.
      Z               Z                                          I
      ZZZZZZ          ZZZZZZ                                     I
---------------------------------------------------------        I
            0.180000 IN. CTD.COLUMB                              I
===26. 0=================================================     -----
```


Table 6.1 (Continued)

TIME = 800.00000 TIME STEP = 0.97308 NO. OF STEPS = 711

ORIGINAL PAGE IS
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INTEGRATED HEAT BTU/SQ.FT			HEAT RATES BTU/SQ.FT-SEC		
CONVECTED	2789.9		CONVECTED	12.0	
RADIATED	517.8		RADIATED	0.8	
NET LOAD		2272.1	NET LOAD		11.2
STORED	240.5		STORED	0.3	
SUBLIMED	202[illegible].9		SUBLIMED	10.9	
[illegible]	8.7		ADVECTED	0.0	
TPS NET		2272.1	TPS NET		11.2

SURFACE RECESSION
DISTANCE 0.11191 IN. RECESSION RATE 0.00039 IN/SEC

TEMPERATURE DEG F

T(1)= 760.400	T(2)= 673.705	T(3)= 574.758	T(4)= 493.329	T(5)= 432.302
T(6)= 383.488	T(7)= 340.771	T(8)= 303.051	T(9)= 269.926	T(10)= 241.045
T(11)= 216.076	T(12)= 194.683	T(13)= 176.528	T(14)= 161.269	T(15)= 148.569
T(16)= 138.095	T(17)= 129.532	T(18)= 122.581	T(19)= 116.968	T(20)= 112.442
T(21)= 108.777	T(22)= 105.772	T(23)= 103.249	T(24)= 100.002	T(25)= 100.002
T(26)= 100.000				

NODE POSITION INCHES

XX(1)= 0.112	XX(2)= 0.132	XX(3)= 0.167	XX(4)= 0.208	XX(5)= 0.250
XX(6)= 0.292	XX(7)= 0.333	XX(8)= 0.375	XX(9)= 0.417	XX(10)= 0.458
XX(11)= 0.500	XX(12)= 0.542	XX(13)= 0.583	XX(14)= 0.625	XX(15)= 0.667
XX(16)= 0.708	XX(17)= 0.750	XX(18)= 0.792	XX(19)= 0.833	XX(20)= 0.875
XX(21)= 0.917	XX(22)= 0.958	XX(23)= 1.000	XX(24)= 2.500	XX(25)= 2.800
XX(26)= 4.800				

Table 6.1 (Continued)

NODE DROPPED FROM SUBLIMER-ABLATOR MODEL

1THIS IS THE CONFIGURATION FOR BODY PT.   3

```
=== 1. 0=============================================   ---
    2. 0                                                 I
    3. 0                                                 I
    4. 0                                                 I
    5. 0                                                 I
    6. 0                                                 I
    7. 0                                                 I
    8. 0                                                 I
    9. 0                                                 I
   10. 0                                                 I
   11. 0                                                 I
   12. 0              B-STG.CORK   ABLATOR SUBLIMER    0.865148 IN.
   13. 0                                                 I
   14. 0                                                 I
   15. 0                                                 I
   16. 0                                                 I
   17. 0                                                 I
   18. 0                                                 I
   19. 0                                                 I
   20. 0                                                 I
   21. 0                                                 I
===22. 0=============================================   ---
          0.125000 IN. CTD.COLUMB                        I
-----------------------------------------------------    I
                                                         I
                               RADIATION GAP          1.500000 IN.
                                                         I
-----------------------------------------------------    I
          0.100000 IN. AL.7075-T6                        I
===23. 0=============================================   ---
                    AL.7075-T6   THIN SKIN            0.300000 IN.
===24. 0=============================================   ---
          0.140000 IN. INCONL 617                        I
-----------------------------------------------------    I
  ZZZZZZ          ZZZZZZ                                 I
       Z               Z                                 I
       Z               Z    AL.7075-T6   Z STANDOFF   2.000000 IN.
       Z               Z                                 I
       ZZZZZZ          ZZZZZZ                            I
-----------------------------------------------------    I
          0.180000 IN. CTD.COLUMB                        I
===25. 0=============================================   ---
```

NODE DROPPED FROM SUBLIMER-ABLATOR MODEL

Table 6.1 (Continued)

1THIS IS THE CONFIGURATION FOR BODY PT.   3

ORIGINAL PAGE IS
OF POOR QUALITY

```
 *** 1. 0*********************************************     ----
     2. 0                                                    I
     3. 0                                                    I
     4. 0                                                    I
     5. 0                                                    I
     6. 0                                                    I
     7. 0                                                    I
     8. 0                                                    I
     9. 0                                                    I
    10. 0                                                    I
    11. 0                   B-STD.CORK   ABLATOR SUBLIMER    0.825189 IN.
    12. 0                                                    I
    13. 0                                                    I
    14. 0                                                    I
    15. 0                                                    I
    16. 0                                                    I
    17. 0                                                    I
    18. 0                                                    I
    19. 0                                                    I
    20. 0                                                    I
 ===21. 0=============================================     ----
              0.125000 IN. CTD.COLUMB                        I
 -------------------------------------------------           I
                                                             I
                                 RADIATION GAP           1.500000 IN.
                                                             I
 -------------------------------------------------           I
              0.100000 IN. AL.7075-T6                        I
 ===22. 0=============================================     ----
                         AL.7075-T6   THIN SKIN          0.300000 IN.
 ===23. 0=============================================     ----
              0.140000 IN. INCONL 617                        I
 -------------------------------------------------           I
  ZZZZZZ          ZZZZZZ                                     I
       Z               Z                                     I
       Z               Z   AL.7075-T6   Z STANDOFF       2.000000 IN.
       Z               Z                                     I
       ZZZZZZ          ZZZZZZ                                I
 -------------------------------------------------           I
              0.180000 IN. CTD.COLUMB                        I
 ===24. 0=============================================     ----
```

Table 6.1   (Continued)

```
TIME =    900.00000    TIME STEP =    0.88153    NO. OF STEPS =    877

INTEGRATED HEAT                              HEAT RATES
BTU/SQ.FT                                    BTU/SQ.FT-SEC

CONVECTED       4369.1                       CONVECTED      17.3
RADIATED         600.5                       RADIATED        0.8
NET LOAD                  3768.6             NET LOAD               16.5
STORED           275.7                       STORED          0.4
SUBLIMED        3476.9                       SUBLIMED       16.0
ADVECTED          15.9                       ADVECTED        0.1
TPS NET                   3768.6             TPS NET                16.5

SURFACE RECESSION
DISTANCE     0.19232 IN.                     RECESSION RATE    0.00080 IN/SEC
TEMPERATURE DEG F
T(  1)= 760.400   T(  2)= 639.981   T(  3)= 522.308   T(  4)= 440.134   T(  5)= 383.468
T(  6)= 337.984   T(  7)= 299.871   T(  8)= 267.453   T(  9)= 239.678   T( 10)= 215.837
T( 11)= 195.415   T( 12)= 177.999   T( 13)= 163.230   T( 14)= 150.784   T( 15)= 140.359
T( 16)= 131.673   T( 17)= 124.461   T( 18)= 118.479   T( 19)= 113.504   T( 20)= 109.332
T( 21)= 105.780   T( 22)= 100.007   T( 23)= 100.007   T( 24)= 100.000
NODE POSITION INCHES
XX(  1)=   0.192   XX(  2)=   0.214   XX(  3)=   0.250   XX(  4)=   0.292   XX(  5)=   0.333
XX(  6)=   0.375   XX(  7)=   0.417   XX(  8)=   0.458   XX(  9)=   0.500   XX( 10)=   0.542
XX( 11)=   0.583   XX( 12)=   0.625   XX( 13)=   0.667   XX( 14)=   0.708   XX( 15)=   0.750
XX( 16)=   0.792   XX( 17)=   0.833   XX( 18)=   0.875   XX( 19)=   0.917   XX( 20)=   0.958
XX( 21)=   1.000   XX( 22)=   2.500   XX( 23)=   2.800   XX( 24)=   4.800

NODE DROPPED FROM SUBLIMER-ABLATOR MODEL
```

Table 6.1   (Continued)

1THIS IS THE CONFIGURATION FOR BODY PT.   3

```
=== 1. 0==========================================   ---
    2. 0                                              I
    3. 0                                              I
    4. 0                                              I
    5. 0                                              I
    6. 0                                              I
    7. 0                                              I
    8. 0                                              I
    9. 0                                              I
   10. 0                                              I
   11. 0                 B-STD.CORK   ABLATOR SUBLIMER  0.782658 IN.
   12. 0                                              I
   13. 0                                              I
   14. 0                                              I
   15. 0                                              I
   16. 0                                              I
   17. 0                                              I
   18. 0                                              I
   19. 0                                              I
===20. 0==========================================   ---
          0.125000 IN. CTD.COLUMB                     I
--------------------------------------------------    I
                                                      I
                              RADIATION GAP         1.500000 IN.
                                                      I
--------------------------------------------------    I
          0.100000 IN. AL.7075-T6                     I



===21. 0==========================================   ---
                     AL.7075-T6   THIN SKIN          0.300000 IN.
===22. 0==========================================   ---
          0.140000 IN. INCONL 617                     I
--------------------------------------------------    I
 ZZZZZZ          ZZZZZZ                               I
      Z               Z                               I
      Z               Z  AL.7075-T6   Z STANDOFF     2.000000 IN.
      Z               Z                               I
      ZZZZZZ          ZZZZZZ                          I
--------------------------------------------------    I
          0.180000 IN. CTD.COLUMB                     I
===23. 0==========================================   ---
```

NODE DROPPED FROM SUBLIMER-ABLATOR MODEL

Table 6.1   (Continued)

```
1THIS IS THE CONFIGURATION FOR BODY PT.    3

=== 1. 0===============================================  ----
    2. 0                                                   I
    3. 0                                                   I
    4. 0                                                   I
    5. 0                                                   I
    6. 0                                                   I
    7. 0                                                   I
    8. 0                                                   I
    9. 0                                                   I
   10. 0                  B-STG.CORK   ABLATOR SUBLIMER    0.741394 IN.
   11. 0                                                   I
   12. 0                                                   I
   13. 0                                                   I
   14. 0                                                   I
   15. 0                                                   I
   16. 0                                                   I
   17. 0                                                   I
   18. 0                                                   I
===19. 0===============================================  ----
             0.125000 IN. CTD.COLUMB                       I
-------------------------------------------------------    I
                                                           I
                                  RADIATION GAP          1.500000 IN.
                                                           I
-------------------------------------------------------    I
             0.100000 IN. AL.7075-T6                       I
===20. 0===============================================  ----
                          AL.7075-T6   THIN SKIN         0.300000 IN.
===21. 0===============================================  ----
             0.140000 IN. INCONL 617                       I
-------------------------------------------------------    I
  ZZZZZZ          ZZZZZZ                                   I
       Z               Z                                   I
       Z               Z  AL.7075-T6   Z STANDOFF        2.000000 IN.
       Z               Z                                   I
       ZZZZZZ          ZZZZZZ                              I
-------------------------------------------------------    I
             0.180000 IN. CTD.COLUMB                       I
===22. 0===============================================  ----
```

```
TIME =   1000.00000    TIME STEP =     0.06152    NO. OF STEPS =     1043

INTEGRATED HEAT                           HEAT RATES
BTU/SQ.FT                                 BTU/SQ.FT-SEC

CONVECTED      6115.4                     CONVECTED     17.6
RADIATED        683.2                     RADIATED       0.8
NET LOAD                 5432.2           NET LOAD               16.7
STORED          319.2                     STORED         0.5
SUBLIMED       5087.5                     SUBLIMED      16.2
ADVECTED         25.4                     ADVECTED       0.1
TPS NET                  5432.1           TPS NET                16.7
```

Table 6.1 (Continued)

ORIGINAL PAGE IS
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```
SURFACE RECESSION
DISTANCE     0.28137 IN.                              RECESSION RATE     0.00089 IN/SEC
TEMPERATURE DEG F
T(  1)= 760.400     T(  2)= 644.619     T(  3)= 513.528     T(  4)= 420.801     T(  5)= 358.621
T(  6)= 310.831     T(  7)= 273.095     T(  8)= 242.609     T(  9)= 217.550     T( 10)= 196.701
T( 11)= 179.223     T( 12)= 164.511     T( 13)= 152.110     T( 14)= 141.655     T( 15)= 132.842
T( 16)= 125.406     T( 17)= 119.116     T( 18)= 113.765     T( 19)= 109.169     T( 20)= 100.016
T( 21)= 100.016     T( 22)= 100.000
NODE POSITION INCHES
XX(  1)=   0.281     XX(  2)=   0.299     XX(  3)=   0.333     XX(  4)=   0.375     XX(  5)=   0.417
XX(  6)=   0.458     XX(  7)=   0.500     XX(  8)=   0.542     XX(  9)=   0.583     XX( 10)=   0.625
XX( 11)=   0.667     XX( 12)=   0.708     XX( 13)=   0.750     XX( 14)=   0.792     XX( 15)=   0.833
XX( 16)=   0.875     XX( 17)=   0.917     XX( 18)=   0.958     XX( 19)=   1.000     XX( 20)=   2.900
XX( 21)=   2.800     XX( 22)=   4.800


NODE DROPPED FROM SUBLIMER-ABLATOR MODEL
```

Table 6.1   (Continued)

1THIS IS THE CONFIGURATION FOR BODY PT.   3


```
=== 1. 0=================================================   ----
     2. 0                                                     I
     3. 0                                                     I
     4. 0                                                     I
     5. 0                                                     I
     6. 0                                                     I
     7. 0                                                     I
     8. 0                                                     I
     9. 0                                                     I
    10. 0                     B-STD.CORK   ABLATOR SUBLINER   0.699540 IN.
    11. 0                                                     I
    12. 0                                                     I
    13. 0                                                     I
    14. 0                                                     I
    15. 0                                                     I
    16. 0                                                     I
    17. 0                                                     I
===18. 0=================================================   ----
              0.125000 IN. CTD.COLUMB                         I
---------------------------------------------------------     I
                                                              I
                                      RADIATION GAP         1.500000 IN.
---------------------------------------------------------     I
              0.100000 IN. AL.7075-T6                         I
===19. 0=================================================   ----
                          AL.7075-T6   THIN SKIN            0.300000 IN.
===20. 0=================================================   ----
              0.140000 IN. INCONL 617                         I
---------------------------------------------------------     I
 ZZZZZZ          ZZZZZZ                                       I
      Z               Z                                       I
      Z               Z      AL.7075-TA   Z STANDOFF        2.000000 IN.
      Z               Z                                       I
      ZZZZZZ          ZZZZZZ                                  I
---------------------------------------------------------     I
              0.180000 IN. CTD.COLUMB                         I
===21. 0=================================================   ----
```

NODE DROPPED FROM SUBLINER-ABLATOR MODEL

Table 6.1   (Continued)

```
1THIS IS THE CONFIGURATION FOR BODY PT.    3

=== 1. 0=============================================    ---
    2. 0                                                  I
    3. 0                                                  I
    4. 0                                                  I
    5. 0                                                  I
    6. 0                                                  I
    7. 0                                                  I
    8. 0                                                  I
    9. 0              B-STG.CORK   ABLATOR SUBLINER    0.458035 IN.
   10. 0                                                  I
   11. 0                                                  I
   12. 0                                                  I
   13. 0                                                  I
   14. 0                                                  I
   15. 0                                                  I
   16. 0                                                  I
===17. 0=============================================    ---
            0.125000 IN. CTD.COLUMB                       I


-----------------------------------------------------     I
                                                          I
                              RADIATION GAP          1.500000 IN.
                                                          I
-----------------------------------------------------     I
            0.100000 IN. AL.7075-T6                       I
===18. 0=============================================    ---
                       AL.7075-T6   THIN SKIN        0.300000 IN.
===19. 0=============================================    ---
            0.140000 IN. INCONL 617                       I
-----------------------------------------------------     I
  ZZZZZZ          ZZZZZZ                                  I
       Z               Z                                  I
       Z               Z    AL.7075-T6   Z STANDOFF  2.000000 IN.
       Z               Z                                  I
       ZZZZZZ          ZZZZZZ                             I
-----------------------------------------------------     I
            0.180000 IN. CTD.COLUMB                       I
===20. 0=============================================    ---


TIME =   1100.00000    TIME STEP =      0.34009    NO. OF STEPS =      1220

INTEGRATED HEAT                               HEAT RATES
BTU/SQ.FT                                     BTU/SQ.FT-SEC

CONVECTED        7701.9                       CONVECTED      12.9
RADIATED          765.8                       RADIATED        0.8
NET LOAD                  6936.0              NET LOAD               12.0
STORED            365.7                       STORED          0.4
SUBLIMED         6535.7                       SUBLIMED       11.5
ADVECTED           34.5                       ADVECTED        0.1
TPS NET                   6936.0              TPS NET                12.0
```


Table 6.1 (Continued)

```
SURFACE RECESSION
DISTANCE      0.36147 IN.                                   RECESSION RATE     0.00080 IN/SEC
TEMPERATURE DEG F
T(  1)= 760.400    T(  2)= 637.213    T(  3)= 505.053    T(  4)= 410.413    T(  5)= 344.900
T(  6)= 294.890    T(  7)= 256.280    T(  8)= 226.039    T(  9)= 201.990    T( 10)= 182.585
T( 11)= 166.725    T( 12)= 153.619    T( 13)= 142.694    T( 14)= 133.516    T( 15)= 125.750
T( 16)= 119.127    T( 17)= 113.425    T( 18)= 100.032    T( 19)= 100.032    T( 20)= 100.000
NODE POSITION INCHES
XX(  1)=   0.361   XX(  2)=   0.382   XX(  3)=   0.417   XX(  4)=   0.458   XX(  5)=   0.500
XX(  6)=   0.542   XX(  7)=   0.583   XX(  8)=   0.625   XX(  9)=   0.667   XX( 10)=   0.708
XX( 11)=   0.750   XX( 12)=   0.792   XX( 13)=   0.833   XX( 14)=   0.875   XX( 15)=   0.917
XX( 16)=   0.958   XX( 17)=   1.000   XX( 18)=   2.500   XX( 19)=   2.800   XX( 20)=   4.800

NODE DROPPED FROM SUBLIMER-ABLATOR MODEL


1THIS IS THE CONFIGURATION FOR BODY PT.    3


*** 1. 0================================================   ---
    2. 0                                                       I
    3. 0                                                       I
    4. 0                                                       I
    5. 0                                                       I
    6. 0                                                       I
    7. 0                                                       I
    8. 0                                                       I
    9. 0                 B-STG.CORK    ABLATOR SUBLIMER    0.616264 IN.
   10. 0                                                       I
   11. 0                                                       I
   12. 0                                                       I
   13. 0                                                       I
   14. 0                                                       I
   15. 0                                                       I
===16. 0================================================   ---
          0.125000 IN. CTD.COLUMB                              I
------------------------------------------------------         I
                                                               I
                               RADIATION GAP              1.500000 IN.
                                                               I
------------------------------------------------------         I
          0.100000 IN. AL.7075-T6                              I
===17. 0================================================   ---
                         AL.7075-T6    THIN SKIN          0.300000 IN.
===18. 0================================================   ---
          0.140000 IN. INCONL 617                              I
------------------------------------------------------         I
 ZZZZZZ          ZZZZZZ                                        I
      Z               Z                                        I
      Z               Z    AL.7075-T6    Z STANDOFF       2.000000 IN.
      Z               Z                                        I
      ZZZZZZ          ZZZZZZ                                   I
------------------------------------------------------         I
          0.180000 IN. CTD.COLUMB                              I
===19. 0================================================   ---
```

ORIGINAL PAGE IS
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Table 6.1   (Continued)

ORIGINAL PAGE IS
OF POOR QUALITY

```
TIME =   1200.00000 .  TIME STEP =     0.16211     NO. OF STEPS =      1384

INTEGRATED HEAT                                  HEAT RATES
BTU/SQ.FT                                        BTU/SQ.FT-SEC

CONVECTED        8741.6                          CONVECTED        7.8
RADIATED          848.5                          RADIATED         0.8
NET LOAD                      7893.0             NET LOAD                   7.0
STORED            406.7                          STORED           0.4
SUBLIMED         7446.8                          SUBLIMED         6.6
ADVECTED           39.5                          ADVECTED         0.0
TPS NET                       7893.0             TPS NET                    7.0

SURFACE RECESSION
DISTANCE      0.41182 IN.                        RECESSION RATE     0.00050 IN/SEC



TEMPERATURE DEG F
T(  1)= 760.400     T(  2)= 680.492     T(  3)= 555.839     T(  4)= 452.119     T(  5)= 380.072
T(  6)= 323.148     T(  7)= 277.637     T(  8)= 241.483     T(  9)= 212.780     T( 10)= 189.906
T( 11)= 171.552     T( 12)= 156.687     T( 13)= 144.518     T( 14)= 134.433     T( 15)= 125.957
T( 16)= 118.715     T( 17)= 100.054     T( 18)= 100.054     T( 19)= 100.002
NODE POSITION INCHES
XX(  1)=   0.412     XX(  2)=   0.426     XX(  3)=   0.458     XX(  4)=   0.500     XX(  5)=   0.542
XX(  6)=   0.583     XX(  7)=   0.625     XX(  8)=   0.667     XX(  9)=   0.708     XX( 10)=   0.750
XX( 11)=   0.792     XX( 12)=   0.833     XX( 13)=   0.875     XX( 14)=   0.917     XX( 15)=   0.958
XX( 16)=   1.000     XX( 17)=   2.500     XX( 18)=   2.800     XX( 19)=   4.800

NODE DROPPED FROM SUBLIMER-ABLATOR MODEL
```

Table 6.1   (Continued)

ORIGINAL PAGE IS
OF POOR QUALITY

```
1THIS IS THE CONFIGURATION FOR BODY.PT.    3

=== 1. 0==================================================   ----
    2. 0                                                       I
    3. 0                                                       I
    4. 0                                                       I
    5. 0                                                       I
    6. 0                                                       I
    7. 0                                                       I
    8. 0                      B-STG.CORK    ABLATOR SUBLINER   0.574676 IN.
    9. 0                                                       I
   10. 0                                                       I
   11. 0                                                       I
   12. 0                                                       I
   13. 0                                                       I
   14. 0                                                       I
===15. 0==================================================   ----
               0.125000 IN. CTD.COLUMB                         I
----------------------------------------------------------     I
                                                               I
                                        RADIATION GAP      1.500000 IN.
                                                               I
----------------------------------------------------------     I
               0.100000 IN. AL.7075-T6                         I
===16. 0==================================================   ----
                          AL.7075-T6    THIN SKIN          0.300000 IN.
===17. 0==================================================   ----
               0.140000 IN. INCONL 617                         I
----------------------------------------------------------     I
  ZZZZZZ          ZZZZZZ                                       I
       Z               Z                                       I
       Z               Z  AL.7075-T6    Z STANDOFF         2.000000 IN.
       Z               Z                                       I
       ZZZZZZ          ZZZZZZ                                  I
----------------------------------------------------------     I
               0.180000 IN. CTD.COLUMB                         I
===18. 0==================================================   ----


TIME =   1300.00000    TIME STEP =     0.71448    NO. OF STEPS =     1565

INTEGRATED HEAT                              HEAT RATES
BTU/SQ.FT                                    BTU/SQ.FT-SEC

CONVECTED        9323.0                      CONVECTED      4.1
RADIATED          931.2                      RADIATED       0.8
NET LOAD                  8391.8             NET LOAD               3.2
STORED            440.1                      STORED         0.3
SUBLIMED         7909.9                      SUBLIMED       2.9
ADVECTED           41.8                      ADVECTED       0.0
TPS NET                   8391.7             TPS NET                3.2
```

Table 6.1 (Continued)

ORIGINAL PAGE IS
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```
SURFACE RECESSION
DISTANCE     0.43748 IN.                      RECESSION RATE    0.00026 IN/SEC
TEMPERATURE DEG F
T(  1)= 760.400    T(  2)= 655.889    T(  3)= 545.233    T(  4)= 457.768    T(  5)= 391.872
T(  6)= 337.706    T(  7)= 292.214    T(  8)= 254.516    T(  9)= 223.571    T( 10)= 198.309
T( 11)= 177.716    T( 12)= 160.885    T( 13)= 147.027    T( 14)= 135.474    T( 15)= 125.657
T( 16)= 100.086    T( 17)= 100.086    T( 18)= 100.004
NODE POSITION INCHES
XX(  1)=   0.437   XX(  2)=   0.462   XX(  3)=   0.500   XX(  4)=   0.542   XX(  5)=   0.583
XX(  6)=   0.625   XX(  7)=   0.667   XX(  8)=   0.708   XX(  9)=   0.750   XX( 10)=   0.792
XX( 11)=   0.833   XX( 12)=   0.875   XX( 13)=   0.917   XX( 14)=   0.958   XX( 15)=   1.000
XX( 16)=   2.500   XX( 17)=   2.800   XX( 18)=   4.800


TIME =   1400.00000     TIME STEP =      0.92102     NO. OF STEPS =       1676

INTEGRATED HEAT                               HEAT RATES
BTU/SQ.FT                                     BTU/SQ.FT-SEC

CONVECTED          9580.4                     CONVECTED         1.2
RADIATED           1013.9                     RADIATED          0.8
NET LOAD                       8566.6         NET LOAD                      0.4
STORED              466.2                     STORED            0.2
SUBLIMED           8057.9                     SUBLIMED          0.1
ADVECTED             42.4                     ADVECTED          0.0
TPS NET                        8566.5         TPS NET                       0.4

SURFACE RECESSION
DISTANCE     0.44543 IN.                      RECESSION RATE    0.00008 IN/SEC
TEMPERATURE DEG F
T(  1)= 760.400    T(  2)= 691.868    T(  3)= 596.517    T(  4)= 509.654    T(  5)= 441.324
T(  6)= 386.024    T(  7)= 337.964    T(  8)= 296.053    T(  9)= 260.032    T( 10)= 229.423
T( 11)= 203.613    T( 12)= 181.932    T( 13)= 163.7[illegible]  T( 14)= 148.292    T( 15)= 135.091
T( 16)= 100.131    T( 17)= 100.131    T( 18)= 100.010
NODE POSITION INCHES
XX(  1)=   0.446   XX(  2)=   0.465   XX(  3)=   0.500   XX(  4)=   0.542   XX(  5)=   0.583
XX(  6)=   0.625   XX(  7)=   0.667   XX(  8)=   0.708   XX(  9)=   0.750   XX( 10)=   0.792
XX( 11)=   0.833   XX( 12)=   0.875   XX( 13)=   0.917   XX( 14)=   0.958   XX( 15)=   1.000
XX( 16)=   2.500   XX( 17)=   2.800   XX( 18)=   4.800


INITIAL MASS =    28.83250   (LBM/SQ.FT.)

1
```

H

Table 6.1 (Concluded)

1 TSTART = 0.000 TSTOP = 1410.000 TIMPT = 100.000 (A)
DTIM = 10.000 STAB = 2.000 TOL = 0.001 BET = 0.500
NBP = 1 NEXT = 20 NSTP = 3000 IPFLAG = 1

1 T A B L E S (B)

HRSI COAT - MAT NO. 4

MAXIMUM TEMPERATURE 2300.40 DEG F

ORIGINAL PAGE IS
OF POOR QUALITY

TEMP. (DEG F)	DENSITY (LBM/CU.FT)
-0.4596E+03	0.1040E+03
0.9540E+04	0.1040E+03

TEMP. (DEG F)	SPECIFIC HEAT (BTU/LBM-DEG F)
-0.4596E+03	0.1500E+00
-0.2496E+03	0.1500E+00
-0.1496E+03	0.1700E+00
0.4000E+00	0.1900E+00
0.2504E+03	0.2150E+00
0.5004E+03	0.2400E+00
0.1000E+04	0.2850E+00
0.2000E+04	0.3450E+00
0.3000E+04	0.3900E+00

TEMP. (DEG F)	CONDUCTIVITY (BTU/FT-S-DEG F)
-0.4596E+03	0.1181E-03
-0.2496E+03	0.1181E-03
-0.1496E+03	0.1250E-03
0.4000E+00	0.1353E-03
0.2504E+03	0.1528E-03
0.5004E+03	0.1678E-03
0.1000E+04	0.1996E-03
0.2000E+04	0.2453E-03
0.3000E+04	0.3278E-03

TEMP. (DEG F)	EMISSIVITY (DIMENSIONLESS)
-0.4596E+03	0.8500E+00
0.9540E+04	0.8500E+00

LI-900 - MAT NO. 5

Table 6.2 Output For Example Case Two (Table 5.9)

MAXIMUM TEMPERATURE 2300.40 DEG F

TEMP. (DEG F)	DENSITY (LBM/CU.FT)
-0.4596E+03	0.9000E+01
0.9540E+04	0.9000E+01

TEMP. (DEG F)	SPECIFIC HEAT (BTU/LBM-DEG F)
-0.4596E+03	0.7000E-01
-0.2496E+03	0.7000E-01
-0.1496E+03	0.1050E+00
0.4000E+00	0.1500E+00
0.2504E+03	0.2100E+00
0.5004E+03	0.2520E+00
0.1000E+04	0.2880E+00
0.1500E+04	0.3000E+00
0.1750E+04	0.3030E+00
0.3000E+04	0.3030E+00

CONDUCTIVITY
(BTU/FT-S-DEG F)

TEMP. (DEG F)	PRESSURE (LB/SQ.FT) 0.00	0.21	2.12	21.16	211.60	2116.00
-0.4596E+03	0.1389E-05	0.1389E-05	0.2083E-05	0.4166E-05	0.6060E-05	0.6472E-05
-0.2496E+03	0.1389E-05	0.1389E-05	0.2083E-05	0.4166E-05	0.6060E-05	0.6472E-05
0.4000E+00	0.2083E-05	0.2083E-05	0.2777E-05	0.5083E-05	0.6944E-05	0.7638E-05
0.2504E+03	0.2555E-05	0.2555E-05	0.3472E-05	0.6250E-05	0.8777E-05	0.9472E-05
0.5004E+03	0.3472E-05	0.3472E-05	0.4638E-05	0.7666E-05	0.1111E-04	0.1202E-04
0.7504E+03	0.4861E-05	0.4861E-05	0.6000E-05	0.9027E-05	0.1366E-04	0.1483E-04
0.1000E+04	0.6472E-05	0.647[illegible]-05	0.7639E-05	0.1088E-04	0.1667E-04	0.1827E-04
0.1250E+04	0.8555E-05	0.8555E-05	0.9722E-05	0.1366E-04	0.2014E-04	0.2172E-04
0.1500E+04	0.1155E-04	0.1155E-04	0.1275E-04	0.1714E-04	0.2430E-04	0.2616E-04
0.1750E+04	0.1575E-04	0.1575E-04	0.1694E-04	0.2130E-04	0.2944E-04	0.3138E-04
0.2000E+04	0.2039E-04	0.2039E-04	0.2172E-04	0.2616E-04	0.3527E-04	0.3777E-04
0.2300E+04	0.2683E-04	0.2683E-04	0.2833E-04	0.3222E-04	0.4305E-04	0.4638E-04
0.2500E+04	0.3222E-04	0.3222E-04	0.3416E-04	0.3861E-04	0.4972E-04	0.5388E-04
0.2800E+04	0.4277E-04	0.4277E-04	0.4500E-04	0.5000E-04	0.6111E-04	0.6722E-04
0.3000E+04	0.5277E-04	0.5277E-04	0.5444E-04	0.6080E-04	0.7277E-04	0.8055E-04

TEMP. (DEG F)	EMISSIVITY (DIMENSIONLESS)
-0.4596E+03	0.1000E+01
0.9540E+04	0.1000E+01

AL.7075-T6 - MAT NO. 1

TABLE 6.2 (Continued)

MAXIMUM TEMPERATURE 200.40 DEG F

ORIGINAL PAGE IS
OF POOR QUALITY

TEMP. (DEG F)	DENSITY (LBM/CU.FT)
-0.4596E+03	0.1750E+03
0.9540E+04	0.1750E+03

TEMP. (DEG F)	SPECIFIC HEAT (BTU/LBM-DEG F)
-0.4596E+03	0.1700E+00
-0.1496E+03	0.1700E+00
0.4000E+00	0.1950E+00
0.2004E+03	0.2100E+00
0.8604E+03	0.2750E+00
0.1000E+04	0.2750E+00
0.9540E+04	0.2750E+00

TEMP. (DEG F)	CONDUCTIVITY (BTU/FT-S-DEG F)
-0.4596E+03	0.1400E-01
-0.1996E+03	0.1400E-01
0.4000E+00	0.2000E-01
0.3004E+03	0.2500E-01
0.4004E+03	0.2700E-01
0.5004E+03	0.2900E-01

TEMP. (DEG F)	EMISSIVITY (DIMENSIONLESS)
-0.4596E+03	0.1200E+00
0.9540E+04	0.1200E+00

INCONL 617 - MAT NO. 17

MAXIMUM TEMPERATURE 1800.40 DEG F

TEMP. (DEG F)	DENSITY (LBM/CU.FT)
-0.4596E+03	0.5219E+03
0.9540E+04	0.5219E+03

TEMP. (DEG F)	SPECIFIC HEAT (BTU/LBM-DEG F)
-0.4596E+03	0.1000E+00

Table 6.2 (Continued)

ORIGINAL PAGE IS
OF POOR QUALITY

0.7840E+02	0.1000E+00
0.2004E+03	0.1040E+00
0.4004E+03	0.1110E+00
0.6004E+03	0.1170E+00
0.1000E+04	0.1310E+00
0.1200E+04	0.1370E+00
0.1400E+04	0.1440E+00
0.1600E+04	0.1800E+00
0.1800E+04	0.1570E+00
0.2000E+04	0.1630E+00
0.9540E+04	0.1630E+00

TEMP. (DEG F)	CONDUCTIVITY (BTU/FT-S-DEG F)
-0.4596E+03	0.2176E-02
0.7840E+02	0.2176E-02
0.2004E+03	0.2328E-02
0.4004E+03	0.2616E-02
0.6004E+03	0.2894E-02
0.1000E+04	0.3449E-02
0.1200E+04	0.3727E-02
0.1400E+04	0.4005E-02
0.1600E+04	0.4282E-02
0.1800E+04	0.4560E-02
0.2000E+04	0.4838E-02
0.9540E+04	0.4838E-02

TEMP. (DEG F)	EMISSIVITY (DIMENSIONLESS)
-0.4596E+03	0.1500E+00
0.9540E+04	0.1500E+00

TITANIUM - MAT NO. 9

MAXIMUM TEMPERATURE 800.40 DEG F

TEMP. (DEG F)	DENSITY (LBM/CU.FT)
-0.4596E+03	0.5120E+03
0.9540E+04	0.5120E+03

TEMP. (DEG F)	SPECIFIC HEAT (BTU/LBM-DEG F)
-0.4596E+03	0.9600E-01
-0.1996E+03	0.9600E-01
0.4000E+00	0.1250E+00
0.4004E+03	0.1460E+00
0.1200E+04	0.1600E+00
0.9540E+04	0.1600E+00

Table 6.2 (Continued)

TEMP. (DEG F)	CONDUCTIVITY (BTU/FT-S-DEG F)
-0.4596E+03	0.1200E-02
0.7040E+02	0.1200E-02
0.5004E+03	0.1500E-02
0.1000E+04	0.2800E-02
0.9540E+04	0.2800E-02

TEMP. (DEG F)	EMISSIVITY (DIMENSIONLESS)
-0.4596E+03	0.1200E+00
0.9540E+04	0.1200E+00

Table 6.2 (Continued)

1
BODY POINT NUMBER = 3 SAMPLE MINIVER INPUT TABLE

TIME (SEC)	FILM COEF. (LBM/SQ.FT-SEC)	REC ENTHALPY (BTU/LBM)	PRESSURE (LBF/SQ.FT)
0.0000E+00	0.6450E-05	0.1126E+05	0.1252E-01
0.5000E+02	0.1221E-04	0.1124E+05	0.3449E-01
0.1000E+03	0.2502E-04	0.1123E+05	0.1090E+00
0.1250E+03	0.3631E-04	0.1123E+05	0.1992E+00
0.1500E+03	0.5367E-04	0.1122E+05	0.3777E+00
0.1750E+03	0.8009E-04	0.1123E+05	0.7313E+00
0.2000E+03	0.1203E-03	0.1124E+05	0.1440E+01
0.2250E+03	0.1795E-03	0.1127E+05	0.2802E+01
0.2750E+03	0.2528E-03	0.1113E+05	0.7749E+01
0.3000E+03	0.3015E-03	0.1109E+05	0.1126E+02
0.3500E+03	0.3710E-03	0.1092E+05	0.1779E+02
0.4000E+03	0.3974E-03	0.1060E+05	0.2004E+02
0.4500E+03	0.4108E-03	0.1027E+05	0.2121E+02
0.5000E+03	0.4259E-03	0.9966E+04	0.2314E+02
0.5280E+03	0.4325E-03	0.9769E+04	0.2379E+02
0.5560E+03	0.4402E-03	0.9577E+04	0.2470E+02
0.5980E+03	0.4515E-03	0.9270E+04	0.2599E+02
0.6400E+03	0.4661E-03	0.8966E+04	0.2806E+02
0.6540E+03	0.5320E-03	0.8876E+04	0.2915E+02
0.6820E+03	0.6853E-03	0.8680E+04	0.3124E+02
0.7100E+03	0.7182E-03	0.8450E+04	0.3105E+02
0.7380E+03	0.8937E-03	0.8228E+04	0.3303E+02
0.7520E+03	0.1013E-02	0.8106E+04	0.3425E+02
0.7660E+03	0.1148E-02	0.7984E+04	0.3565E+02
0.7800E+03	0.1328E-02	0.7863E+04	0.3738E+02
0.7940E+03	0.1540E-02	0.7738E+04	0.3927E+02
0.8080E+03	0.1784E-02	0.7610E+04	0.4128E+02
0.8220E+03	0.2090E-02	0.7476E+04	0.4368E+02
0.8500E+03	0.2389E-02	0.7149E+04	0.4938E+02
0.8780E+03	0.2615E-02	0.6779E+04	0.5542E+02
0.9060E+03	0.2856E-02	0.6385E+04	0.6202E+02
0.9760E+03	0.3470E-02	0.5284E+04	0.7639E+02
0.1004E+04	0.3900E-02	0.4800E+04	0.8486E+02
0.1032E+04	0.4267E-02	0.4291E+04	0.8986E+02
0.1060E+04	0.4461E-02	0.3797E+04	0.9285E+02
0.1074E+04	0.4484E-02	0.3562E+04	0.9301E+02
0.1102E+04	0.4499E-02	0.3117E+04	0.9302E+02
0.1116E+04	0.4557E-02	0.2903E+04	0.9263E+02
0.1144E+04	0.4844E-02	0.2496E+04	0.9407E+02
0.1172E+04	0.5133E-02	0.2125E+04	0.9565E+02
0.1200E+04	0.5153E-02	0.1813E+04	0.9244E+02
0.1260E+04	0.5462E-02	0.1253E+04	0.8645E+02
0.1290E+04	0.5814E-02	0.1034E+04	0.8521E+02
0.1350E+04	0.6301E-02	0.6930E+03	0.8369E+02
0.1380E+04	0.6169E-02	0.5627E+03	0.8032E+02
0.1410E+04	0.5844E-02	0.4545E+03	0.7643E+02

ORIGINAL PAGE IS OF POOR QUALITY

Table 6.2 (Continued)

1 STRUCTURE DEFINITION

BODY POINT 3

TINIT = 100.00 DEG F   TSINK = 0.00 DEG F   FIJ = 1.000

```
NODE NUMBER =   1     DISTANCE FROM SURFACE =   0.000000E+00 IN.
    CONDUCTOR NUMBER =   1
    STRUCTURE TYPE   =   1     SLAB
    MATERIAL  1 = HRSI COAT
NODE NUMBER =   2     DISTANCE FROM SURFACE =   0.100000E+00 IN.

NODE NUMBER =   2     DISTANCE FROM SURFACE =   0.100000E+00 IN.
    CONDUCTOR NUMBER =   2
    STRUCTURE TYPE   =   1     SLAB
    MATERIAL  1 = LI-900
NODE NUMBER =   3     DISTANCE FROM SURFACE =   0.162500E+00 IN.

NODE NUMBER =   3     DISTANCE FROM SURFACE =   0.162500E+00 IN.
    CONDUCTOR NUMBER =   3
    STRUCTURE TYPE   =   1     SLAB
    MATERIAL  1 = LI-900
NODE NUMBER =   4     DISTANCE FROM SURFACE =   0.225000E+00 IN.

NODE NUMBER =   4     DISTANCE FROM SURFACE =   0.225000E+00 IN.
    CONDUCTOR NUMBER =   4
    STRUCTURE TYPE   =   1     SLAB
    MATERIAL  1 = LI-900
NODE NUMBER =   5     DISTANCE FROM SURFACE =   0.287500E+00 IN.

NODE NUMBER =   5     DISTANCE FROM SURFACE =   0.287500E+00 IN.
    CONDUCTOR NUMBER =   5
    STRUCTURE TYPE   =   1     SLAB
    MATERIAL  1 = LI-900
NODE NUMBER =   6     DISTANCE FROM SURFACE =   0.350000E+00 IN.

NODE NUMBER =   6     DISTANCE FROM SURFACE =   0.350000E+00 IN.
    CONDUCTOR NUMBER =   6
    STRUCTURE TYPE   =   1     SLAB
    MATERIAL  1 = LI-900
NODE NUMBER =   7     DISTANCE FROM SURFACE =   0.412500E+00 IN.

NODE NUMBER =   7     DISTANCE FROM SURFACE =   0.412500E+00 IN.
    CONDUCTOR NUMBER =   7
    STRUCTURE TYPE   =   1     SLAB
    MATERIAL  1 = LI-900
NODE NUMBER =   8     DISTANCE FROM SURFACE =   0.475000E+00 IN.
```

ORIGINAL PAGE IS OF POOR QUALITY

Table 6.2 (Continued)

```
NODE NUMBER =    8      DISTANCE FROM SURFACE =   0.475000E+00 IN.
    CONDUCTOR NUMBER =    8
    STRUCTURE TYPE   =    1      SLAB
    MATERIAL  1 = LI-900
NODE NUMBER =    9      DISTANCE FROM SURFACE =   0.537500E+00 IN.

NODE NUMBER =    9      DISTANCE FROM SURFACE =   0.537500E+00 IN.
    CONDUCTOR NUMBER =    9
    STRUCTURE TYPE   =    1      SLAB
    MATERIAL  1 = LI-900
NODE NUMBER =   10      DISTANCE FROM SURFACE =   0.600000E+00 IN.

NODE NUMBER =   10      DISTANCE FROM SURFACE =   0.600000E+00 IN.
    CONDUCTOR NUMBER =   10
    STRUCTURE TYPE   =    3      HONEY COMB
    MATERIAL  1 = AL.7075-T6
    MATERIAL  2 = AL.7075-T6
    MATERIAL  3 = AL.7075-T6
NODE NUMBER =   11      DISTANCE FROM SURFACE =   0.135000E+01 IN.

NODE NUMBER =   11      DISTANCE FROM SURFACE =   0.135000E+01 IN.
    CONDUCTOR NUMBER =   11
    STRUCTURE TYPE   =    4      CORRUGATED
    MATERIAL  1 = INCONL 617
    MATERIAL  2 = INCONL 617
    MATERIAL  3 = TITANIUM
NODE NUMBER =   12      DISTANCE FROM SURFACE =   0.235000E+01 IN.
```

Table 6.2 (Continued)

```
1THIS IS THE CONFIGURATION FOR BODY PT.    3

=== 1. O==================================================  ----
                                                              I
                                  HRSI COAT    SLAB         0.100000 IN.      (E)
                                                              I
=== 2. O==================================================  ----
    3. O                                                      I
    4. O                                                      I
    5. O                                                      I
    6. O                          LI-900       SLAB         0.900000 IN.
    7. O                                                      I
    8. O                                                      I
    9. O                                                      I
===10. O==================================================  ----
                    0.120000 IN. AL.7075-T6                   I
  ---------------------------------------------------------   I
  I    I    I    I    I                                       I
  I    I    I    I    I                                       I
  I    I    I    I    I       AL.7075-T6   HONEY COMB       0.750000 IN.
  I    I    I    I    I                                       I
  I    I    I    I    I                                       I
  ---------------------------------------------------------   I
                    0.110000 IN. AL.7075-T6                   I
===11. O==================================================  ----
                    0.080000 IN. INCONL 617                   I
  ---------------------------------------------------------   I
 V      V      V      V                                       I
  V    V V    V V    V V                                      I
   V   V   V   V   V   V   V   TITANIUM    CORRUGATED       1.000000 IN.
    V V     V V     V V     V                                 I
     V       V       V       V                                I
  ---------------------------------------------------------   I
                    0.080000 IN. INCONL 617                   I
===12. O==================================================  ----
1


TIME =     0.00000    TIME STEP =     0.00000    NO. OF STEPS =      0         (F)

INTEGRATED HEAT                               HEAT RATES
BTU/SQ.FT                                     BTU/SQ.FT-SEC

CONVECTED          0.0                        CONVECTED        0.0
RADIATED           0.0                        RADIATED         0.0
NET LOAD                     0.0              NET LOAD                   0.0
STORED             0.0                        STORED           0.0
SUBLIMED           0.0                        SUBLIMED         0.0
ADVECTED           0.0                        ADVECTED         0.0
TPS NET                      0.0              TPS NET                    0.0
```

Table 6.2 (Continued)

```
SURFACE RECESSION
DISTANCE     0.00000 IN.                              RECESSION RATE    0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)= 100.000      T(  2)= 100.000      T(  3)= 100.000      T(  4)= 100.000      T(  5)= 100.000
T(  6)= 100.000      T(  7)= 100.000      T(  8)= 100.000      T(  9)= 100.000      T( 10)= 100.000
T( 11)= 100.000      T( 12)= 100.000


TIME =    100.00000    TIME STEP =      0.98808    NO. OF STEPS =        41

INTEGRATED HEAT                                    HEAT RATES
BTU/SQ.FT                                          BTU/SQ.FT-SEC

CONVECTED          15.3                            CONVECTED        0.3
RADIATED            3.0                            RADIATED         0.0
NET LOAD                      12.3                 NET LOAD                  0.2
STORED             12.3                            STORED           0.2
SUBLIMED            0.0                            SUBLIMED         0.0
ADVECTED            0.0                            ADVECTED         0.0
TPS NET                       12.3                 TPS NET                 . 0.2

SURFACE RECESSION
DISTANCE     0.00000 IN.                              RECESSION RATE    0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)= 169.266      T(  2)= 162.265      T(  3)= 132.831      T(  4)= 116.628      T(  5)= 108.067
T(  6)= 103.731      T(  7)= 101.635      T(  8)= 100.668      T(  9)= 100.232      T( 10)= 100.001
T( 11)= 100.000      T( 12)= 100.000


TIME =    200.00000    TIME STEP =      1.02477    NO. OF STEPS =        82

INTEGRATED HEAT                                    HEAT RATES
BTU/SQ.FT                                          BTU/SQ.FT-SEC

CONVECTED          81.0                            CONVECTED        1.3
RADIATED           13.8                            RADIATED         0.3
NET LOAD                      67.2                 NET LOAD                  1.1
STORED             67.2                            STORED           1.1
SUBLIMED            0.0                            SUBLIMED         0.0
ADVECTED            0.0                            ADVECTED         0.0
TPS NET                       67.2                 TPS NET                   1.1

SURFACE RECESSION
DISTANCE     0.00000 IN.                              RECESSION RATE    0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)= 452.735      T(  2)= 423.512      T(  3)= 293.834      T(  4)= 211.620      T(  5)= 163.752
T(  6)= 135.797      T(  7)= 119.560      T(  8)= 110.078      T(  9)= 104.253      T( 10)= 100.026
T( 11)= 100.020      T( 12)= 100.002
```

Table 6.2 (Continued)

ORIGINAL PAGE IS
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```
TIME =    300.00000    TIME STEP =     0.19823    NO. OF STEPS =       124

INTEGRATED HEAT                                   HEAT RATES
BTU/SQ.FT                                         BTU/SQ.FT-SEC

CONVECTED          312.4                          CONVECTED       3.2
RADIATED           105.4                          RADIATED        1.9
NET LOAD                     207.0                NET LOAD                  1.4
STORED             207.0                          STORED          1.4
SUBLIMED             0.0                          SUBLIMED        0.0
ADVECTED             0.0                          ADVECTED        0.0
TPS NET                      207.0                TPS NET                   1.4

SURFACE RECESSION
DISTANCE      0.00000 IN.                         RECESSION RATE    0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)=1012.758     T(  2)= 976.538     T(  3)= 782.617     T(  4)= 602.946     T(  5)= 451.330
T(  6)= 333.322     T(  7)= 246.278     T(  8)= 184.383     T(  9)= 138.668     T( 10)= 100.391
T( 11)= 100.301     T( 12)= 100.029


TIME =    400.00000    TIME STEP =     0.46954    NO. OF STEPS =       179

INTEGRATED HEAT                                   HEAT RATES
BTU/SQ.FT                                         BTU/SQ.FT-SEC

CONVECTED          689.1                          CONVECTED       4.0
RADIATED           385.9                          RADIATED        3.5
NET LOAD                     303.2                NET LOAD                  0.6
STORED             303.2                          STORED          0.6
SUBLIMED             0.0                          SUBLIMED        0.0
ADVECTED             0.0                          ADVECTED        0.0
TPS NET                      303.2                TPS NET                   0.6

SURFACE RECESSION
DISTANCE      0.00000 IN.                         RECESSION RATE    0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)=1255.578     T(  2)=1237.569     T(  3)=1103.591     T(  4)= 959.801     T(  5)= 812.666
T(  6)= 666.667     T(  7)= 524.981     T(  8)= 386.589     T(  9)= 247.565     T( 10)= 103.293
T( 11)= 102.816     T( 12)= 100.352
```

Table 6.2 (Continued)

TIME = 500.00000 TIME STEP = 0.29517 NO. OF STEPS = 249

INTEGRATED HEAT
BTU/SQ.FT

CONVECTED	1094.5	
RADIATED	752.5	
NET LOAD		342.0
STORED	342.0	
SUBLIMED	0.0	
ADVECTED	0.0	
TPS NET		342.0

HEAT RATES
BTU/SQ.FT-SEC

CONVECTED	4.1	
RADIATED	3.8	
NET LOAD		0.3
STORED	0.3	
SUBLIMED	0.0	
ADVECTED	0.0	
TPS NET		0.3

SURFACE RECESSION
DISTANCE 0.00000 IN. RECESSION RATE 0.00000 IN/SEC
TEMPERATURE DEG F

T(1)=1288.586	T(2)=1277.074	T(3)=1171.510	T(4)=1056.575	T(5)= 929.987
T(6)= 793.873	T(7)= 646.440	T(8)= 487.771	T(9)= 312.073	T(10)= 109.496
T(11)= 108.731	T(12)= 101.737			

TIME = 600.00000 TIME STEP = 0.54968 NO. OF STEPS = 322

INTEGRATED HEAT
BTU/SQ.FT

CONVECTED	1497.7	
RADIATED	1129.4	
NET LOAD		368.3
STORED	368.3	
SUBLIMED	0.0	
ADVECTED	0.0	
TPS NET		368.3

HEAT RATES
BTU/SQ.FT-SEC

CONVECTED	4.0	
RADIATED	3.8	
NET LOAD		0.2
STORED	0.2	
SUBLIMED	0.0	
ADVECTED	0.0	
TPS NET		0.2

SURFACE RECESSION
DISTANCE 0.00000 IN. RECESSION RATE 0.00000 IN/SEC
TEMPERATURE DEG F

T(1)=1287.774	T(2)=1277.886	T(3)=1179.176	T(4)=1071.059	T(5)= 950.515
T(6)= 818.517	T(7)= 672.034	T(8)= 511.087	T(9)= 329.583	T(10)= 116.426
T(11)= 115.991	T(12)= 104.472			

Table 6.2 (Continued)

ORIGINAL PAGE IS
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```
TIME =    700.00000     TIME STEP =      0.98474     NO. OF STEPS =       396

INTEGRATED HEAT                                  HEAT RATES
BTU/SQ.FT                                        BTU/SQ.FT-SEC

CONVECTED       1959.9                           CONVECTED       5.7
RADIATED        1532.6                           RADIATED        4.9
NET LOAD                  427.3                  NET LOAD                0.8
STORED           427.3                           STORED          0.8
SUBLIMED           0.0                           SUBLIMED        0.0
ADVECTED           0.0                           ADVECTED        0.0
TPS NET                   427.3                  TPS NET                 0.8

SURFACE RECESSION
DISTANCE     0.00000 IN.                         RECESSION RATE     0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)=1407.930      T(  2)=1384.297      T(  3)=1256.196      T(  4)=1123.893      T(  5)= 985.418
T(  6)= 841.158      T(  7)= 687.121      T(  8)= 521.981      T(  9)= 338.205      T( 10)= 123.225
T( 11)= 122.360      T( 12)= 108.277


TIME =    800.00000     TIME STEP =      0.84961     NO. OF STEPS =       481

INTEGRATED HEAT                                  HEAT RATES
BTU/SQ.FT                                        BTU/SQ.FT-SEC

CONVECTED       2752.0                           CONVECTED      11.7
RADIATED        2188.2                           RADIATED        9.6
NET LOAD                  563.8                  NET LOAD                2.1
STORED           563.8                           STORED          2.1
SUBLIMED           0.0                           SUBLIMED        0.0
ADVECTED           0.0                           ADVECTED        0.0
TPS NET                   563.8                  TPS NET                 2.1

SURFACE RECESSION
DISTANCE     0.00000 IN.                         RECESSION RATE     0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)=1750.231      T(  2)=1700.599      T(  3)=1535.362      T(  4)=1366.276      T(  5)=1191.687
T(  6)=1009.413      T(  7)= 818.077      T(  8)= 614.490      T(  9)= 392.530      T( 10)= 130.807
T( 11)= 129.737      T( 12)= 112.903
```

Table 6.2 (Continued)

ORIGINAL PAGE IS
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```
TIME =   900.00000     TIME STEP =      0.65125     NO. OF STEPS =       600

INTEGRATED HEAT                               HEAT RATES
BTU/SQ.FT                                     BTU/SQ.FT-SEC

CONVECTED        4264.8                       CONVECTED      16.5
RADIATED         3543.0                       RADIATED       15.6
NET LOAD                      721.8           NET LOAD                      0.9
STORED            721.8                       STORED          0.9
SUBLIMED            0.0                       SUBLIMED        0.0
ADVECTED            0.0                       ADVECTED        0.0
TPS NET                       721.8           TPS NET                       0.9

SURFACE RECESSION
DISTANCE     0.00000 IN.                      RECESSION RATE     0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)=2031.192     T(  2)=2003.605     T(  3)=1865.158     T(  4)=1711.928     T(  5)=1541.245
T(  6)=1347.765     T(  7)=1123.810     T(  8)= 858.972     T(  9)= 543.878     T( 10)= 142.943
T( 11)= 141.158     T( 12)= 118.692


TIME =  1000.00000     TIME STEP =      0.52612     NO. OF STEPS =       741

INTEGRATED HEAT                               HEAT RATES
BTU/SQ.FT                                     BTU/SQ.FT-SEC

CONVECTED        5911.3                       CONVECTED      16.4
RADIATED         5118.6                       RADIATED       15.7
NET LOAD                      792.7           NET LOAD                      0.7
STORED            792.7                       STORED          0.7
SUBLIMED            0.0                       SUBLIMED        0.0
ADVECTED            0.0                       ADVECTED        0.0
TPS NET                       792.7           TPS NET                       0.7

SURFACE RECESSION
DISTANCE     0.00000 IN.                      RECESSION RATE     0.00000 IN/SEC
TEMPERATURE DEG F
T(  1)=2036.951     T(  2)=2013.915     T(  3)=1887.971     T(  4)=1748.456     T(  5)=1591.306
T(  6)=1409.575     T(  7)=1195.487     T(  8)= 933.759     T(  9)= 602.838     T( 10)= 160.256
T( 11)= 158.092     T( 12)= 126.829


TIME =  1100.00000     TIME STEP =      0.05627     NO. OF STEPS =       885
```

Table 6.2 (Continued)

INTEGRATED HEAT BTU/SQ.FT			HEAT RATES BTU/SQ.FT-SEC		
CONVECTED	7370.4		CONVECTED	11.6	
RADIATED	6561.9		RADIATED	12.0	
NET LOAD		808.5	NET LOAD		-0.4
STORED	808.5		STORED	-0.4	
SUBLIMED	0.0		SUBLIMED	0.0	
ADVECTED	0.0		ADVECTED	0.0	
TPS NET		808.5	TPS NET		-0.4

SURFACE RECESSION
DISTANCE 0.00000 IN. RECESSION RATE 0.00000 IN/SEC
TEMPERATURE DEG F

T(1)=1874.705	T(2)=1872.074	T(3)=1771.484	T(4)=1653.845	T(5)=1515.935
T(6)=1352.080	T(7)=1153.591	T(8)= 908.004	T(9)= 595.531	T(10)= 177.758
T(11)= 175.627	T(12)= 137.475			

TIME = 1200.00000 TIME STEP = 0.07275 NO. OF STEPS = 1010

INTEGRATED HEAT BTU/SQ.FT			HEAT RATES BTU/SQ.FT-SEC		
CONVECTED	8295.0		CONVECTED	6.8	
RADIATED	7521.9		RADIATED	7.4	
NET LOAD		773.1	NET LOAD		-0.6
STORED	773.1		STORED	-0.6	
SUBLIMED	0.0		SUBLIMED	0.0	
ADVECTED	0.0		ADVECTED	0.0	
TPS NET		773.1	TPS NET		-0.6

SURFACE RECESSION
DISTANCE 0.00000 IN. RECESSION RATE 0.00000 IN/SEC
TEMPERATURE DEG F

T(1)=1606.336	T(2)=1610.530	T(3)=1528.443	T(4)=1429.194	T(5)=1311.007
T(6)=1168.583	T(7)= 997.009	T(8)= 787.067	T(9)= 527.224	T(10)= 191.614
T(11)= 189.900	T(12)= 149.606			

TIME = 1300.00000 TIME STEP = 0.00439 NO. OF STEPS = 1112

INTEGRATED HEAT BTU/SQ.FT			HEAT RATES BTU/SQ.FT-SEC		
CONVECTED	8785.6		CONVECTED	3.3	
RADIATED	8071.3		RADIATED	3.9	
NET LOAD		714.3	NET LOAD		-0.6
STORED	714.3		STORED	-0.6	
SUBLIMED	0.0		SUBLIMED	0.0	
ADVECTED	0.0		ADVECTED	0.0	
TPS NET		714.3	TPS NET		-0.6

Table 6.2 (Continued)

SURFACE RECESSION
DISTANCE 0.00000 IN. RECESSION RATE 0.00000 IN/SEC
TEMPERATURE DEG F

T(1)=1300.551	T(2)=1308.961	T(3)=1249.432	T(4)=1173.469	T(5)=1079.632
T(6)= 964.443	T(7)= 824.781	T(8)= 655.586	T(9)= 452.626	T(10)= 200.894 *
T(11)= 199.625	T(12)= 161.701			

TIME = 1400.00000 TIME STEP = 0.10059 NO. OF STEPS = 1194

INTEGRATED HEAT BTU/SQ.FT			HEAT RATES BTU/SQ.FT-SEC		
CONVECTED	8986.6		CONVECTED	0.9	
RADIATED	8343.8		RADIATED	1.7	
NET LOAD		642.8	NET LOAD		-0.8
STORED	642.8		STORED	-0.8	
SUBLIMED	0.0		SUBLIMED	0.0	
ADVECTED	0.0		ADVECTED	0.0	
TPS NET		642.8	TPS NET		-0.8

SURFACE RECESSION
DISTANCE 0.00000 IN. RECESSION RATE 0.00000 IN/SEC
TEMPERATURE DEG F

T(1)= 974.126	T(2)= 990.248	T(3)= 961.280	T(4)= 913.690	T(5)= 847.822
T(6)= 763.097	T(7)= 658.051	T(8)= 532.607	T(9)= 383.915	T(10)= 206.506 *
T(11)= 205.611 *	T(12)= 172.647			

INITIAL MASS = 32.26707 (LBM/SQ.FT.)

(H)

1

MAXIMUM TEMPERATURE OF AL.7075-T6 EXCEEDED AT NODE 10

MAXIMUM TEMPERATURE OF AL.7075-T6 EXCEEDED AT NODE 10

MAXIMUM TEMPERATURE OF AL.7075-T6 EXCEEDED AT NODE 11

MAXIMUM TEMPERATURE OF AL.7075-T6 EXCEEDED AT NODE 11

Table 6.2 (Concluded)

Section 7.0

CONCLUSIONS AND RECOMMENDATIONS

The EXITS code is an interactive one dimensional thermal analysis tool which has the capability to model a large variety of aerospace thermostructures with a minimum amount of effort on the part of the analyst. The code is used in conjunction with the LANMIN code which produces the environments and is linked to the EXITS code using an output file. The ability to store data describing the structure and the ability to access any number of environment files, allows the user to make parametric studies using various trajectories and TPS structure types, trading thermal performance and weight.

The present program's capabilities allow the analyst to investigate many of the current and envisioned TPS structures. However, limitations do exist as every candidate structure type could not be anticipated. In view of this, an effort was made to allow changes, modifications, and additions to be made with a minimum of reprogramming effort. Additional capability can be added to give the user a more versatile tool by incorporating the following recommendations:

1. Add the capability to include additional types of boundary conditions on the backwall. Presently an adiabatic boundary is assumed. Known temperature and known heat flux should be added.

2. Logic should be added to automatically change a slab structure type to a thin type if the computed time step is too small. Presently, the user must make this change.

3. Add logic that would allow heat flux on the surface to be computed given the temperature history of a thermocouple placed within the structure.

4. Include a TPS sizing routine to automatically optimize the structure given temperature, weight and cost constraints.

5. Add additional routines for computing equivalent thermal conductance, capacitance, and weight for additional structure types e. g. hot section stringer-panel etc.

6. Add logic which will allow all ablation material to be removed. Presently the surface node must remain in the ablation material.

Consequently, a small amount of ablator material must remain on the substructure.

Additional studies are recommended to lend confidence to the accuracy of the effective thermal conductance calculations of the various structure types. Comparison with experimental or test data would be quite useful in determining the dependence of the conductance as a function of temperature level, temperature difference, joint or contact conductance and material properties.

Section 8.0

REFERENCES

1. Schneider, P. J. Conduction Heat Transfer, Addison,Wesley Publishing Company, Inc. , Reading, Massachusetts, 1955.

2. Landau, H. G. ''Heat Conduction in a Melting Solid'', Quart. Appl. Math., Vol. 8, No. 1, Jan. 1950, pp 81-94.

3. Love T. J. Radiative Heat Transfer, Merrill Publishing Co., Columbus, Ohio, 1968.

APPENDIX
(EXITS Listing)

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```
      PROGRAM MAIN
C                        EXITS CODE
C          EXPLICIT INTERACTIVE THERMAL STRUCTUI.ES CODE
C
C                     REMTECH INC.    1983
C                                               BY  J. POND
C                                                   C. SCHMITZ
C                                               PH. 205-536-8581
C
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6,NMB5=40,NMB6=10,NMB10=100)
C     NMB1  - MAX NUMBER BODY POINTS
C     NMB2  - MAX NUMBER LAYERS/BODY POINT
C     NMB3  - MAX NUMBER MATERIALS/LAYER
C     NMB4  - MAX NUMBER DIMENSIONS/LAYER
C     NMB5  - MAX NUMBER CONDUCTORS/NODES
C     NMB6  - MAX NUMBER MATERIALS USED
C     NMB7  - LARGEST MATERIAL NUMBER
C     NMB8  - MAX NUMBER MATERIAL PROPERTY TABLES STORED
C             ((4*NMB6)+1)
C     NMB9  - SIZE OF MONOVARIATE MATERIAL PROPERTY TABLES ARRAY
C             ((MAX   TABLE ENTRIES)*2+1)
C     NMB10 - MAX NUMBER TIMES FOR MINIVER ENVIRONMENT TABLE
C     NMB11 - SIZE OF BIVARIATE MATERIAL PROPERTY TABLE ARRAY(2ND DIM)
C             (MAX NUMBER OF TEMPERATURES)
C     NMB12 - SIZE OF BIVARIATE MATERIAL PROPERTY TABLE ARRAY(3RD DIM)
C             ((MAX NUMBER OF PRESSURES)+1)
C
      COMMON/ENVIR/TM1(NMB10),HC1(NMB10),HAW1(NMB10),PRES1(NMB10)
      COMMON/GAP/T1,T2,TH1,TH2,TH3,TH,P,H,M1,M2,M3,TOL,BET,SIG,XM,
     $ CAP1,CAP2,XK
      COMMON/INIT/TSTART,TSTOP,TIMPT,DTIM,NBP,NEXT,METRIC,
     $ METRIK,METRIX,NSTP,IPFLAG,TINI(NMB1),SINKT(NMB1),XFIJ(NMB1),
     $ MBP(NMB1),IIN,IIN2
      COMMON/TAX/ TK(NMB2),XX(NMB5)
      COMMON/TIME/NNDS,CONV,CRAD,STAB,ISBFG,NCDS
      COMMON/ARA/T(NMB5),TO(NMB5),C(NMB5),CD(NMB5),ICD(NMB5),L(NMB5,2)
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $ NS(NMB1)
      COMMON /NODES/NN,I,TT,TINIT,TSINK,FIJ,TMPMAX(NMB6)
      COMMON/CTMP/TAW,DTSM
      COMMON/CAC/NEXFG,NIT,XMAS
      COMMON/PICT/NNIS(NMB1,NMB2)
      COMMON/SUBLM/TSUB,XL,XLP,EXCHT,NAB,ISTAR,NDIV,IAB,EXCHSV,QADV,
     $ QADVS,TMSV,IDROP
      COMMON/TITLE/CHAR2,CHAR1,FNAM1,FNAM3
      COMMON/PRESS/PRES
      COMMON/SAVE/XEND1,XEND2,XTST1,XTST2,XLTS,XMIN
      DIMENSION TTT(NMB5),ZXX(NMB5),FLGG(NMB5,NMB3,2)
      CHARACTER*13 CHAR1(NMB6)
      CHARACTER*20 FNAM1,FNAM3
      CHARACTER*10 CHAR2(NMB6)
      INTEGER      FLG(NMB5)
      IIN=5
      IIN2=5
      CPW=.24
```

```
      SIG=.1714E-8/3600.0
      TT=1000.0
C  DETERMINE INITIAL CONDITIONS AND STRUCTURE FOR ALL BODY POINTS
      CALL INPGEO
      WRITE(9,720)TSTART,TSTOP,TIMPT
      WRITE(9,722)DTIM,STAB,TOL,BET
      WRITE(9,723)NBP,NEXT,NSTP,IPFLAG
      DO 8000 I=1,NBP
      IAB=0
      NDIV=4
      ISTAR=0
      TINIT=TINI(I)
      TSINK=SINKT(I)
      FIJ=XFIJ(I)
C  FIND PROPERTIES OF MATERIALS
      CALL DATA1
C  FIND MINIVER ENVIRONMENT FOR BODY POINT
      CALL DATA2(MBP(I))
      NN=NS(I)
      XX(1)=0.0
      XMAS=0.0
C  DETERMINE NODAL NETWORK
      CALL NODE
      MP=1
C  DRAW PICTURE (INCLUDING NODES) FOR OUTPUT FILE
      CALL PICTUR(9,I)
      ISBFG=0
      DO 436 IK=1,NN
      IF(LS(I,IK).EQ.6)ISBFG=1
  436 CONTINUE
      TIM=TSTART
      DT=0.0
      NCTRL=0
      NIT=0
      NPR=0
      NPFG=1
      ISV=1
      DTSM=0.0
      NEXFG=0
      DO 140 K=1,NNDS
      C(K)=0.0
      FLG(K)=(1H )
  140 CONTINUE
      DO 141 K=1,NCDS
      CD(K)=0.0
  141 CONTINUE
      WRITE(9,749)
      QCONV=0.0
      QRAD=0.0
      QNET=0.0
      QSTOR=0.0
      QSUB=0.0
      EXCHSV=0.0
      EXCHT=0.0
      QTOT=0.0
```

```
      QADV=0.0
      QADVS=0.0
      TMSV=0.0
      QCOR=0.0
      QRAR=0.0
      QNER=0.0
      QSTR=0.0
      QSUR=0.0
      QTOR=0.0
      RECR=0.0
      QADR=0.0
      QAD=0.0
C
C       START TIME LOOP
C
 1000 CONTINUE
      IF(NPFG.NE.1)GO TO 501
      XXSV=XX(1)
      TMPSV=TIM
      WRITE(9,750)TIM,DTSM,NIT
      WRITE(9,600)
  600 FORMAT(/,1X,'INTEGRATED HEAT',34X,'HEAT RATES')
      IF(METRIK.EQ.0)WRITE(9,601)
      IF(METRIK.EQ.1)WRITE(9,602)
  601 FORMAT(1X,'BTU/SQ.FT',40X,'BTU/SQ.FT-SEC',/)
  602 FORMAT(1X,'JOULES/SQ.M',38X,'WATTS/SQ.M',/)
      IF(METRIK.EQ.0)WRITE(9,603)QCONV,QCOR,QRAD,QRAR,QNET,QNER,
     $ QSTOR,QSTR,QSUB,QSUR,QAD,QADR,QTOT,QTOR
      Z1=QCONV*11355.9
      Z2=QCOR*11355.9
      Z3=QRAD*11355.9
      Z4=QRAR*11355.9
      Z5=QNET*11355.9
      Z6=QNER*11355.9
      Z7=QSTOR*11355.9
      Z8=QSTR*11355.9
      Z9=QSUB*11355.9
      Z10=QSUR*11355.9
      Z11=QAD*11355.9
      Z12=QADR*11355.9
      Z13=QTOT*11355.9
      Z14=QTOR*11355.9
      IF(METRIK.EQ.1)WRITE(9,603)Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8,Z9,
     $ Z10,Z11,Z12,Z13,Z14
  603 FORMAT(1X,'CONVECTED',T16,F10.1,T51,'CONVECTED',T61,F10.1,/,
     $ ' RADIATED',T16,F10.1,T51,'RADIATED',T61,F10.1,/,
     $ ' NET LOAD',T26,F10.1,T51,'NET LOAD',T71,F10.1,/,
     $ ' STORED',T16,F10.1,T51,'STORED',T61,F10.1,/,
     $ ' SUBLIMED',T16,F10.1,T51,'SUBLIMED',T61,F10.1,/,
     $ ' ADVECTED',T16,F10.1,T51,'ADVECTED',T61,F10.1,/,
     $ ' TPS NET',T26,F10.1,T51,'TPS NET',T71,F10.1,/)
      ZZ1=XX(1)*12.
      ZZ2=RECR*12.
      IF(METRIK.EQ.0)WRITE(9,604)ZZ1,ZZ2
  604 FORMAT(1X,'SURFACE RECESSION',/,' DISTANCE ',F11.5,
```

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```
     $ ' IN.',T51,'RECESSION RATE ',F11.5,' IN/SEC')
      ZZ1=XX(1)*12.0*2.54
      ZZ2=RECR*12.0*2.54
      IF(METRIK.EQ.1)WRITE(9,605)ZZ1,ZZ2
  605 FORMAT(1X,'SURFACE RECESSION',/,' DISTANCE ',F11.5,
     $ ' CM.',T51,'RECESSION RATE ',F11.5,' CM/SEC')
      DO 2000 INC3=1,NCDS
      N1=L(INC3,1)
      N2=L(INC3,2)
      IF(METRIK.EQ.0)TTT(N1)=T(N1)-459.6
      IF(METRIK.EQ.0)TTT(N2)=T(N2)-459.6
      IF(METRIK.EQ.1)TTT(N1)=T(N1)/1.8
      IF(METRIK.EQ.1)TTT(N2)=T(N2)/1.8
      IF(LS(I,ICD(INC3)).EQ.7)GO TO 2000
      IF(MATS(I,ICD(INC3),1).EQ.0)GO TO 11
C  FLAGS FOR MAXIMIM TEMPERATURE OF MATERIALS
      IF(T(N1).GT.TMPMAX(MATS(I,ICD(INC3),1)))FLGG(N1,1,1)=1
      IF(T(N1).GT.TMPMAX(MATS(I,ICD(INC3),1)))FLG(N1)=1H*
   11 IF(MATS(I,ICD(INC3),3).EQ.0)GO TO 12
      IF(T(N1).GT.TMPMAX(MATS(I,ICD(INC3),3)))FLGG(N1,3,1)=1
      IF(T(N1).GT.TMPMAX(MATS(I,ICD(INC3),3)))FLG(N1)=1H*
   12 IF(MATS(I,ICD(INC3),2).EQ.0)GO TO 13
      IF(T(N2).GT.TMPMAX(MATS(I,ICD(INC3),2)))FLGG(N2,2,1)=1
      IF(T(N2).GT.TMPMAX(MATS(I,ICD(INC3),2)))FLG(N2)=1H*
   13 IF(MATS(I,ICD(INC3),3).EQ.0)GO TO 14
      IF(T(N2).GT.TMPMAX(MATS(I,ICD(INC3),3)))FLGG(N2,3,2)=1
      IF(T(N2).GT.TMPMAX(MATS(I,ICD(INC3),3)))FLG(N2)=1H*
   14 CONTINUE
 2000 CONTINUE
      IF(METRIK.EQ.0)WRITE(9,714)
      IF(METRIK.EQ.1)WRITE(9,715)
  714 FORMAT(1X,'TEMPERATURE DEG F')
  715 FORMAT(1X,'TEMPERATURE DEG K')
      WRITE(9,711)(JJ,TTT(JJ),FLG(JJ),JJ=1,NNDS)
      IF(LS(I,1).NE.7)GO TO 499
      DO 2020 IR1=1,NNDS
      IF(METRIK.EQ.0)ZXX(IR1)=XX(IR1)*12.0
      IF(METRIK.EQ.1)ZXX(IR1)=XX(IR1)*12.0*2.54
 2020 CONTINUE
      IF(METRIK.EQ.0)WRITE(9,716)
      IF(METRIK.EQ.1)WRITE(9,717)
  716 FORMAT(1X,'NODE POSITION INCHES')
  717 FORMAT(1X,'NODE POSITION CM')
      WRITE(9,726)(JJ,ZXX(JJ),JJ=1,NNDS)
  499 CONTINUE
      IF(IPFLAG.EQ.1)GO TO 500
      DO 2021 IR1=1,NCDS
      IF(METRIK.EQ.0)ZXX(IR1)=CD(IR1)
      IF(METRIK.EQ.1)ZXX(IR1)=CD(IR1)*1899.0
 2021 CONTINUE
      IF(METRIK.EQ.0)WRITE(9,718)
      IF(METRIK.EQ.1)WRITE(9,719)
  718 FORMAT(1X,'CONDUCTORS BTU/SEC-DEG F')
  719 FORMAT(1X,'CONDUCTORS WATTS/DEG K')
      WRITE(9,713)(JJ,ZXX(JJ),JJ=1,NCDS)
```

```
      DO 2022 IR1=1,NNDS
      IF(METRIK.EQ.0)ZXX(IR1)=C(IR1)
      IF(METRIK.EQ.1)ZXX(IR1)=C(IR1)*1899.0
 2022 CONTINUE
      IF(METRIK.EQ.0)WRITE(9,727)
      IF(METRIK.EQ.1)WRITE(9,728)
 727  FORMAT(1X,'CAPACITORS BTU/DEG F')
 728  FORMAT(1X,'CAPACITORS JOULES/DEG K')
      WRITE(9,712)(JJ,ZXX(JJ),JJ=1,NNDS)
 500  CONTINUE
      NPR=NPR+1
      NPFG=0
 501  CONTINUE
      MAT=MATS(I,1,1)
      CALL HEATN(TIM,HC,HAW,PRES,ISV)
      CALL PROP(TO(1),PRES,MAT,RO,CP,XK,EP)
      CRAD=SIG*EP*FIJ*(TO(1)**2+TSINK**2)*(TO(1)+TSINK)
      IF(LS(I,1).NE.7)GO TO 502
C  IF ABLATOR SUBLIMER THEN DETERMINE TEMPERATURE OF SUBLIMATION AND
C  HEAT OF SUBLIMATION
      CALL SUBPR(PRES,1,TSUB)
      CALL SUBPR(PRES,2,XL)
      IF(TIM.LE.0.0)XLP=XL
 502  CONTINUE
      TAW=HAW/CPW
      CONV=CPW*HC
      IF(NEXT*(NIT/NEXT).EQ.NIT)NEXFG=1
      IF(NEXFG.NE.1)GO TO 466
C  FIND CAPACITOR AND CONDUCTOR VALUES
      CALL COMPCC
 466  CONTINUE
C  DETERMINE TIME STEP
      CALL TMSTEP(DTSM,I)
      TMPT1=TIM-TSTART
      TTEMP=TMPT1+DTSM
      PTIM=FLOAT(NPR)*TIMPT
      IF(TTEMP.LT.PTIM)GO TO 365
      DTSM=PTIM-TMPT1
      NEXFG=1
      NPFG=1
 365  CONTINUE
C  COMPUTE TEMPERATURES
      CALL COMTMP
      JJ=ICD(1)
      JN=LS(I,JJ)
      IF(JN.NE.7)GO TO 366
      TMSV=TIM
C  FIND RECESSION DISTANCE
      CALL ABSUB(1)
      IF(IDROP.EQ.0)GO TO 3659
      DO 3658 JIL=1,NMB5
 3658 FLG(JIL)=0.0
 3659 CONTINUE
      NEXFG=1
 366  CONTINUE
```

```
C -----------------------------------------------------------------------
C                                                    INTEGRATE HEAT LOADS
      QQ=0.0
      QAD=QAD+QADV
      QCONV=QCONV+DTSM*(TAW-TO(1))*CONV
      QRAD=QRAD+DTSM*(TO(1)-TSINK)*CRAD
      QCOR=(TAW-TO(1))*CONV
      QRAR=(TO(1)-TSINK)*CRAD
      QNER=QCOR-QRAR
      DO 492 JJ=1,NNDS
      QQ=QQ+(T(JJ)-TO(JJ))*C(JJ)
      TO(JJ)=T(JJ)
  492 CONTINUE
      QNET=QCONV-QRAD
      QSTOR=QSTOR+QQ
      QSUB=QSUB+EXCHT-QADV
      QTOT=QSTOR+QSUB+QAD
C -----------------------------------------------------------------------
C
C  TIME STEP
      TIM=TIM+DTSM
C -----------------------------------------------------------------------
C                                                        FIND HEAT RATES
      QADR=QADV/DTSM
      QSTR=QQ/DTSM
      QSUR=EXCHT/DTSM-QADR
      QTOR=QSTR+QSUR+QADR
      RECR=(XX(1)-XXSV)/(TIM-TMPSV)
C -----------------------------------------------------------------------
      EXCHSV=EXCHT
      NIT=NIT+1
      IF(NIT.GE.NSTP)GO TO 8000
      IF(TIM.LE.TSTOP) GO TO 1000
      IF(METRIK.EQ.1)XMAS2=XMAS*4.8824
      IF(METRIK.EQ.0)WRITE(9,752)XMAS
      IF(METRIK.EQ.1)WRITE(9,753)XMAS2
      WRITE(9,760)
 760  FORMAT('1')
      DO 3000 NDS1=1,NCDS
      ND1=L(NDS1,1)
      ND2=L(NDS1,2)
      IF(MATS(I,ICD(NDS1),1).EQ.0)GO TO 770
      IF(FLGG(ND1,1,1).EQ.1)WRITE(9,761)CHAR2(MATS(I,ICD(NDS1),1)),ND1
 770  IF(MATS(I,ICD(NDS1),3).EQ.0)GO TO 771
      IF(FLGG(ND1,3,1).EQ.1)WRITE(9,761)CHAR2(MATS(I,ICD(NDS1),3)),ND1
 771  IF(MATS(I,ICD(NDS1),2).EQ.0)GO TO 772
      IF(FLGG(ND2,2,1).EQ.1)WRITE(9,761)CHAR2(MATS(I,ICD(NDS1),2)),ND2
 772  IF(MATS(I,ICD(NDS1),3).EQ.0)GO TO 773
      IF(FLGG(ND2,3,2).EQ.1)WRITE(9,761)CHAR2(MATS(I,ICD(NDS1),3)),ND2
 761  FORMAT(/,1X,'MAXIMUM TEMPERATURE OF ',A10,' EXCEEDED AT NODE ',
     $ I3)
 773  CONTINUE
3000  CONTINUE
8000  CONTINUE
 711  FORMAT((5(3H T(, I3, 2H)=,F8.3,2X,A1,4X,:)))
```

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726  FORMAT((5(4H XX(,I3, 2H)=,F8.3,6X,:)))
712  FORMAT((5(3H C(, I3, 2H)=, E10.3,:, 5X)))
713  FORMAT((5(4H CD(,I3, 2H)=, E10.3,:, 4X)))
749  FORMAT(1H1)
750  FORMAT(///,1H ,7HTIME = ,F12.5,5X,12HTIME STEP = ,F12.5,5X,
    $       15HNO. OF STEPS = ,I10)
752  FORMAT(///,' INITIAL MASS = ',F11.5,3X,'(LBM/SQ.FT.)',///)
753  FORMAT(///,' INITIAL MASS = ',F11.5,3X,'(KGM/SQ.M.)',///)
720  FORMAT(1H1,5X,'TSTART = ',F12.3,5X,'TSTOP = ',F12.3,5X,
    $       'TIMPT = ',F12.3)
722  FORMAT(1H ,5X,'DTIM   = ',F12.3,5X,'STAB  = ',F12.3,5X,
    $       'TOL   = ',F12.3,5X,'BET    = ',F12.3)
723  FORMAT(1H ,5X,'NBP    = ',3X,I5,9X,'NEXT  = ',3X,I5,9X,
    $       'NSTP  = ',I8,9X,'IPFLAG = ',I8,/)
     WRITE(IIN2,724)
724  FORMAT(//,15X,'- - - EXECUTION  COMPLETE - - -')
     WRITE(IIN2,725)FNAM1
725  FORMAT(/,1X,'OUTPUT FILENAME = ',A20,/)
     CLOSE(UNIT=7,STATUS='KEEP')
     CLOSE(UNIT=9,STATUS='KEEP')
     CALL EXIT
     END
```

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```
      SUBROUTINE ABSUB(II)
C  SUBROUTINE TO COMPUTE RECESSION RATE OF ABLATOR AND ALSO
C  THE HEAT REQUIRED TO CAUSE THE MELT LINE TO RECEDE.
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6,NMB5=40,NMB6=10)
      COMMON/INIT/TSTART,TSTOP,TIMPT,DTIM,NBP,NEXT,METRIC,
     $ METRIK,METRIX,NSTP,IPFLAG,TINI(NMB1),SINKT(NMB1),XFIJ(NMB1),
     $ MBP(NMB1),IIN,IIN2
      COMMON/SUBLM/TSUB,XL,XLP,EXCHT,NAB,ISTAR,NDIV,IAB,EXCHSV,QADV,
     $ QADVS,TMSV,IDROP
      COMMON/TIME/NNDS,CONV,CRAD,STAB,ISBFG,NCDS
      COMMON/ARA/T(NMB5),TO(NMB5),C(NMB5),CD(NMB5),ICD(NMB5),L(NMB5,2)
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $ NS(NMB1)
      COMMON/TAX/TK(NMB2),XX(NMB5)
      COMMON/NODES/NN,I,TT,TINIT,TSINK,FIJ,TMPMAX(NMB6)
      COMMON/PICT/NNIS(NMB1,NMB2)
      COMMON/PRESS/PRES
      COMMON/SAVE/XEND1,XEND2,XTST1,XTST2,XLTS,XMIN
      COMMON/TITLE/CHAR2,CHAR1,FNAM1,FNAM3
      CHARACTER*10 CHAR2(NMB6)
      CHARACTER*13 CHAR1(NMB6)
      CHARACTER*20 FNAM1,FNAM3
      DIMENSION ZXX(NMB5)
      IF(NAB.EQ.0) GO TO 1000
      JJ=ICD(II)
      IIP1=II+1
      JJP1=ICD(IIP1)
      DIV=FLOAT(NDIV)
      JN=LS(I,JJ)
      N1=L(II,1)
      N2=L(II,2)
      N3=L(IIP1,2)
      MA=MATS(I,JJ,1)
C  COMPUTE RECESSION DISTANCE
      QADVS=QADV
      CALL PROP(TT,PRES,MA,RO,CP,XK,EP)
      DS=EXCHT/(XLP*RO)
      EXCHSV=EXCHT
      IDROP=0
      IF(ISTAR.NE.0)GO TO 555
      ISTAR=1
C  COMPUTE NODE BOUNDARIES
      XEND1=(XX(N2)+XX(N1))/2.0
      XEND2=(XX(N3)+XX(N2))/2.0
      XMIN=XEND1/DIV
 555  CONTINUE
C  MOVE NODE LOCATIONS
      XX(N1)=XX(N1)+DS
      XX(N2)=XX(N2)+DS/3.0
      XP(I,JJ,1)=XP(I,JJ,1)-DS
      XTST1=XEND1-XX(N1)
      XTST2=2.0*DS/3.0
      XLTS=XX(N2)-XX(N1)
      IF(XLTS.GT.XMIN)GO TO 560
      XTST2=XEND2-XEND1
```

```
      IDROP=1
 560  CONTINUE
      XEND1=XEND1+XTST2
C  COMPUTE EFFECTIVE HEAT OF ABLATION
      QMEL=RO*(XLP*XTST1+XL*XTST2+CP*XTST2*(TSUB-TO(N2)))
      XLP=QMEL/(RO*(XTST1+XTST2))
C  COMPUTE ADVECTED HEAT
      QADV=RO*CP*XTST2*(TSUB-TO(N2))
      IF(IDROP.EQ.1)GO TO 520
      GO TO 1000
 520  CONTINUE
C  RENUMBER NODES IF NODE DROPPED
      NNDS=NNDS-1
      NCDS=NCDS-1
      DO 521 KK=1,NNDS
      IF(KK.EQ.1) GO TO 521
      KKP1=KK+1
      XX(KK)=XX(KKP1)
      C(KK)=C(KKP1)
      TO(KK)=TO(KKP1)
      T(KK)=T(KKP1)
  521 CONTINUE
      XEND2=(XX(N3)+XX(N2))/2.0
      DO 522 KK=1,NCDS
      IF(KK.EQ.1) GO TO 522
      KKP1=KK+1
      CD(KK)=CD(KKP1)
      ICD(KK)=ICD(KKP1)
  522 CONTINUE
      WRITE(9,700)
      NNIS(I,JJ)=NNIS(I,JJ)-1
C  PRINT PICTURE OF NEW CONFIGURATION
      CALL PICTUR(9,I)
      IF(NCDS.EQ.1)GO TO 2000
      IF(JJ.NE.JJP1)GO TO 2000
 1000 CONTINUE
  700 FORMAT(1H ,//,' NODE DROPPED FROM SUBLIMER-ABLATOR MODEL',//)
      GO TO 3000
 2000 CONTINUE
      WRITE(I!N2,2003)FNAM1
 2003 FORMAT(//,1X,'RUN STOPPED DUE TO INSUFFICIENT ABLATIVE MATERIAL',
     $ ' LEFT',//,1X,'OUTPUT FILE  =   ',A20)
      STOP
 3000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE COMPCC
C  SUBROUTINE TO COMPUTE VALUES OF THERMAL CAPACITORS AND CONDUCTORS
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6,NMB5=40,NMB6=10)
      COMMON/CAC/NEXFG,NIT,XMAS
      COMMON/GAP/T1,T2,TH1,TH2,TH3,TH,P,H,M1,M2,M3,TOL,BET,SIG,XM,
     $      CAP1,CAP2,XK
      COMMON/TAX/ TK(NMB2),XX(NMB5)
      COMMON/TIME/NNDS,CONV,CRAD,STAB,ISBFG,NCDS
      COMMON/ARA/T(NMB5),TO(NMB5),C(NMB5),CD(NMB5),ICD(NMB5),L(NMB5,2)
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $      NS(NMB1)
      COMMON /NODES/NN,I,TT,TINIT,TSINK,FIJ,TMPMAX(NMB6)
      COMMON/PRESS/PRES
      NEXFG=0
      DO 176 K=1,NNDS
      C(K)=0.0
 176  CONTINUE
      DO 177 K=1,NCDS
      CD(K)=0.0
 177  CONTINUE
      DO 226 II=1,NCDS
      JJ=ICD(II)
      JN=LS(I,JJ)
      N1=L(II,1)
      N2=L(II,2)
      MA=MATS(I,JJ,1)
      IF(JN.EQ.6) GO TO 227
      IF(JN.EQ.1) GO TO 225
      IF(JN.EQ.7) GO TO 225
      GO TO 227
 225  CONTINUE
C  COMPUTE CAPACITANCE AND CONDUCTANCE OF SLAB AND ABLATOR NODES
      TT=(TO(N1)+TO(N2))/2.0
      CALL PROP(TT,PRES,MA,RO,CP,XK,EP)
      DI=XX(N2)-XX(N1)
      CTM=DI*RO*CP/2.0
      CMAS=DI*RO
      IF(NIT.NE.0)CMAS=0.0
      XMAS=XMAS+CMAS
      C(N1)=C(N1)+CTM
      C(N2)=C(N2)+CTM
      CD(II)=XK/DI
      GO TO 226
 227  CONTINUE
C  LOAD GEOMETRY AND MATERIAL NUMBERS INTO COMMON - GAP
      CALL LOAD(I,JJ,N1,N2)
      ITST=JN-1
C  COMPUTE EQUIVALENT CONDUCTIVITY AND CAPACITANCE OF ALL
C  OTHER STRUCTURES
      GO TO (1,2,3,4,5),ITST
 1    CONTINUE
      CALL RGAP
      GO TO 7
 2    CONTINUE
      CALL HONEY
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      GO TO 7
 3    CONTINUE
      CALL CORG
      GO TO 7
 4    CONTINUE
      CALL STAND
      GO TO 7
 5    CONTINUE
      CALL THINS
 7    CONTINUE
      C(N1)=C(N1)+CAP1
      C(N2)=C(N2)+CAP2
      IF(NIT.NE.0)XM=0.0
C   SUM MASS OF STRUCTURE
      XMAS=XMAS+XM
      CD(II)=XK
 226  CONTINUE
      RETURN
      END
```

```
      SUBROUTINE COMTMP
C  THIS SUBROUTINE COMPUTES THE TEMPERATURES
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6,NMB5=40,NMB6=10)
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $ NS(NMB1)
      COMMON /NODES/NN,I,TT,TINIT,TSINK,FIJ,TMPMAX(NMB6)
      COMMON/CTMP/TAW,DTSM
      COMMON/TIME/NNDS,CONV,CRAD,STAB,ISBFG,NCDS
      COMMON/ARA/T(NMB5),TO(NMB5),C(NMB5),CD(NMB5),ICD(NMB5),L(NMB5,2)
      COMMON/SUBLM/TSUB,XL,XLP,EXCHT,NAB,ISTAR,NDIV,IAB,EXCHSV,QADV,
     $ QADVS,TMSV,IDROP
      NAB=0
      DO 456 JJ=1,NNDS
C  CHECK TO SEE IF THIN SKIN SECTIONS EXIST ANYWHERE IN STRUCTURE
      IF(ISBFG.EQ.0)GO TO 615
C -------------------------------------------------------------------
C  THIN SKIN LAYER
      JM2=JJ-2
      JP2=JJ+2
      JP1=JJ+1
      JM1=JJ-1
      IF(JJ.EQ.NNDS)GO TO 599
      IF(CD(JJ).GT.1.0E9)GO TO 601
      IF(JJ.EQ.1)GO TO 615
 599  CONTINUE
      IF(CD(JM1).GT.1.0E9)GO TO 610
      GO TO 615
 601  CONTINUE
C  NODE ABOVE THIN SECTION
      CC=C(JJ)/(C(JP1)+C(JJ))
      IF(JJ.EQ.1)GO TO 602
      IT=NNDS-1
      A1=TO(JM1)*CD(JM1)
      A3=TO(JJ)*CD(JM1)
      IF(JJ.EQ.IT)GO TO 603
      A2=TO(JP2)*CD(JP1)
      A4=TO(JJ)*CD(JP1)
      GO TO 461
 603  CONTINUE
      A2=0.0
      A4=0.0
      GO TO 461
 602  CONTINUE
C  THIN SKIN ON SURFACE, NODE ABOVE THIN SECTION
      A1=TAW*CONV+TSINK*CRAD
      A3=TO(JJ)*CONV+TO(JJ)*CRAD
      IF(NNDS.EQ.2)GO TO 604
      A4=TO(JJ)*CD(JP1)
      A2=TO(JP2)*CD(JP1)
      GO TO 461
 604  CONTINUE
      A4=0.0
      A2=0.0
      GO TO 461
 610  CONTINUE
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C  NODE BELOW THIN SECTION
      CC=C(JJ)/(C(JM1)+C(JJ))
      IF(JJ.EQ.2)GO TO 612
      A1=TO(JM2)*CD(JM2)
      A3=TO(JJ)*CD(JM2)
      IF(JJ.EQ.NNDS)GO TO 613
      A2=TO(JP1)*CD(JJ)
      A4=TO(JJ)*CD(JJ)
      GO TO 461
 613  CONTINUE
      A2=0.0
      A4=0.0
      GO TO 461
 612  CONTINUE
C  THIN SKIN ON SURFACE, NODE BELOW THIN SECTION
      A1=TAW*CONV+TSINK*CRAD
      A3=TO(JJ)*CONV+TO(JJ)*CRAD
      IF(NNDS.EQ.2)GO TO 614
      A2=TO(JP1)*CD(JJ)
      A4=TO(JJ)*CD(JJ)
      GO TO 461
 614  CONTINUE
      A4=0.0
      A2=0.0
 461  CONTINUE
      F1=(A1+A2)*CC
      F2=(A3+A4)*CC
      GO TO 460
C ---------------------------------------------------------------
 615  CONTINUE
C  STANDARD HEAT BALANCE
      IF(JJ.NE.1)GO TO 457
C  SURFACE NODE
      F1=TSINK*CRAD+TAW*CONV+TO(2)*CD(1)
      F2=TO(1)*(CRAD+CONV+CD(1))
      GO TO 460
 457  CONTINUE
      IF(JJ.NE.NNDS)GO TO 458
C  LAST NODE
      JM1=JJ-1
      F1=TO(JM1)*CD(JM1)
      F2=TO(NNDS)*CD(JM1)
      GO TO 460
 458  CONTINUE
C  GENERAL NODE
      JM1=JJ-1
      JP1=JJ+1
      F1=TO(JM1)*CD(JM1)+TO(JP1)*CD(JJ)
      F2=TO(JJ)*(CD(JM1)+CD(JJ))
 460  CONTINUE
C  COMPUTE TEMPERATURES
      T(JJ)=TO(JJ)+(F1-F2)*(DTSM/C(JJ))
C  CHECK TO SEE IF SUBLIMER TEMPERATURE HAS BEEN EXCEEDED
      IF(JJ.NE.1) GO TO 456
      IF(LS(I,1).NE.7) GO TO 456
```

```
      EXCHT=0.0
      IF(T(JJ).LE.TSUB) GO TO 456
      NAB=1
      EXCHT=(T(JJ)-TSUB)*C(JJ)
      T(JJ)=TSUB
  456 CONTINUE
      RETURN
      END
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```
      SUBROUTINE CORG
C  SUBROUTINE COMPUTES EFFECTIVE THERMAL CONDUCTIVITY,CAPACITY,
C  AND MASS OF A CORRUGATED STRUCTURE
      COMMON/GAP/T1,T2,TH1,TH2,TH3,TH,P,H,M1,M2,M3,TOL,BET,SIG,
     $ XM,CAP1,CAP2,XK
      COMMON/FACT/XX(10,2),YY(10,2)
      COMMON/SF/AR(10),EPP(10),F(10,10),ASF(10,10)
      COMMON/PRESS/PRES
      T30=(T1+T2)/2.0
      T3=T30
      CONK=1.0E8
      AKC=CONK*2.0*TH3
      P2=P/2.0
      TT1=T1
      TT2=T2
      TT3=(T1+T2)/2.0
      B1=P2/2.0
      B2=TH/2.0
      B3=SQRT(B1**2+B2**2)
      A1=P2
      A3=2.0*B3
      VOL=TH1+TH2+(2.0*B3)*TH3/P2
C  START ITERATION FOR MIDPOINT TEMPERATURES
      DO 100 I=1,100
      CALL PROP(TT1,PRES,M1,RHO1,CP1,XK1,EPP(1))
      CALL PROP(TT2,PRES,M2,RHO2,CP2,XK2,EPP(2))
      CALL PROP(TT3,PRES,M3,RHO3,CP3,XK3,EPP(3))
      IF(I.NE.1)GO TO 101
C  SET COORDINATES FOR ENDS OF EACH OF THREE SURFACES FOR
C  RADIATION ENCLOSURE
      DO 102 II=1,3
      EPP(2)=1.0
      DO 103 JJ=1,2
      XT=0.0
      YT=TH
      IF(II.EQ.2.AND.JJ.EQ.1)YT=0.0
      IF(II.EQ.3.AND.JJ.EQ.1)YT=0.0
      IF(II.EQ.1.AND.JJ.EQ.2)XT=P2
      IF(II.EQ.3.AND.JJ.EQ.2)XT=P2
      XX(II,JJ)=XT
      YY(II,JJ)=YT
 103  CONTINUE
 102  CONTINUE
C  FIND GEOMETRIC VIEW FACTORS AND RADIANT INTERCHANGE FACTORS
      CALL VFAC(3)
      CALL SRIPF(3)
      A2F23=ASF(1,3)
      A1F13=ASF(1,3)
 101  CONTINUE
      AK1=XK1*TH1/B1
      AK2=XK2*TH2/B1
      AK3=XK3*TH3/B3
C  COMPUTE EQUIVALENT CONDUCTOR
      C1=AK1*AKC*AK3/(AK1*AKC+AK1*AK3+AKC*AK3)
      C2=AK2*AKC*AK3/(AK2*AKC+AK2*AK3+AKC*AK3)
```

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```
C  COMPUTE RADIATION CONDUCTOR
      C4=A1F13*SIG*(T1**2+T3**2)*(T1+T3)
      C5=A2F23*SIG*(T2**2+T3**2)*(T2+T3)
C  ITERATE ON T3
      T3N=(T1*C1+T2*C2+T1*C4+T2*C5)/(C1+C2+C4+C5)
      T3=BET*T3N+(1.0-BET)*T3
      TEST=ABS(T3-T30)/T3
      IF(TEST.LT.TOL)GO TO 200
      TT3=T3
      T30=T3
 100  CONTINUE
      GO TO 300
 200  CONTINUE
      T12=ABS(T1-T2)
      T13=ABS(T1-T3)
C  COMPUTE TOTAL HEAT TRANSFER
      Q=T13*(C1+C4)/P2
      XK=Q/T12
C  COMPUTE EQUIVALENT CONDUCTIVITY
      XM=TH1*RHO1+TH2*RHO2+(2.0*B3)*TH3*RHO3/P2
C  COMPUTE CAPACITORS
      CAP1=(VOL/2.0)*RHO1*CP1
      CAP2=(VOL/2.0)*RHO2*CP2
 300  CONTINUE
      RETURN
      END
```

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```
      SUBROUTINE DATA1
C  SUBROUTINE TO READ AND STORE THERMOPHYSICAL PROPERTY DATA
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6)
      PARAMETER (NMB8=41,NMB9=41,NMB6=10,NMB11=20,NMB12=8)
      COMMON/DTA/CC(NMB8,NMB9),BSV(NMB8,NMB11,NMB12)
      COMMON/CSUB/CCS(2,NMB9)
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $      NS(NMB1)
      COMMON/TITLE/CHAR2,CHAR1,FNAM1,FNAM3
      COMMON /NODES/NN,I,TT,TINIT,TSINK,FIJ,TMPMAX(NMB6)
      COMMON/INIT/TSTART,TSTOP,TIMPT,DTIM,NBP,NEXT,METRIC,
     $ METRIK,METRIX,NSTP,IPFLAG,TINI(NMB1),SINKT(NMB1),XFIJ(NMB1),
     $ MBP(NMB1),IIN,IIN2
      CHARACTER*10 CHAR2(NMB6),TEST1
      CHARACTER*13 CHAR1(NMB6),TEST2
      CHARACTER*20 FNAM1,FNAM3
      DIMENSION MTST(NMB6),BB(6),ARD(8),ARDS(8)
      OPEN(UNIT=8,NAME='INP1.DAT',TYPE='OLD',RECORDSIZE=132)
      WRITE(9,703)
      DO 471 JJ=1,NMB6
      MTST(JJ)=0
 471  CONTINUE
      IC=0
      NLA=NS(I)
C  LOOP 1 TO NUMBER OF LAYERS
      DO 400 LT=1,NLA
C  LOOP 1 TO NUMBER OF MATERIALS PER LAYER(MAX)
      DO 500 IM=1,NMB3
      MA=MATS(I,LT,IM)
      IF(MA.EQ.0)GO TO 500
 100  CONTINUE
      READ(8,701)KD
 701  FORMAT(I3,2X,I5,4X,A10,1X,A13,E10.0)
 707  FORMAT(5X,I5,4X,A10,1X,A13)
      IF(KD.LT.0)GO TO 300
C  CHECK TO SEE IF MATERIAL NUMBER MATCHES
      IF(KD.NE.MA)GO TO 100
      BACKSPACE (UNIT=8)
      READ(8,701)KD,JD,TEST1,TEST2,TMPMXA
      DO 351 K5=1,NMB6
      KSV=K5
C  CHECK TO SEE IF MATERIAL HAS BEEN USED
      IF(MA.EQ.MTST(K5))GO TO 352
 351  CONTINUE
      IC=IC+1
      MTST(IC)=MA
C  RENUMBER MATERIAL INDENTIFIERS
      MATS(I,LT,IM)=IC
      TMPMAX(IC)=TMPMXA
      GO TO 353
 352  CONTINUE
      MATS(I,LT,IM)=KSV
      REWIND (UNIT=8)
      GO TO 500
 353  CONTINUE
```

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```
C  STORE TITLES
      CHAR2(IC)=TEST1
      CHAR1(IC)=TEST2
      DO 250 IB=1,4
      IF(IB.EQ.1)GO TO 251
C  READ TABLE TITLE FOR TABLE 2,3,AND 4
      READ(8,707)JD,TEST1,TEST2
 251  CONTINUE
C  STORE NUMBER OF ENTRIES
      IT=(IC-1)*4+IB
      CC(IT,1)=FLOAT(JD)
      DO 200 ITT=1,JD
      READ(8,702)(ARD(MR),MR=1,8)
      IF(ARD(1).LT.0)GO TO 600
      IF(ITT.GT.1)GO TO 210
C  STORE MAXIMUM TEMPERATURE FOR PRINTING IN DESIRED UNITS
      IF(METRIK.EQ.0)TEMMAX=TMPMAX(IC)-459.6
      IF(METRIK.EQ.1)TEMMAX=TMPMAX(IC)/1.8
      IF(IB.EQ.1.AND.METRIK.EQ.0)WRITE(9,800)TEST1,KD,TEMMAX,TEST2
 800  FORMAT(//,8X,A10,'  -  MAT NO. ',I2,//,' MAXIMUM TEMPERATURE',11X,
     $ F7.2,' DEG F',//,5X,'TEMP.',9X,A13,/,4X,'(DEG F)',6X,
     $ '(LBM/CU.FT)',/)
      IF(IB.EQ.1.AND.METRIK.EQ.1)WRITE(9,801)TEST1,KD,TEMMAX,TEST2
 801  FORMAT(//,8X,A10,'  -  MAT NO. ',I2,//,' MAXIMUM TEMPERATURE',11X,
     $ F7.2,' DEG K',//,5X,'TEMP.',9X,A13,/,4X,'(DEG K)',6X,
     $ '(KGM/CU.M.)',/)
      IF(IB.EQ.2.AND.METRIK.EQ.0)WRITE(9,802)TEST2
 802  FORMAT(//,5X,'TEMP.',7X,A13,/,4X,'(DEG F)',5X,'(BTU/LBM-DEG F)',/)
      IF(IB.EQ.2.AND.METRIK.EQ.1)WRITE(9,803)TEST2
 803  FORMAT(//,5X,'TEMP.',7X,A13,/,4X,'(DEG K)',4X,
     $ '(JOULES/KGM-DEG K)',/)
      IF(IB.EQ.3.AND.METRIK.EQ.0)WRITE(9,804)TEST2
 804  FORMAT(//,5X,'TEMP.',7X,A13,/,4X,'(DEG F)',4X,
     $ '(BTU/FT-S-DEG F)',/)
      IF(IB.EQ.3.AND.METRIK.EQ.1)WRITE(9,805)TEST2
 805  FORMAT(//,5X,'TEMP.',7X,A13,/,4X,'(DEG K)',4X,'(WATTS/M-DEG K)',/)
      IF(IB.EQ.4.AND.METRIK.EQ.0)WRITE(9,806)TEST2
 806  FORMAT(//,5X,'TEMP.',8X,A13,/,4X,'(DEG F)',4X,'(DIMENSIONLESS)',/)
      IF(IB.EQ.4.AND.METRIK.EQ.1)WRITE(9,807)TEST2
 807  FORMAT(//,5X,'TEMP.',8X,A13,/,4X,'(DEG K)',4X,'(DIMENSIONLESS)',/)
 210  CONTINUE
      A=ARD(1)
      B=ARD(2)
      IF(METRIK.EQ.0)AAA=A-459.6
      IF(METRIK.EQ.1)AAA=A/1.8
      BBB=B
      IF(METRIK.EQ.1.AND.IB.EQ.1)BBB=B*16.018067
      IF(METRIK.EQ.1.AND.IB.EQ.2)BBB=B*4187.6
      IF(METRIK.EQ.1.AND.IB.EQ.3)BBB=B*6228.343
      WRITE(9,705)AAA,BBB
 705  FORMAT(1X,E12.4,3X,E12.4)
      K1=ITT*2
      K2=K1+1
C  STORE INDEPENDENT AND DEPENDENT ARRAYS
      CC(IT,K1)=A
```

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      CC(IT,K2)=B
 200  CONTINUE
      GO TO 250
 600  CONTINUE
C BIVARIAT TABLE
      IARDS=IFIX(-ARD(1))
      IF(METRIK.EQ.1)GO TO 605
      WRITE(9,808)(ARD(MR),MR=2,IARDS+1)
 808  FORMAT(//,35X,'CONDUCTIVITY',/,33X,'(BTU/FT-S-DEG F)',
     $ //,5X,'TEMP.    PRESSURE (LB/SQ.FT)',/,4X,'(DEG F) ',
     $ 7(4X,F7.2,2X))
      GO TO 610
 605  CONTINUE
      DO 606 MR1=2,IARDS+1
 606  ARDS(MR1)=ARD(MR1)*47.88
      WRITE(9,809)(ARDS(MR),MR=2,IARDS+1)
 809  FORMAT(//,35X,'CONDUCTIVITY',/,33X,'(WATTS/M-DEG K)',
     $ //,5X,'TEMP.    PRESSURE (N/SQ.M)',/,4X,'(DEG K) ',
     $ 7(3X,F9.2,1X))
 610  CONTINUE
      WRITE(9,810)
 810  FORMAT(13X,'')
C  STORE NUMBER OF PRESSURES
      CC(IT,2)=ARD(1)
      NARD=-ARD(1)+2
C  STORE PRESSURES
      DO 601 IKS=3,NARD
      IM1=IKS-1
      CC(IT,IKS)=ARD(IM1)
 601  CONTINUE
      NSTR=NARD+1
      NSS=NARD-2
C  READ REST OF BIVARIAT TABLE
      DO 602 I6=1,JD
      READ(8,702)(ARD(MR),MR=1,IARDS+1)
      DO 620 MKR=1,IARDS+1
      IF(METRIK.EQ.0)ARDS(1)=ARD(1)-459.6
      IF(METRIK.EQ.1)ARDS(1)=ARD(1)/1.8
      ARDS(MKR)=ARD(MKR)
      IF(METRIK.EQ.1)ARDS(MKR)=ARD(MKR)*6231.1
 620  CONTINUE
      WRITE(9,811)(ARDS(MKR),MKR=1,IARDS+1)
 811  FORMAT(8(2X,E11.4))
C  SAVE TEMPERATURES
      CC(IT,NSTR)=ARD(1)
      NSTR=NSTR+1
      DO 603 I7=1,NSS
      I71=I7+1
C  SAVE DEPENDENT VARIABLE
      BSV(IT,I6,I7)=ARD(I71)
 603  CONTINUE
 602  CONTINUE
 250  CONTINUE
      READ(8,701,END=1000)KDS,JD,TEST1,TEST2,TMPMXA
      IF(KDS.NE.KD)GO TO 1000
```

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```
C  STORE TWO ABLATOR PROPERTIES
      DO 1100 IM2=1,2
      CCS(IM2,1)=FLOAT(JD)
      IF(IM2.EQ.1.AND.METRIK.EQ.0)WRITE(9,830)TEST2
 830  FORMAT(//,4X,'PRESSURE',5X,A13,/,3X,'(LB/SQ.FT)',6X,
     $ '(DEG F)',/)
      IF(IM2.EQ.1.AND.METRIK.EQ.1)WRITE(9,831)TEST2
 831  FORMAT(//,4X,'PRESSURE',5X,A13,/,4X,'(N/SQ.M)',7X,
     $ '(DEG K)',/)
      IF(IM2.EQ.2.AND.METRIK.EQ.0)WRITE(9,832)TEST2
 832  FORMAT(//,4X,'PRESSURE',5X,A13,/,3X,'(LB/SQ.FT)',5X,
     $ '(BTU/LBM)',/)
      IF(IM2.EQ.2.AND.METRIK.EQ.1)WRITE(9,833)TEST2
 833  FORMAT(//,4X,'PRESSURE',5X,A13,/,4X,'(N/SQ.M)',5X,
     $ '(JOULES/KGM)',/)
      DO 1101 ITT=1,JD
      READ(8,702)A,B
      IF(METRIK.EQ.0)AA1=A
      IF(METRIK.EQ.1)AA1=A*47.88
      IF(IM2.EQ.1.AND.METRIK.EQ.0)BB1=B-459.6
      IF(IM2.EQ.1.AND.METRIK.EQ.1)BB1=B/1.8
      IF(IM2.EQ.2.AND.METRIK.EQ.0)BB1=B
      IF(IM2.EQ.2.AND.METRIK.EQ.1)BB1=B*2326.4
      WRITE(9,705)AA1,BB1
      K1=ITT*2
      K2=K1+1
      CCS(IM2,K1)=A
      CCS(IM2,K2)=B
1101  CONTINUE
      READ(8,701)KD,JD,TEST1,TEST2,TMPMXA
1100  CONTINUE
1000  CONTINUE
      REWIND (UNIT=8)
      GO TO 500
 300  CONTINUE
      WRITE(9,708)MA
 708  FORMAT(1H ,'MATERIAL NUMBER',3X,I5,3X,'CANNOT BE FOUND.')
      REWIND (UNIT=8)
      GO TO 500
 500  CONTINUE
 400  CONTINUE
      REWIND (UNIT=8)
 702  FORMAT(5X,8E10.0)
 703  FORMAT(1H1,10X,11HT A B L E S)
      CLOSE(UNIT=8,STATUS='KEEP')
      RETURN
      END
```

```
      SUBROUTINE DATA2(LBP)
C  SUBROUTINE TO READ AND STORE ENVIRONMENT FROM LANMIN FILE (UNIT 7)
      PARAMETER (NMB10=100,NMB1=20)
      COMMON/INIT/TSTART,TSTOP,TIMPT,DTIM,NBP,NEXT,METRIC,
     $ METRIK,METRIX,NSTP,IPFLAG,TINI(NMB1),SINKT(NMB1),XFIJ(NMB1),
     $ MBP(NMB1),IIN,IIN2
      COMMON/ENVIR/TM1(NMB10),HC1(NMB10),HAW1(NMB10),PRES1(NMB10)
      CHARACTER*72 DESCRP
      WRITE(9,666)
 666  FORMAT(1H1)
 100  CONTINUE
      IC=0
      READ(7,700,END=1000)DESCRP,IBP
 700  FORMAT(A72,I5)
C  CHECK FOR CORRECT BODY POINT NUMBER
      IF(IBP.EQ.LBP)GO TO 900
 50   CONTINUE
      READ(7,701)D1,D2,D3,D4
 701  FORMAT(2X,F6.1,39X,E10.3,2X,E10.3,36X,E10.3)
      IF(D1.LT.0.0)GO TO 100
      GO TO 50
 900  CONTINUE
      IF(METRIC.EQ.0)WRITE(9,750)IBP,DESCRP
 750  FORMAT(1H ,'BODY POINT NUMBER = ',I5,5X,A72,//,10X,'TIME',9X,
     $'FILM COEF.',5X,'REC ENTHALPY',6X,'PRESSURE',/,10X,'(SEC)',
     $6X,'(LBM/SQ.FT-SEC)',4X,'(BTU/LBM)',6X,'(LBF/SQ.FT)',/)
      IF(METRIC.EQ.1)WRITE(9,850)IBP,DESCRP
 850  FORMAT(1H ,'BODY POINT NUMBER = ',I5,5X,A72,//,10X,'TIME',9X,
     $'FILM COEF.',5X,'REC ENTHALPY',6X,'PRESSURE',/,10X,'(SEC)',
     $7X,'(KGM/SQM-SEC)',4X,'(JOULES/KGM)',5X,'(N/SQ.M)',/)
 901  CONTINUE
      IC=IC+1
C  READ LANMIN DATA
      READ(7,701)TM1(IC),HC1(IC),HAW1(IC),PRES1(IC)
      IF(TM1(IC).GE.0.0)WRITE(9,751)TM1(IC),HC1(IC),
     $HAW1(IC),PRES1(IC)
      IF(METRIC.EQ.0)GO TO 500
      HC1(IC)=HC1(IC)/4.8824
      HAW1(IC)=HAW1(IC)/2.32456E3
      PRES1(IC)=PRES1(IC)/47.88
 500  CONTINUE
 751  FORMAT(1H ,4(6X,E10.4))
      IF(TM1(IC).GE.0.0)GO TO 901
      REWIND (UNIT=7)
      GO TO 1001
 1000 CONTINUE
      WRITE(9,752)LBP
 752  FORMAT(1H ,'CANNOT FIND BODY POINT ',I5)
 1001 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DIST(I1,J1,I2,J2,D)
C   SUBROUTINE TO COMPUTE DISTANCE BETWEEN TWO POINTS GIVEN
C   COORDINATES XX(I,J),YY(I,J)
C      I = SURFACE NO
C      J = 1 OR 2 ; END POINTS
C
C
      COMMON/FACT/XX(10,2),YY(10,2)
      X1=XX(I1,J1)
      Y1=YY(I1,J1)
      X2=XX(I2,J2)
      Y2=YY(I2,J2)
      D=SQRT((X1-X2)**2+(Y1-Y2)**2)
      RETURN
      END
```

```
      SUBROUTINE HEATN(TIME,HC,HAW,PRES,ISV)
C  THIS ROUTINE DETERMINES FILM COEFFICIENT,ADIABATIC WALL ENTHALPY,
C  AND PRESSURE AS A FUNCTION OF TIME
      PARAMETER (NMB10=100)
      COMMON/ENVIR/TM1(NMB10),HC1(NMB10),HAW1(NMB10),PRES1(NMB10)
      I1=ISV
 100  CONTINUE
      I2=I1+1
      IF(TM1(I2).GT.TIME)GO TO 50
      I1=I1+1
      GO TO 100
 50   CONTINUE
      ISV=I1
      DT=TM1(I2)-TM1(I1)
      DINC=(TIME-TM1(I1))/DT
      HC=HC1(I1)+(HC1(I2)-HC1(I1))*DINC
      HAW=HAW1(I1)+(HAW1(I2)-HAW1(I1))*DINC
      PRES=PRES1(I1)+(PRES1(I2)-PRES1(I1))*DINC
      RETURN
      END
```

```
      SUBROUTINE HONEY
C  SUBROUTINE TO COMPUTE EQUIVALENT THERMAL CONDUCTIVITY,CAPACITY,
C  AND MASS OF HEXAGONAL HONEYCOMB STRUCTURE
      COMMON/GAP/T1,T2,TH1,TH2,TH3,TH,P,H,M1,M2,M3,TOL,BET,SIG,
     $ XM,CAP1,CAP2,XK
      COMMON/PRESS/PRES
      F12=.1
      F13=.9
C  SET GEOMETRIC PARAMETERS
      D=H*3.0/(2.0*SQRT(3.0))
      CPFT2=2.0*SQRT(3.0)/(H**2*3.0)
      WPFT2=CPFT2*3.0
      DWAL=D*2.0/3.0
      VOL=(TH1+TH2)+WPFT2*(TH*TH3*DWAL)
      A1=(D/3.0*H/2.0)/2.0
      A2=A1
      A3=DWAL*TH
      T3=(T1+T2)/2.0
      CON=1.0E8
      CONK=CON*DWAL*TH3
      T30=T3
      DO 100 I=1,100
      CALL PROP(T1,PRES,M1,RHO1,CP1,XK1,EP1)
      CALL PROP(T2,PRES,M2,RHO2,CP2,XK2,EP2)
      CALL PROP(T3,PRES,M3,RHO3,CP3,XK3,EP3)
C  COMPUTE RADIANT INTERCHANGE FACTORS
      F1=(1.0/A1)*(1.0/EP1-1.0)
      F2=(1.0/A3)*(1.0/EP3-1.0)
      F3=1.0/(A1*F13)
      A1F13=1.0/(F1+F2+F3)
      F2=(1.0/A2)*(1.0/EP2-1.0)
      F3=1.0/(A1*F12)
      A1F12=1.0/(F1+F2+F3)
C  SET CONDUCTORS
      C1=4.0*TH1*5.0*DWAL*XK1/H
      C2=C1*XK2/XK1
      C3=2.0*XK3*TH3*DWAL/TH
      XC1=C1*CONK*C3/(C1*CONK+C1*C3+CONK*C3)
      XC2=C2*CONK*C3/(C2*CONK+C2*C3+CONK*C3)
      R1=2.0*A1F13*SIG*(T1**2+T3**2)*(T1+T3)
      R2=2.0*A1F13*SIG*(T2**2+T3**2)*(T1+T3)
      R3=2.0*A1F12*SIG*(T1**2+T2**2)*(T1+T2)
C  ITERATE ON CELL WALL TEMPERATURE - T3
      T3N=(T1*(XC1+R1)+T2*(XC2+R2))/(XC1+R1+XC2+R2)
      T3=(1.0-BET)*T3+BET*T3N
      TEST=ABS(T3-T30)/T3
      IF(TEST.LT.TOL)GO TO 200
      T30=T3
      TT3=T3
  100 CONTINUE
      GO TO 300
  200 CONTINUE
      T12=ABS(T1-T2)
      T13=ABS(T1-T3)
C  COMPUTE TOTAL HEAT TRANSFER
```

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      Q=(T12*R3+T13*(R2+XC2))*WPFT2
C   COMPUTE CONDUCTIVITY,MASS,AND CAPACITANCE
      XK=Q/T12
      XM=TH1*RHO1+TH2*RHO2+RHO3*WPFT2*TH*TH3*DWAL
      CAP1=(VOL/2.0)*RHO1*CP1
      CAP2=(VOL/2.0)*RHO2*CP2
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INPGEO
C  SUBROUTINE FOR INTERACTIVE INPUT OF DATA FOR EXITS CODE
C    INCLUDES INTERACTIVE INPUT OF STRUCTURES
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6,NMB6=10,NMB7=100)
      COMMON/GAP/T1,T2,TH1,TH2,TH3,TH,P,H,M1,M2,M3,TOL,BET,SIG,XM,
     $       CAP1,CAP2,XK
      COMMON/INIT/TSTART,TSTOP,TIMPT,DTIM,NBP,NEXT,METRIC,
     $ METRIK,METRIX,NSTP,IPFLAG,TINI(NMB1),SINKT(NMB1),XFIJ(NMB1),
     $ MBP(NMB1),IIN,IIN2
      COMMON/TIME/NNDS,CONV,CRAD,STAB,ISBFG,NCDS
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $       NS(NMB1)
      COMMON/PICT/NNIS(NMB1,NMB2)
      COMMON/TITL2/ CHAR3
      COMMON/TITLE/CHAR2,CHAR1,FNAM1,FNAM3
      CHARACTER*20 CHAR(7),FNAM1,FNAM2,FNAM3
      CHARACTER*10 CHAR3(NMB7),CHAR2(NMB6)
      CHARACTER*13 CHAR1(NMB6)
      INTEGER ANS1,ANS2,ANS4,ANS5,ANS6,ANS7,ANS8,ANS9,ANS10,STRFLG
      DATA CHAR/
     1             'SLAB                ',
     2             'RADIATION GAP       ',
     3             'HONEY COMB          ',
     4             'CORRUGATED          ',
     5             'Z STANDOFF          ',
     6             'THIN SKIN           ',
     7             'ABLATOR SUBLIMER    '/
    9 WRITE(IIN2,10)
   10 FORMAT(1H ,'WHAT IS THE MINIVER INPUT DATA FILE NAME ?')
      READ(IIN,20,END=1234)FNAM2
   20 FORMAT(A20)
      OPEN(UNIT=7,NAME=FNAM2,TYPE='OLD',ERR=9,RECORDSIZE=80)
   22 WRITE(IIN2,23)
   23 FORMAT(1H ,'WHAT IS THE STRUCTURE FILE NAME ?')
      READ(IIN,20,END=1234)FNAM3
      WRITE(IIN2,30)
   30 FORMAT(1H ,'WHAT IS THE NAME OF THE OUTPUT FILE ?')
      READ(IIN,20,END=1234)FNAM1
      OPEN(UNIT=9,NAME=FNAM1,TYPE='NEW',ERR=22,RECORDSIZE=132)
C ---------------------------------------------------------------------
C                                DEFAULT VALUES FOR CONTROL PARAMETERS
      DTIM=10.0
      STAB=2.0
      TOL=.001
      BET=0.5
      NEXT=20
      NSTP=3000
      IPFLAG=1
      METRIC=0
      METRIK=0
      METRIX=0
C ---------------------------------------------------------------------
C  SET INITIAL,FINAL,AND DELTA PRINT TIMES
   40 WRITE(IIN2,50)
   50 FORMAT(1H ,'WHAT IS THE INITIAL TIME(SEC) ?')
```

```
      READ(IIN,*,ERR=40,END=1234)TSTART
60    WRITE(IIN2,70)
70    FORMAT(1H ,'WHAT IS THE FINAL TIME(SEC) ?')
      READ(IIN,*,ERR=60,END=1234)TSTOP
80    WRITE(IIN2,90)
90    FORMAT(1H ,'WHAT IS THE TIME(SEC) BETWEEN PRINTOUTS ?')
      READ(IIN,*,ERR=80,END=1234)TIMPT
100   WRITE(IIN2,110)
110   FORMAT(1H ,'DO YOU WANT TO RESET CONTROL PARAMETERS ?')
      READ(IIN,120,ERR=100,END=1234)ANS1
120   FORMAT(A1)
130   FORMAT(E20.10)
140   FORMAT(I10)
      IF(ANS1.NE.1HY)GO TO 190
C -------------------------------------------------------------------
C                                              RESET CONTROL PARAMETERS
160   WRITE(IIN2,170)DTIM
170   FORMAT(1H ,'RESOLUTION: DEFAULT = ',F4.1,'  NEW VALUE = ')
      READ(IIN,130,ERR=160,END=1234)A1
      IF(A1.GT..00001)DTIM=A1
180   WRITE(IIN2,190)STAB
190   FORMAT(1H ,'STABILITY: DEFAULT = ',F3.1,'  NEW VALUE = ')
      READ(IIN,130,ERR=180,END=1234)A2
      IF(A2.GT..00001)STAB=A2
200   WRITE(IIN2,210)TOL
210   FORMAT(1H ,'ITERATION TOLERENCE: DEFAULT = ',F4.3,' NEW VALUE = ')
      READ(IIN,130,ERR=200,END=1234)A3
      IF(A3.GT..00001)TOL=A3
220   WRITE(IIN2,230)BET
230   FORMAT(1H ,'RELAXATION FACTOR: DEFAULT = ',F3.1,' NEW VALUE = ')
      READ(IIN,130,ERR=220,END=1234)A4
      IF(A4.GT..00001)BET=A4
240   WRITE(IIN2,250)NEXT
250   FORMAT(1H ,'NUMBER OF STEPS BETWEEN PARAMETER CALC.: DEFAULT = ',I2,
     $       ' NEW VALUE = ')
      READ(IIN,140,ERR=240,END=1234)K1
      IF(K1.GT.0)NEXT=K1
260   WRITE(IIN2,270)NSTP
270   FORMAT(1H ,'MAXIMUM NUMBER OF ITERATIONS: DEFAULT = ',I4,
     $       ' NEW VALUE = ')
      READ(IIN,140,ERR=260,END=1234)K2
      IF(K2.GT.0)NSTP=K2
      WRITE(IIN2,278)
278   FORMAT(/,
     $ 16X,'ENGLISH(DEFAULT)',5X,'METRIC',//,
     $ 1X,'TEMPERATURE',4X,'DEG F',16X,'DEG K',/,
     $ 1X,'LENGTH',9X,'INCHES',15X,'CM',/,
     $ 1X,'ENERGY',9X,'BTU',18X,'JOULES',/,
     $ 1X,'MASS',11X,'LBM',18X,'KGM',///)
275   WRITE(IIN2,277)FNAM2
277   FORMAT(1H ,'ARE THE UNITS OF ',A20,' IN ENGLISH OR METRIC ?')
      READ(IIN,120,ERR=275,END=1234)ANS8
      IF(ANS8.EQ.1HM)METRIC=1
281   WRITE(IIN2,282)
282   FORMAT(1H ,'DO YOU WANT OUTPUT DATA IN ENGLISH OR METRIC ?')
```

```
      READ(IIN,120,ERR=281,END=1234)ANS8
      IF(ANS8.EQ.1HM)METRIK=1
  283 WRITE(IIN2,284)
  284 FORMAT(1H ,'DO YOU WANT INPUT DATA IN ENGLISH OR METRIC ?')
      READ(IIN,120,ERR=283,END=1234)ANS8
      IF(ANS8.EQ.1HM)METRIX=1
  280 WRITE(IIN2,290)
  290 FORMAT(1H ,'DO YOU WANT ADDITIONAL PRINTOUT ?')
      READ(IIN,120,ERR=280,END=1234)ANS7
      IF(ANS7.EQ.1HY)IPFLAG=0
C                                   END OF CONTROL PARAMETER LOOP
C ------------------------------------------------------------------
  150 CONTINUE
  300 CONTINUE
  310 WRITE(IIN2,320)
  320 FORMAT(1H ,'WHAT IS THE TOTAL NUMBER OF BODY POINTS ?')
      READ(IIN,*,ERR=310,END=1234)NBP
      IF(NBP.GT.NMB1)WRITE(IIN2,330)
  330 FORMAT(1X,'ERROR---NUMBER OF BODY PTS. EXCEEDS DIMENSIONING')
      IF(NBP.GT.NMB1)GO TO 300
      DO 1000 IB=1,NBP
C  DEFINE STRUCTURE AND INITIAL CONDITIONS FOR THE CURRENT BODY POINT
  340 CONTINUE
      IF(IB.EQ.1)WRITE(IIN2,350)
      IF(IB.NE.1)WRITE(IIN2,360)
  360 FORMAT(1H ,'WHAT IS THE NEXT BODY PT. NUMBER ?')
  350 FORMAT(1H ,'WHAT IS THE BODY POINT NUMBER ?')
      READ(IIN,*,ERR=340,END=1234)MBP(IB)
      IF(IB.EQ.1)GO TO 370
C  IF STRUCTURE SAME AS FOR PREVIOUS B.P. USE SAME DATA
  390 WRITE(IIN2,380)MBP(IB),MBP(IB-1)
  380 FORMAT(1H ,'DOES BODY PT. ',I5,' HAVE THE SAME DATA',
     $       ' REQUIREMENTS AS BODY PT. ',I5,' ?')
      READ(IIN,120,ERR=390,END=1234)ANS5
      IF(ANS5.EQ.1HY)GO TO 890
  370 CONTINUE
C  RESET TIME OR CONTROL PARAMETERS ?
C       YES(Y)     =  RESET TIMING PARAMETERS
C       TIME(T)    =  RESET TIMING PARAMETERS
C       CONTROL(C) =  RESET CONTROL PARAMETERS
  410 WRITE(IIN2,420)
  420 FORMAT(1H ,'DO YOU WANT TO RESET THE TIME OR CONTROL ',
     $'PARAMETERS ?')
      READ(IIN,120,ERR=410,END=1234)ANS6
      IF(ANS6.EQ.1HY)GO TO 40
      IF(ANS6.EQ.1HT)GO TO 40
      IF(ANS6.EQ.1HC)GO TO 160
C  DEFINE INITIAL TEMPERATURE DATA FOR BODY POINT
  430 WRITE(IIN2,400)MBP(IB)
  400 FORMAT(1H ,'WHAT IS THE INITIAL TEMPERATURE OF BODY PT. ',
     $I5,' ?')
      READ(IIN,*,ERR=430,END=1234)TINI(IB)
      IF(METRIX.EQ.0)TINI(IB)=TINI(IB)+459.6
      IF(METRIX.EQ.1)TINI(IB)=TINI(IB)*1.8
  440 WRITE(IIN2,450)MBP(IB)
```

```
 450  FORMAT(1H ,'WHAT IS THE SINK TEMPERATURE OF BODY PT. ',
     $I5,' ?')
      READ(IIN,*,ERR=440,END=1234)SINKT(IB)
      IF(METRIX.EQ.0)SINKT(IB)=SINKT(IB)+459.6
      IF(METRIX.EQ.1)SINKT(IB)=SINKT(IB)*1.8
 460  WRITE(IIN2,470)MBP(IB)
 470  FORMAT(1H ,'WHAT IS THE VIEW FACTOR FOR BODY PT. ',I5,' ?')
      READ(IIN,*,ERR=460,END=1234)XFIJ(IB)
      STRFLG=0
C  DEFINE STRUCTURE
 472  WRITE(IIN2,473)MBP(IB)
 473  FORMAT(1H ,'DOES THE STRUCTURE FOR BODY PT. ',I5,
     $ ' EXIST IN THE STRUCTURE FILE ?')
      READ(IIN,120,ERR=472,END=1234)ANS9
C  OBTAIN STRUCTURE DATA FROM STRUCTURE FILE
      IF(ANS9.EQ.1HY)CALL STRUCT(1,IB)
      IF(ANS9.EQ.1HY)GO TO 830
 474  WRITE(IIN2,475)MBP(IB)
 475  FORMAT(1H ,'DO YOU WANT TO ADD THE STRUCTURE FOR BODY PT. ',
     $ I5,' TO THE STRUCTURE FILE ?')
      READ(IIN,120,ERR=474,END=1234)ANS10
      IF(ANS10.EQ.1HY)STRFLG=1
 480  CONTINUE
C  DEFINE NUMBER OF LAYERS
 490  WRITE(IIN2,500)MBP(IB)
 500  FORMAT(1H ,'HOW MANY LAYERS AT BODY PT. ',I5,' ?')
      READ(IIN,*,ERR=490,END=1234)NS(IB)
      IF(NS(IB).GT.NMB2)WRITE(IIN2,510)
 510  FORMAT(1X,'ERROR---NUMBER OF LAYERS EXCEEDS ARRAY DIMENSIONING')
      IF(NS(IB).GT.NMB2)GO TO 480
C  LOOP 1 - NUMBER OF LAYERS
      DO 2000 KK=1,NS(IB)
C  DEFINE STRUCTURE TYPE AND DIMENSIONS FOR EACH LAYER
 520  WRITE(IIN2,530)
 530  FORMAT(////,'           STRUCTURE TYPE  - - -  NUMBER  ',//,
     $           '             SLAB                   1      ',/,
     $           '             RADIATION GAP          2      ',/,
     $           '             HONEYCOMB              3      ',/,
     $           '             CORRUGATED             4      ',/,
     $           '             Z STANDOFF             5      ',/,
     $           '             THIN SKIN              6      ',/,
     $           '             ABLATOR SUBLIMER       7      ',///)
 540  WRITE(IIN2,550)KK,MBP(IB)
 550  FORMAT(1H ,'WHAT IS THE STRUCTURE TYPE NUMBER ',
     $    'FOR LAYER ',I2,' OF BODY PT. ',I5,' ?')
      READ(IIN,*,ERR=540,END=1234)LS(IB,KK)
      GO TO(560,570,580,590,600,610,620),LS(IB,KK)
 560  WRITE(IIN2,630)KK,MBP(IB)
      READ(IIN,*,ERR=560,END=1234)MATS(IB,KK,1),XP(IB,KK,1)
      GO TO 640
 570  CONTINUE
      DO 3000 LLL=1,2
 650  WRITE(IIN2,660)LLL,KK,MBP(IB)
      READ(IIN,*,ERR=650,END=1234)MATS(IB,KK,LLL),XP(IB,KK,LLL)
3000  CONTINUE
```

```
 670  WRITE(IIN2,680)KK,MBP(IB)
 680  FORMAT(1H ,'WHAT IS THE STRUCTURE HEIGHT FOR LAYER ',
     $      I2,' OF BODY PT. ',I5,' ?')
      READ(IIN,*,ERR=670,END=1234)XP(IB,KK,4)
      GO TO 640
 580  CONTINUE
      DO 4000 LLL=1,3
 690  WRITE(IIN2,660)LLL,KK,MBP(IB)
      READ(IIN,*,ERR=690,END=1234)MATS(IB,KK,LLL),XP(IB,KK,LLL)
4000  CONTINUE
 700  WRITE(IIN2,710)KK,MBP(IB)
      READ(IIN,*,ERR=700,END=1234)XP(IB,KK,4),XP(IB,KK,6)
      GO TO 640
 590  CONTINUE
      DO 4500 LLL=1,3
 720  WRITE(IIN2,660)LLL,KK,MBP(IB)
      READ(IIN,*,ERR=720,END=1234)MATS(IB,KK,LLL),XP(IB,KK,LLL)
4500  CONTINUE
 730  WRITE(IIN2,740)KK,MBP(IB)
      READ(IIN,*,ERR=730,END=1234)XP(IB,KK,4),XP(IB,KK,5)
      GO TO 640
 600  CONTINUE
      DO 5000 LLL=1,3
 750  WRITE(IIN2,660)LLL,KK,MBP(IB)
      READ(IIN,*,ERR=750,END=1234)MATS(IB,KK,LLL),XP(IB,KK,LLL)
5000  CONTINUE
 760  WRITE(IIN2,770)KK,MBP(IB)
      READ(IIN,*,ERR=760,END=1234)(XP(IB,KK,LLL+3),LLL=1,3)
      GO TO 640
 610  CONTINUE
 780  WRITE(IIN2,630)KK,MBP(IB)
      READ(IIN,*,ERR=780,END=1234)MATS(IB,KK,1),XP(IB,KK,4)
      GO TO 640
 620  CONTINUE
 790  WRITE(IIN2,630)KK,MBP(IB)
      READ(IIN,*,ERR=790,END=1234)MATS(IB,KK,1),XP(IB,KK,1)
      GO TO 640
 630  FORMAT(1H ,'WHAT IS THE MAT. IDENTIFIER AND THE MAT.',
     $  ' THICKNESS',/,' FOR LAYER ',I2,' OF BODY PT. ',I5,' ?')
 660  FORMAT(' WHAT IS THE MAT. IDENTIFIER AND THICKNESS OF MAT. ',
     $         I2,/,' FOR LAYER ',I2,' OF BODY PT. ',I5,' ?')
 710  FORMAT(1H ,'WHAT IS THE STRUCTURE HEIGHT AND CELL DIMENSIONS',
     $       ' OF LAYER ',I2,' OF BODY PT. ',I5,' ?')
 740  FORMAT(1H ,'WHAT IS THE STRUCTURE HEIGHT AND PITCH FOR LAYER ',
     $      I2,' OF BODY PT. ',I5,' ?')
 770  FORMAT(1H ,'WHAT IS THE STRUCTURE HEIGHT,PITCH,AND FLANGE',
     $       ' WIDTH FOR LAYER ',I2,' OF BODY PT. ',I5,' ?')
 640  CONTINUE
 800  WRITE(IIN2,665)KK,MBP(IB)
 665  FORMAT(1H ,'ARE THERE ANY CORRECTIONS FOR LAYER ',
     $         I2,' OF BODY POINT ',I5,' ?')
      READ(IIN,810,ERR=800,END=1234)ANS2
 810  FORMAT(A1)
      IF(ANS2.EQ.1HY)GO TO 520
2000  CONTINUE                               /* CONTINUE WITH NEXT LAYER
```

```
  830 CONTINUE
      IF(IB.GT.1)GO TO 855
C
C OBTAIN MATERIAL NAMES TO MATCH MATERIAL NUMBERS(USED BY PICTURE)
      OPEN(UNIT=8,NAME='INP1.DAT',TYPE='OLD',RECORDSIZE=132)
 6000 CONTINUE
      READ(8,840)MNUMB
      IF(MNUMB.EQ.0)GO TO 6000
      IF(MNUMB.LT.0)GO TO 850
      BACKSPACE (UNIT=8)
      READ(8,840)MNUMB,CHAR3(MNUMB)
  840 FORMAT(I3,11X,A10)
      GO TO 6000
  850 CONTINUE
      REWIND (UNIT=8)
      CLOSE(UNIT=8,STATUS='KEEP')
C
C
      IF(ANS9.EQ.1HY)GO TO 911
  855 CONTINUE
      DO 910 INC1=1,NMB2
      DO 910 INC2=1,NMB4
      IF(METRIX.EQ.0)XP(IB,INC1,INC2)=XP(IB,INC1,INC2)/12.
      IF(METRIX.EQ.1)XP(IB,INC1,INC2)=XP(IB,INC1,INC2)/2.54/12.
  910 CONTINUE
  911 CONTINUE
C DISPLAY PICTURE OF COMPLETE STRUCTURE ON SCREEN
      CALL PICTUR(5,IB)
  860 WRITE(IIN2,870)MBP(IB)
  870 FORMAT(///,1H ,'ARE THERE ANY CORRECTIONS FOR BODY PT. ',I5,' ?')
      READ(IIN,810,ERR=860,END=1234)ANS4
      IF(ANS4.EQ.1HY)GO TO 370
C ADD STRUCTURE TO STRUCTURE FILE
      IF(STRFLG.EQ.1)CALL STRUCT(2,IB)
      GO TO 820
  890 CONTINUE
C IF STRUCTURE FOR BODY POINT MATCHES STRUCTURE FOR PREVIOUS
C BODY POINT THEN USE SAME STRUCTURE DATA
      TINI(IB)=TINI(IB-1)
      SINKT(IB)=SINKT(IB-1)
      XFIJ(IB)=XFIJ(IB-1)
      NS(IB)=NS(IB-1)
      DO 7000 KKKK=1,NS(IB-1)
      LS(IB,KKKK)=LS(IB-1,KKKK)
      DO 8000 LLLL=1,6
      XP(IB,KKKK,LLLL)=XP(IB-1,KKKK,LLLL)
 8000 CONTINUE
      DO 9000 MMMM=1,3
      MATS(IB,KKKK,MMMM)=MATS(IB-1,KKKK,MMMM)
 9000 CONTINUE
 7000 CONTINUE
      IF(ANS5.EQ.1HY)GO TO 911
      GO TO 830
  820 CONTINUE
 1000 CONTINUE                               /* CONTINUE WITH NEXT BODY POINT
```

```
      WRITE(I IN2,880)
  880 FORMAT(//,1X,'             MODEL COMPLETE - - - - - - GONE TO EXECUTE')
      RETURN
 1234 CONTINUE
      STOP
      END
```

```
      SUBROUTINE INTP(X,P,N,Y)
C
C  SUBROUTINE TO INTERPOLATE MONO AND BIVARIATE TABLES FOR PROPERTIES
      PARAMETER (NMB8=41,NMB9=41,NMB11=20,NMB12=8)
      COMMON/DTA/CC(NMB8,NMB9),BSV(NMB8,NMB11,NMB12)
C  CHECK TO SEE IF TABLE IS BIVARIATE
      IF(CC(N,2).LT.0.0)GO TO 2000
C  MONOVARIATE INTERPOLATION - DATA STORED IN CC(N,J)
      J=CC(N,1)
      J1=J*2
      XLST=CC(N,2)
      XHST=CC(N,J1)
      IF(X.EQ.XLST)GO TO 700
      IF(X.LT.XLST)GO TO 100
      IF(X.GT.XHST)GO TO 200
      JT=4
 500  CONTINUE
      IF(CC(N,JT)-X)300,600,400
 300  CONTINUE
      JT=JT+2
      GO TO 500
 400  CONTINUE
      N1=JT-2
      N2=N1+1
      N3=JT
      N4=N3+1
      GO TO 900
 600  CONTINUE
      NT=JT+1
      Y=CC(N,NT)
      GO TO 1000
 700  CONTINUE
      Y=CC(N,3)
      GO TO 1000
 100  CONTINUE
      N1=2
      N2=3
      N3=4
      N4=5
      GO TO 900
 200  CONTINUE
      N1=2*J-2
      N2=N1+1
      N3=2*J
      N4=N3+1
 900  CONTINUE
C  COMPUTE PROPERTY
      SL=(CC(N,N4)-CC(N,N2))/(CC(N,N3)-CC(N,N1))
      Y=CC(N,N2)+SL*(X-CC(N,N1))
 1000 CONTINUE
      GO TO 3000
 2000 CONTINUE
C  BIVARIATE TABLES
C    INDEPENDENT VARIABLES IN CC(N,J)
C    DEPENDENT VARIABLES IN BSV(N,JT,IL)
```

```
      N9=-CC(N,2)+2.0
      N8=4
  450 CONTINUE
      IF(CC(N,N8)-P)351,352,353
  351 CONTINUE
      IF(N8.GE.N9)GO TO 375
      N8=N8+1
      GO TO 450
  352 CONTINUE
      GO TO 375
  353 CONTINUE
      N7=N8-1
      GO TO 560
  375 CONTINUE
      N7=N8
      PFAC=0.0
      GO TO 561
  560 CONTINUE
C  FIND INCREMENT IN PRESSURE DIRECTION
      PFAC=(P-CC(N,N7))/(CC(N,N8)-CC(N,N7))
  561 CONTINUE
      L8=-CC(N,2)+4.0
      L9=-CC(N,2)+2.0+CC(N,1)
  550 CONTINUE
      IF(CC(N,L8)-X)751,752,753
  751 CONTINUE
      IF(L8.GE.L9)GO TO 775
      L8=L8+1
      GO TO 550
  752 CONTINUE
      GO TO 775
  753 CONTINUE
      L7=L8-1
      GO TO 760
  775 CONTINUE
      L7=L8
      TFAC=0.0
      GO TO 761
  760 CONTINUE
C  FIND INCREMENT IN TEMPERATURE DIRECTION
      TFAC=(X-CC(N,L7))/(CC(N,L8)-CC(N,L7))
  761 CONTINUE
      IR=N8-2
      IL=N7-2
      JT=L7-N9
      JB=L8-N9
      F1=BSV(N,JT,IL)+PFAC*(BSV(N,JT,IR)-BSV(N,JT,IL))
      F2=BSV(N,JB,IL)+PFAC*(BSV(N,JB,IR)-BSV(N,JB,IL))
C  FIND PROPERTY
      Y=F1+TFAC*(F2-F1)
 3000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE LOAD(MP,IS,IT1,IT2)
C  SUBROUTINE TO LOAD GEOMETRIC AND MATERIAL IDENTIFICATION
C   INTO COMMON GAP
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6,NMB5=40)
      COMMON/GAP/T1,T2,X(6),M(3),TOL,BET,SIG,XM,CAP1,CAP2,XK
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $      NS(NMB1)
      COMMON/ARA/T(NMB5),TO(NMB5),C(NMB5),CD(NMB5),ICD(NMB5),L(NMB5,2)
      DT=25.0
      T1=TO(IT1)+DT
      T2=TO(IT2)-DT
C  LOAD MATERIALS
      DO 100 I=1,3
      M(I)=MATS(MP,IS,I)
 100  CONTINUE
C  LOAD GEOMETRY
      DO 200 J=1,6
      X(J)=XP(MP,IS,J)
 200  CONTINUE
      RETURN
      END
```

```
      SUBROUTINE NODE                                        ORIGINAL PAGE IS
C  THIS SUBROUTINE SETS UP THE NODAL NETWORK                 OF POOR QUALITY
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6,NMB5=40,NMB6=10)
      COMMON /NODES/NN,I,TT,TINIT,TSINK,FIJ,TMPMAX(NMB6)
      COMMON/GAP/T1,T2,TH1,TH2,TH3,TH,P,H,M1,M2,M3,TOL,BET,SIG,XM,
     $        CAP1,CAP2,XK
      COMMON/INIT/TSTART,TSTOP,TIMPT,DTIM,NBP,NEXT,METRIC,
     $ METRIK,METRIX,NSTP,IPFLAG,TINI(NMB1),SINKT(NMB1),XFIJ(NMB1),
     $ MBP(NMB1),IIN,IIN2
      COMMON/TAX/ TK(NMB2),XX(NMB5)
      COMMON/TIME/NNDS,CONV,CRAD,STAB,ISBFG,NCDS
      COMMON/ARA/T(NMB5),TO(NMB5),C(NMB5),CD(NMB5),ICD(NMB5),L(NMB5,2)
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $        NS(NMB1)
      COMMON/PICT/NNIS(NMB1,NMB2)
      COMMON/TITLE/CHAR2,CHAR1,FNAM1,FNAM3
      COMMON/PRESS/PRES
      CHARACTER*4  UNIT1(2)
      CHARACTER*6  UNIT2(2)
      CHARACTER*13 CHAR1(NMB6)
      CHARACTER*10 CHAR2(NMB6)
      CHARACTER*20 CHAR(7),FNAM1,FNAM3
      DIMENSION XXX(NMB5)
      DATA UNIT1/' IN.',' CM.'/
      DATA UNIT2/' DEG F',' DEG K'/
      DATA CHAR/
     1             'SLAB                ',
     2             'RADIATION GAP       ',
     3             'HONEY COMB          ',
     4             'CORRUGATED          ',
     5             'Z STANDOFF          ',
     6             'THIN SKIN           ',
     7             'ABLATOR SUBLIMER    '/
      IC=0
      METRC=METRIK+1
      DO 7000 J=1,NN
      IST=LS(I,J)
      IF(IST.EQ.1) GO TO 140
      IF(IST.EQ.7) GO TO 140
      GO TO 120
  140 CONTINUE
C  DIVIDE SLAB OR ABLATOR INTO NX-1 LAYERS
      THKNS=XP(I,J,1)
      MA=MATS(I,J,1)
      CALL PROP(TT,PRES,MA,RO,CP,XK,EP)
      DX=SQRT(DTIM*2.0*XK/(RO*CP))
      NX=THKNS/DX+1
      IF(NX+1.GE.NMB5)GO TO 999
      NNIS(I,J)=NX
      TK(J)=THKNS/FLOAT(NX)
C  ASSIGN NODE NUMBERS AND INITIAL TEMPERATURES,NODE NUMBERS FOR
C  EACH CONDUCTOR,NODE POSITIONS FOR SLAB AND ABLATOR
      DO 130 K=1,NX
      IC=IC+1
      ICD(IC)=J
```

```
      IU=IC
      IL=IC+1
      L(IC,1)=IU
      L(IC,2)=IL
      TO(IU)=TINIT
      TO(IL)=TINIT
      T(IU)=TO(IU)
      T(IL)=TO(IL)
      XX(IL)=XX(IU)+TK(J)
  130 CONTINUE
      GO TO 7000
  120 CONTINUE
C  ASSIGN NODE NUMBERS,INITIAL TEMPERATURES,NODE NUMBERS FOR EACH
C  CONDUCTOR,NODE POSITIONS FOR ALL OTHER STRUCTURE TYPES
      IC=IC+1
      ICD(IC)=J
      IU=IC
      IL=IC+1
      L(IC,1)=IU
      L(IC,2)=IL
      TO(IU)=TINIT
      TO(IL)=TINIT
      T(IU)=TO(IU)
      T(IL)=TO(IL)
      XX(IL)=XX(IU)+XP(I,J,4)
 7000 CONTINUE
      NNDS=IL
      NCDS=IC
      WRITE(9,769)
      WRITE(9,768)MBP(I)
      IF(METRIK.EQ.0)ATINIT=TINIT-459.6
      IF(METRIK.EQ.1)ATINIT=TINIT/1.8
      IF(METRIK.EQ.0)ATSINK=TSINK-459.6
      IF(METRIK.EQ.1)ATSINK=TSINK/1.8
      WRITE(9,721)ATINIT,UNIT2(METRC),ATSINK,UNIT2(METRC),FIJ
      DO 137 KK=1,NCDS
      NOD1=L(KK,1)
      IF(METRIK.EQ.0)XXX(NOD1)=XX(NOD1)*12.
      IF(METRIK.EQ.1)XXX(NOD1)=XX(NOD1)*12.*2.54
      WRITE(9,770)NOD1,XXX(NOD1),UNIT1(METRC)
      WRITE(9,771)KK
      JST=ICD(KK)
      KST=LS(I,JST)
      WRITE(9,772)KST,CHAR(KST)
C  WRITE OUT DESCRIPTION OF NETWORK
      DO 429 LL=1,3
      MA=MATS(I,JST,LL)
      IF(MA.EQ.0)GO TO 429
      WRITE(9,773)LL,CHAR2(MA)
  429 CONTINUE
  773 FORMAT(1H ,20X,'MATERIAL ',I2,' = ',A10)
      NOD2=L(KK,2)
      IF(METRIK.EQ.0)XXX(NOD2)=XX(NOD2)*12.
      IF(METRIK.EQ.1)XXX(NOD2)=XX(NOD2)*12.*2.54
      WRITE(9,774)NOD2,XXX(NOD2),UNIT1(METRC)
```

```
137     CONTINUE
721  FORMAT(1H ,5X,'TINIT  = ',F7.2,A6,4X,'TSINK = ',F7.2,A6,4X,
    $       'FIJ   = ',F12.3)
768  FORMAT(1H ,28X,'BODY POINT',I5)
769  FORMAT(1H1,25X,'STRUCTURE DEFINITION')
770  FORMAT(//,1H ,15X,'NODE NUMBER = ',I5,7X,
    $       'DISTANCE FROM SURFACE = ',E15.6,A4)
771  FORMAT(1H ,20X,'CONDUCTOR NUMBER = ',I5)
772  FORMAT(1H ,20X,'STRUCTURE TYPE   = ',I5,5X,A20)
774  FORMAT(1H ,15X,'NODE NUMBER = ',I5,7X,
    $       'DISTANCE FROM SURFACE = ',E15.6,A4)
     RETURN
999     CONTINUE
     WRITE(IIN2,998)
     WRITE(9,998)
998  FORMAT(1X,'ERROR---THE NUMBER OF NODES EXCEEDS THE ARRAY ',
    $       'DIMENSIONING.')
     STOP
     END
```

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```
      SUBROUTINE PICTUR(IIN3,MP)
C  SUBROUTINE THATS PRINTS A PICTURE OF THE STRUCTURE AT A BODY POINT
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6,NMB6=10,NMB7=100)
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $      NS(NMB1)
      COMMON/INIT/TSTART,TSTOP,TIMPT,DTIM,NBP,NEXT,METRIC,
     $ METRIK,METRIX,NSTP,IPFLAG,TINI(NMB1),SINKT(NMB1),XFIJ(NMB1),
     $ MBP(NMB1),IIN,IIN2
      COMMON/PICT/NNIS(NMB1,NMB2)
      COMMON/TITLE/CHAR2M,CHAR1,FNAM1,FNAM3
      COMMON/TITL2/CHAR3
      CHARACTER*4  UNIT(2)
      CHARACTER*20 CHAR(7),FNAM1,FNAM3
      CHARACTER*10 CHAR2(NMB7),CHAR3(NMB7),CHAR2M(NMB6)
      CHARACTER*13 CHAR1(NMB6)
      DIMENSION ZXP(NMB1,NMB2,NMB4)
      INTEGER ANS1,ANS2,ANS4,ANS5
      DATA UNIT/' IN.',' CM.'/
C  NAME OF EACH STRUCTURE TYPE
      DATA CHAR/
     1              'SLAB               ',
     2              'RADIATION GAP      ',
     3              'HONEY COMB         ',
     4              'CORRUGATED         ',
     5              'Z STANDOFF         ',
     6              'THIN SKIN          ',
     7              'ABLATOR SUBLIMER   '/
C  CONVERT UNITS OF MAT DIMENSIONS FOR PICTURE
      DO 300 INC1=1,NMB2
      DO 300 INC2=1,NMB4
      IF(METRIK.EQ.0)ZXP(MP,INC1,INC2)=XP(MP,INC1,INC2)*12.
      IF(METRIK.EQ.1)ZXP(MP,INC1,INC2)=XP(MP,INC1,INC2)*12.*2.54
 300  CONTINUE
      METRC=METRIK+1
      IF(IIN3.EQ.9)GO TO 3
C  IF PICTURE DISPLAYED TO SCREEN(NODES NOT INCLUDED)
      DO 2 IKJ=1,NMB7
      CHAR2(IKJ)=CHAR3(IKJ)
 2    CONTINUE
      GO TO 1
 3    CONTINUE
C  IF PICTURE PRINTED TO OUTPUT FILE(NODES INCLUDED)
      DO 4 IKJ=1,NMB6
      CHAR2(IKJ)=CHAR2M(IKJ)
 4    CONTINUE
 1    CONTINUE
C  CREATE THE PICTURE
      IJK=1
      WRITE(IIN3,619)MBP(MP)
C  TOP LAYER BOUNDARY
      IF(IIN3.EQ.5)WRITE(IIN3,620)
      IF(IIN3.EQ.9)WRITE(IIN3,720)IJK
      IJK=IJK+1
C  LOOP 1 - NUMBER OF LAYERS FOR THIS BODY POINT
C     J    - LAYER NUMBER
```

```
C     MP   - BODY POINT NUMBER
C     IIN3 = 5  DISPLAY TO SCREEN        (NODES AVAILABLE)
C     IIN3 = 9  PRINT TO OUTPUT FILE     (NODES NOT AVAILABLE)
      DO 700 J=1,NS(MP)
C  SLAB
      IF(LS(MP,J).EQ.1.AND.IIN3.EQ.5)WRITE(IIN3,621)CHAR2(MATS(MP,J,1)),
     $      CHAR(LS(MP,J)),ZXP(MP,J,1),UNIT(METRC)
      IF(LS(MP,J).EQ.1.AND.IIN3.EQ.9)GO TO 100
C  ABLATOR SUBLIMER
      IF(LS(MP,J).EQ.7.AND.IIN3.EQ.5)WRITE(IIN3,621)CHAR2(MATS(MP,J,1)),
     $      CHAR(LS(MP,J)),ZXP(MP,J,1),UNIT(METRC)
      IF(LS(MP,J).EQ.7.AND.IIN3.EQ.9)GO TO 100
C  RADIATION GAP
      IF(LS(MP,J).EQ.2)WRITE(IIN3,622)ZXP(MP,J,1),UNIT(METRC),
     $CHAR2(MATS(MP,J,1)),CHAR(LS(MP,J)),ZXP(MP,J,4),UNIT(METRC),
     $ZXP(MP,J,2),UNIT(METRC),CHAR2(MATS(MP,J,2))
C  HONEY COMB
      IF(LS(MP,J).EQ.3)WRITE(IIN3,623)ZXP(MP,J,1),UNIT(METRC),
     $CHAR2(MATS(MP,J,1)),CHAR2(MATS(MP,J,3)),CHAR(LS(MP,J)),
     $ZXP(MP,J,4),UNIT(METRC),ZXP(MP,J,2),UNIT(METRC),
     $      CHAR2(MATS(MP,J,2))
C  CORRUGATED
      IF(LS(MP,J).EQ.4)WRITE(IIN3,624)ZXP(MP,J,1),UNIT(METRC),
     $CHAR2(MATS(MP,J,1)),CHAR2(MATS(MP,J,3)),CHAR(LS(MP,J)),
     $ZXP(MP,J,4),UNIT(METRC),ZXP(MP,J,2),UNIT(METRC),
     $      CHAR2(MATS(MP,J,2))
C  Z STANDOFF
      IF(LS(MP,J).EQ.5)WRITE(IIN3,625)ZXP(MP,J,1),UNIT(METRC),
     $CHAR2(MATS(MP,J,1)),CHAR2(MATS(MP,J,3)),CHAR(LS(MP,J)),
     $ZXP(MP,J,4),UNIT(METRC),ZXP(MP,J,2),UNIT(METRC),
     $      CHAR2(MATS(MP,J,2))
C  THIN SKIN
      IF(LS(MP,J).EQ.6)WRITE(IIN3,626)CHAR2(MATS(MP,J,1)),
     $      CHAR(LS(MP,J)),ZXP(MP,J,4),UNIT(METRC)
 200      CONTINUE
C  BOTTOM LAYER BOUNDARY
      IF(IIN3.EQ.5)WRITE(IIN3,620)
      IF(IIN3.EQ.9)WRITE(IIN3,720)IJK
      IJK=IJK+1
      GO TO 700
 100  CONTINUE
C  SLAB / ABLATOR SUBLIMER (CONTINUED)
      NX=NNIS(MP,J)-1
      IF(NX.LE.0)GO TO 11
      NXO2=NX/2+1
      DO 10 K=1,NX
      IF(K.EQ.1.AND.K.LT.NXO2)WRITE(IIN3,800)IJK
      IF(K.GT.1.AND.K.LT.NXO2)WRITE(IIN3,801)IJK
      IF(K.EQ.NXO2)WRITE(IIN3,802)IJK,CHAR2(MATS(MP,J,1)),
     $      CHAR(LS(MP,J)),ZXP(MP,J,1),UNIT(METRC)
      IF(K.GT.NXO2.AND.K.LT.NX)WRITE(IIN3,801)IJK
      IF(K.GT.NXO2.AND.K.EQ.NX)WRITE(IIN3,803)IJK
      IJK=IJK+1
 10   CONTINUE
 11   CONTINUE
```

```
      IF(NX.EQ.0)WRITE(IIN3,621)CHAR2(MATS(MP,J,1)),
     $       CHAR(LS(MP,J)),ZXP(MP,J,1),UNIT(METRC)
      GO TO 200
 700  CONTINUE
 619  FORMAT(1H1,'THIS IS THE CONFIGURATION FOR BODY PT.',I5,///)
 620  FORMAT(1X,60('='),3X,5('-'))
 621  FORMAT(66X,'|',/,
     $       31X,A10,3X,A20,F8.6,A4,/,
     $  66X,'|')
 622  FORMAT(18X,F8.6,A4,1X,A10,25X,'|',/,
     $       1X,60('-')5X,'|',/,
     $  66X,'|',/,
     $  44X,A20,F8.6,A4,/,
     $  66X,'|',/,
     $  1X,60('-')5X,'|',/,
     $  18X,F8.6,A4,1X,A10,25X,'|')
 623  FORMAT(18X,F8.6,A4,1X,A10,25X,'|',/,
     $       1X,60('-')5X,'|',/,
     $  '  |     |     |     |     |   ',36X,'|',/,
     $  '  |     |     |     |     |   ',36X,'|',/,
     $  '  |     |     |     |     |   ',1X,A10,3X,A20,F8.6,A4,/,
     $  '  |     |     |     |     |   ',36X,'|',/,
     $  '  |     |     |     |     |   ',36X,'|',/,
     $  1X,60('-')5X,'|',/,
     $  18X,F8.6,A4,1X,A10,25X,'|')
 624  FORMAT(18X,F8.6,A4,1X,A10,25X,'|',/,
     $       1X,60('-')5X,'|',/,
     $  ' V       V       V       V    ',36X,'|',/,
     $  '  V     V V     V V     V V   ',36X,'|',/,
     $  '   V   V   V   V   V   V   V  ',1X,A10,3X,A20,F8.6,A4,/,
     $  '    V V     V V     V V     V ',36X,'|',/,
     $  '     V       V       V       V',36X,'|',/,
     $  1X,60('-')5X,'|',/,
     $  18X,F8.6,A4,1X,A10,25X,'|')
 625  FORMAT(18X,F8.6,A4,1X,A10,25X,'|',/,
     $       1X,60('-')5X,'|',/,
     $  '   ZZZZZZ           ZZZZZZ    ',36X,'|',/,
     $  '        Z                Z    ',36X,'|',/,
     $  '        Z                Z    ',1X,A10,3X,A20,F8.6,A4,/,
     $  '        Z                Z    ',36X,'|',/,
     $  '        ZZZZZZ           ZZZZZZ',35X,'|',/,
     $  1X,60('-')5X,'|',/,
     $  18X,F8.6,A4,1X,A10,25X,'|')
 626  FORMAT(31X,A10,3X,A20,F8.6,A4)
 720  FORMAT(1X,3('='),I2,'. 0',52('='),3X,5('-'))
 800  FORMAT(4X,I2,'. 0',57X,'|')
 801  FORMAT(4X,I2,'. 0',57X,'|')
 802  FORMAT(4X,I2,'. 0',22X,A10,3X,A20,F8.6,A4)
 803  FORMAT(4X,I2,'. 0',57X,'|')
      RETURN
      END
```

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```
      SUBROUTINE PROP(T1,P,MAT,RHO,CP,XK,EP)
C  UNITS ARE BTU,FT,SEC,OR,LBM
C
C  TABLES ARE DENSITY,SP.HT.,CONDUCTIVITY,EMISSIVITY
C        IN THAT ORDER AND REPEATED
C
C  T1 =TEMP.
C  MAT=MATERIAL NUMBER
C  RHO=DENSITY
C  CP =SPECIFIC HEAT
C  XC =CONDUCTIVITY
C  EP =EMISSIVITY
C
      MDEN=(MAT-1)*4+1
      MSCP=MDEN+1
      MCON=MSCP+1
      MEP=MCON+1
      CALL INTP(T1,P,MDEN,RHO)
      CALL INTP(T1,P,MSCP,CP)
      CALL INTP(T1,P,MCON,XK)
      CALL INTP(T1,P,MEP,EP)
      RETURN
      END
```


C-3

```
      SUBROUTINE RGAP
C  SUBROUTINE COMPUTES EQUIVALENT THERMAL CONDUCTANCE THROUGH
C  RADIADION GAP
      COMMON/GAP/T1,T2,TH1,TH2,TH3,TH,P,H,M1,M2,M3,TOL,BET,SIG,
     $ XM,CAP1,CAP2,XK
      COMMON/PRESS/PRES
      TT1=T1
      TT2=T2
      TAO=T1
      TBO=T2
      DO 100 I=1,100
C  FIND PROPERTIES OF UPPER AND LOWER SURFACES
      CALL PROP(TT1,PRES,M1,RHO1,CP1,XK1,EP1)
      CALL PROP(TT2,PRES,M2,RHO2,CP2,XK2,EP2)
      F1=1.0/EP1
      F2=1.0/EP2
      SF=1.0/(F1+F2-1.0)
      YK1=XK1/TH1
      YK2=XK2/TH2
      YK3=SIG*SF*(TAO**2+TBO**2)*(TAO+TBO)
C  COMPUTE INTERIOR SURFACE TEMPERATURE OF UPPER AND LOWER SURFACE
      TA=((T1*YK1+TBO*YK3)/(YK1+YK3))*BET+(1.0-BET)*TAO
      TB=((T2*YK2+TAO*YK3)/(YK2+YK3))*BET+(1.0-BET)*TBO
      TEST1=ABS((TA-TAO)/TAO)
      TEST2=ABS((TB-TBO)/TBO)
C  CHECK FOR CONVERGENCE
      IF(TEST1.LT.TOL.AND.TEST2.LT.TOL)GO TO 200
      TT1=(T1+TA)/2.0
      TT2=(T2+TB)/2.0
      TAO=TA
      TBO=TB
 100  CONTINUE
      GO TO 300
 200  CONTINUE
C  COMPUTE EQUIVALENT CONDUCTANCE
      XK=YK1*YK2*YK3/(YK1*YK2+YK1*YK3+YK2*YK3)
      XM=RHO1*TH1+RHO2*TH2
      CAP1=RHO1*TH1*CP1
      CAP2=RHO2*TH2*CP2
 300  CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SRIPF(NN)
C  SUBROUTINE TO FIND RADIATION INTERCHANGE FACTORS
C  GIVEN EMISSIVITIES,GEOMETRIC VIEW FACTORS,AREAS UNING THE
C  NETWORK METHOD
      COMMON/SF/AR(10),EPP(10),F(10,10),ASF(10,10)
      DIMENSION EB(10),XJ(10),XJN(10),RHO(10)
      TOL=.001
      BETA=.5
      EMPOW=1000.0
      N=NN
      DO 100 I=1,N
      RI=FLOAT(I)
      EB(I)=EMPOW*RI
      RHO(I)=1.0-EPP(I)
      XJ(I)=EB(I)
  100 CONTINUE
C  ITERATE ON RADIOSITY,XJ
      DO 500 M=1,50
      TESTM=1.0E-8
      DO 200 J=1,N
      SUMJF=0.C
      F1=EPP(J)/(1.0-RHO(J)*F(J,J))*EB(J)
      F2=RHO(J)/(1.0-RHO(J)*F(J,J))
      DO 300 K=1,N
      IF(J.EQ.K)GO TO 300
      SUMJF=SUMJF+XJ(K)*F(J,K)
  300 CONTINUE
      XJN(J)=(1.0-BETA)*XJ(J)+BETA*(F1+F2*SUMJF)
      TEST=ABS(XJ(J)-XJN(J))/XJ(J)
      IF(TEST.GT.TESTM)TESTM=TEST
      XJ(J)=XJN(J)
  200 CONTINUE
      IF(TESTM.LT.TOL)GO TO 600
  500 CONTINUE
  600 CONTINUE
C  COMPUTE NET EXCHANGE BY RADIOSITY DIFFERENCE
C  COMPUTE AREA*SCRIPT "F" BY DIVISION BY BLACK BODY EMISSIVE POWER
      DO 800 I=1,N
      DO 900 J=1,N
      ASF(I,J)=0.0
      IF(I.EQ.J)GO TO 900
      ASF(I,J)=AR(I)*F(I,J)*(XJ(I)-XJ(J))/(EB(I)-EB(J))
  900 CONTINUE
  800 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STAND
C  SUBROUTINE TO COMPUTE EQUIVALENT CONDUCTANCE,MASS,CAPACITANCE
C  OF Z STANDOFF STRUCTURE
      COMMON/GAP/T1,T2,TH1,TH2,TH3,TH,P,H,M1,M2,M3,TOL,BET,SIG,
     $ XM,CAP1,CAP2,XK
      COMMON/FACT/XX(10,2),YY(10,2)
      COMMON/SF/AR(10),EPP(10),F(10,10),ASF(10,10)
      COMMON/PRESS/PRES
      H2=TH/2.0
      P2=P/2.0
      CONK=1.0E8
      T3=(T1+T2)/2.0
      VOL=TH1+TH2+(2.0*H+TH)*TH3/P
C  SET COORDINATES OF INTERIOR TO COMPUTE VIEW FACTORS
      DO 100 I=1,4
      XT=0.0
      YT=0.0
      DO 200 J=1,2
      IF(I.EQ.1.AND.J.EQ.1)YT=TH
      IF(I.EQ.1.AND.J.EQ.2)XT=P
      IF(I.EQ.2.AND.J.EQ.2)XT=P
      IF(I.EQ.3.AND.J.EQ.1)XT=P
      IF(I.EQ.3.AND.J.EQ.2)YT=TH
      IF(I.EQ.4.AND.J.EQ.2)YT=TH
      XX(I,J)=XT
      YY(I,J)=YT
  200 CONTINUE
  100 CONTINUE
C  COMPUTE INTERIOR VIEW FACTORS
      CALL VFAC(4)
      DO 1000 I=1,100
      T30=T3
      CALL PROP(T1,PRES,M1,RHO1,CP1,XK1,EPP(1))
      CALL PROP(T2,PRES,M2,RHO2,CP2,XK2,EPP(2))
      CALL PROP(T3,PRES,M3,RHO3,CP3,XK3,EPP(3))
      EPP(4)=EPP(3)
      IF(I.NE.1)GO TO 1001
C  GET RADIATION INTERCHANGE FACTORS
      CALL SRIPF(4)
 1001 CONTINUE
C  COMPUTE CONDUCTION PATH VALUE
      C1A=XK1*TH1/P2
      C1B=CONK*TH3/2.0
      C1C=XK3*TH3/(2.0*H2)
      C1=C1A*C1B*C1C/(C1A*C1B+C1A*C1C+C1B*C1C)
      DIS=P2-(H+TH3)/2.0
      C3A=XK1*TH1/DIS
      C3B=CONK*(H+TH3/2.0)
      C3C=XK3*TH3/(2.0*H2)
      C3=C3A*C3B*C3C/(C3A*C3B+C3A*C3C+C3B*C3C)
      C2C=C3C
      C2B=C3B
      C2A=C1A*XK2/XK1
      C2=C2A*C2B*C2C/(C2A*C2B+C2A*C2C+C2B*C2C)
      C4A=C1A*XK2/XK1
```

```
      C4B=C1B
      C4C=C1C
      C4=C4A*C4B*C4C/(C4A*C4B+C4A*C4C+C4B*C4C)
C  COMPUTE RADIATION PATH VALUES
      R1=ASF(1,4)*SIG*(T1**2+T3**2)*(T1+T3)
      R2=ASF(1,3)*SIG*(T1**2+T3**2)*(T1+T3)
      R3=ASF(4,2)*SIG*(T3**2+T2**2)*(T3+T2)
      R4=ASF(3,2)*SIG*(T3**2+T2**2)*(T3+T2)
      R5=ASF(1,2)*SIG*(T1**2+T2**2)*(T1+T2)
C  FIND NEW STANDOFF TEMPERATURE
      T3N=(T1*(R1+R2+C1+C3)+T2*(C2+R3+C4+R4))/
     $ (R1+R2+R3+R4+C1+C2+C3+C4)
      T3=(1.0-BET)*T3+BET*T3N
      TEST=ABS(T3-T30)/T3
      IF(TEST.LT.TOL)GO TO 2000
      T30=T3
 1000 CONTINUE
 2000 CONTINUE
C  FIND MASS,CAPACITORS,AND EQUIVALENT CONDUCTIVITY
      XM=TH1*RHO1+TH2*RHO2+RHO3*(2.0*H+TH)*TH3/P
      CAP1=XM/2.0*CP1
      CAP2=XM/2.0*CP2
      T12=ABS(T1-T2)
      T13=ABS(T1-T3)
      Q=(T12*R5+T13*(C2+C4+R3+R4))/P
      XK=Q/T12
      RETURN
      END
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```
      SUBROUTINE STRUCT(M,N)
C  SUBROUTINE THAT HANDLES STRUCTURE FILE
C  EITHER ADDING NEW STRUCTURES OR COPYING OLD STRUCTURE
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6,NMB6=10)
      COMMON/INIT/TSTART,TSTOP,TIMPT,DTIM,NBP,NEXT,METRIC,
     $ METRIK,METRIX,NSTP,IPFLAG,TINI(NMB1),SINKT(NMB1),XFIJ(NMB1),
     $ MBP(NMB1),IIN,IIN2
      COMMON/TITLE/CHAR2,CHAR1,FNAM1,FNAM3
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $ NS(NMB1)
      CHARACTER*10 CHAR2(NMB6)
      CHARACTER*13 CHAR1(NMB6)
      CHARACTER*20 FNAM1,FNAM3
      CHARACTER*80 LABEL1,LABEL2
      IFLAG=-9999
      OPEN(UNIT=10,NAME=FNAM3,TYPE='OLD',RECORDSIZE=132)
      IF(M.EQ.2)GO TO 500
C  LOOKUP OLD STRUCTURE FROM STRUCTURE FILE
 10   WRITE(IIN2,20)MBP(N)
 20   FORMAT(1H ,'WHAT IS THE STRUCTURE NUMBER FOR BODY PT. ',I5,' ?')
     - READ(IIN,*,ERR=10,END=1234)ND
C  LOCATE STRUCTURE BY STRUCTURE NUMBER
 35   READ(10,40,END=9000)NA
 40   FORMAT(I5)
      IF(NA.EQ.ND)GO TO 150
      IF(NA.EQ.IFLAG)GO TO 9000
      GO TO 35
C  REACHED END OF FILE WITHOUT LOCATING STRUCTURE NUMBER
 9000 WRITE(IIN2,9001)ND
 9001 FORMAT(1H ,'UNABLE TO FIND STRUCTURE NUMBER ',I5)
      REWIND (UNIT=10)
      GO TO 10
 150  CONTINUE
      BACKSPACE (UNIT=10)
C  OBTAIN STRUCTURE DATA FOR DESIRED STRUCTURE NUMBER
      READ(10,55)NA,NS(N),N3,N4
 55   FORMAT(I5,5X,3(I5,5X))
      READ(10,60)LABEL1,LABEL2
 60   FORMAT(5X,A80,/,5X,A80)
      WRITE(IIN2,70)NA,LABEL1,LABEL2
 70   FORMAT(/,10X,'STRUCTURE NUMBER = ',I5,/,1X,A80,/,1X,A80)
      DO 200 I=1,NS(N)
      READ(10,210,END=1000)LS(N,I),(MATS(N,I,J),J=1,N3),
     $ (XP(N,I,J),J=1,N4)
 210  FORMAT(10X,I5,3I5,6E15.7)
 200  CONTINUE
      GO TO 1000
C
C  ADD NEW STRUCTURE TO STRUCTURE FILE
 500  CONTINUE
 510  WRITE(IIN2,520)MBP(N)
 520  FORMAT(1H ,'WHAT IS THE STRUCTURE NUMBER FOR BODY PT. ',I5)
      READ(IIN,*,ERR=510,END=1234)ND
C  SEARCH THROUGH STRUCTURE FILE
 551  DO 550 IK=1,1000
```

```
      READ(10,40,END=560)NB
C  CHECK TO SEE IF STRUCTURE NUMBER ALREADY EXISTS
      IF(ND.EQ.NB)WRITE(IIN2,530)ND
 530  FORMAT(1H ,'STRUCTURE NUMBER ',I5,' ALREADY EXISTS.')
      IF(ND.EQ.NB)REWIND (UNIT=10)
      IF(ND.EQ.NB)GO TO 510
C  CHECK FOR END OF FILE
      IF(NB.EQ.IFLAG)GO TO 560
 550  CONTINUE
      GO TO 551
 560  BACKSPACE (UNIT=10)
C  ADD NEW STRUCTURE DATA
      N4=NMB4
      N3=NMB3
      WRITE(10,570)ND,NS(N),N3,N4
 570  FORMAT(I5,5X,3(I5,5X))
      WRITE(IIN2,580)MBP(N)
 580  FORMAT(1H ,'GIVE A TWO LINE DESCRIPTION OF THE STRUCTURE',
     $ ' FOR BODY PT. ',I5)
      READ(IIN,590)LABEL1,LABEL2
 590  FORMAT(A80,/,A80)
      WRITE(10,600)LABEL1,LABEL2
 600  FORMAT(5X,A80,/,5X,A80)
      DO 700 I=1,NS(N)
      WRITE(10,610)LS(N,I),(MATS(N,I,J),J=1,N3),(XP(N,I,J),J=1,N4)
 610  FORMAT(10X,I5,3I5,6E15.7)
 700  CONTINUE
      WRITE(10,800)IFLAG
 800  FORMAT(I5)
 1000 CONTINUE
      CLOSE (UNIT=10,STATUS='KEEP')
      RETURN
 1234 CONTINUE
      STOP
      END
```

```
      SUBROUTINE SUBPR(X,N,Y)
C  SUBROUTINE TO RETURN TEMPERATURE OF SUBLIMATION AND HEAT OF
C  SUBLIMATION,Y,GIVEN PRESSURE,X.
C
C      N = 1  RETURN TEMPERATURE
C      N = 2  RETURN PRESSURE
C      X =    PRESSURE
C
      PARAMETER (NMB9=41)
      COMMON/CSUB/CCS(2,NMB9)
      J=CCS(N,1)
      J1=J*2
      XLST=CCS(N,2)
      XHST=CCS(N,J1)
      IF(X.EQ.XLST)GO TO 700
      IF(X.LT.XLST)GO TO 100
      IF(X.GT.XHST)GO TO 200
      JT=4
  500 CONTINUE
C  SEARCH INDEPENDENT VARIABLE
      IF(CCS(N,JT)-X)300,600,400
  300 CONTINUE
C  GO BACK AND CHECK ANOTHER
      JT=JT+2
      GO TO 500
  400 CONTINUE
C  X LIES BETWEEN CCS(N,N1) AND CCS(N,N3)
      N1=JT-2
      N2=N1+1
      N3=JT
      N4=N3+1
      GO TO 900
  600 CONTINUE
C  X EQUAL TO A INDEPENDENT VARIABLE
      NT=JT+1
      Y=CCS(N,NT)
      GO TO 1000
  700 CONTINUE
C  X EQUAL TO LOWEST INDEPENDENT VARIABLE
      Y=CCS(N,3)
      GO TO 1000
  100 CONTINUE
C  X LESS THAN LOWEST INDEPENDENT VARIABLE, EXTRAPOLATE
      N1=2
      N2=3
      N3=4
      N4=5
      GO TO 900
  200 CONTINUE
C  X GREATER THAN HIGHEST INDEPENDENT VARIABLE, EXTRAPOLATE
      N1=2*J-2
      N2=N1+1
      N3=2*J
      N4=N3+1
  900 CONTINUE
```

```
C  FIND SLOPE AND INTERPOLATE
      SL=(CCS(N,N4)-CCS(N,N2))/(CCS(N,N3)-CCS(N,N1))
      Y=CCS(N,N2)+SL*(X-CCS(N,N1))
 1000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE THINS
C  SUBROUTINE TO SET CAPICITANCE,MASS,AND CONDUCTOR OF INFINITELY
C  CONDUCTING OR THERMALLY THIN PLATE
      COMMON/GAP/T1,T2,TH1,TH2,TH3,TH,P,H,M1,M2,M3,TOL,BET,SIG,XM,
     $       CAP1,CAP2,XK
      COMMON/PRESS/PRES
      T=(T1+T2)/2.0
      CALL PROP(T,PRES,M1,RO,CP,XK,EP)
      CAP1=RO*CP*TH/2.0
      CAP2=CAP1
      XM=RO*TH
      XK=1.0E10
      RETURN
      END
```

```
      SUBROUTINE TMSTEP(DTSM,I)
C  SUBROUTINE TO COMPUTE STABLE TIME STEP
      PARAMETER (NMB1=20,NMB2=6,NMB3=3,NMB4=6,NMB5=40)
      COMMON/TIME/NNDS,CONV,CRAD,STAB,ISBFG,NCDS
      COMMON/ARA/T(NMB5),TO(NMB5),C(NMB5),CD(NMB5),ICD(NMB5),L(NMB5,2)
      COMMON/LD/LS(NMB1,NMB2),XP(NMB1,NMB2,NMB4),MATS(NMB1,NMB2,NMB3),
     $      NS(NMB1)
      DTSM=1.0E30
C  GENERAL HEAT BALANCE NODE
      DO 379 J=1,NNDS
      IF(J.NE.1)GO TO 380
C  SURFACE NODE
      C1=CONV+CRAD
      C2=CD(1)
      GO TO 381
  380 CONTINUE
      IF(J.NE.NNDS)GO TO 370
C  LAST NODE
      C1=CD(NCDS)
      C2=0.0
      GO TO 381
  370 CONTINUE
C  GENERAL NODE
      JM1=J-1
      C1=CD(JM1)
      C2=CD(J)
  381 CONTINUE
C  IF ADJACENT CONDUCTORS ARE THIN SKIN,SKIP
      IF(C1.GT.1.0E9) GO TO 379
      IF(C2.GT.1.0E9) GO TO 379
      STEST=C(J)/((C1+C2)*STAB)
      IF(STEST.LT.DTSM)DTSM=STEST
  379 CONTINUE
C  THIN SKIN ALGORITHM
      IF(ISBFG.EQ.0)GO TO 382
      DO 387 KAP=1,NCDS
      JJ=ICD(KAP)
      JN=LS(1,JJ)
      IF(JN.NE.6)GO TO 387
      N1=L(KAP,1)
      N2=L(KAP,2)
      KP1=KAP+1
      KM1=KAP-1
      IF(KAP.EQ.1)GO TO 388
      IF(KAP.EQ.NCDS)GO TO 389
C  GENERAL THIN SKIN NODE
      STEST=(C(N1)+C(N2))/((CD(KM1)+CD(KP1))*STAB)
      GO TO 390
  388 CONTINUE
C  SURFACE NODE
      STEST=(C(N1)+C(N2))/((CONV+CRAD+CD(KP1))*STAB)
      GO TO 390
  389 CONTINUE
C  ADIABATIC BACK SIDE
      STEST=(C(N1)+C(N2))/(CD(KM1)*STAB)
```

```
390  CONTINUE
     IF(STEST.LT.DTSM)DTSM=STEST
387  CONTINUE
382  CONTINUE
     RETURN
     END
```

```
      SUBROUTINE VFAC(NN)
C
C      THEORY OF CROSSED STRINGS (PLANAR 2-D)
C
      COMMON/FACT/XX(10,2),YY(10,2)
      COMMON/SF/AR(10),EPP(10),F(10,10),ASF(10,10)
      N=NN
      DO 100 I=1,N
      SUMF=0.0
C  FIND AREA OF SURFACE I
      CALL DIST(I,1,I,2,AR(I))
      DO 200 J=1,N
C  FIND LENGTHS OF CROSSED AND UNCROSSED STRINGS
      CALL DIST(I,1,J,1,D11)
      CALL DIST(I,1,J,2,D12)
      CALL DIST(I,2,J,1,D21)
      CALL DIST(I,2,J,2,D22)
C  FIND WHICH ARE CROSSED
      S1=D11+D22
      S2=D12+D21
      A1=S1
      A2=S2
      IF(S1.GT.S2)GO TO 201
      A1=S2
      A2=S1
 201      CONTINUE
      F(I,J)=0.0
      IF(I.EQ.J)GO TO 200
      F(I,J)=(A1-A2)/(2.0*AR(I))
C  SUM OF VIEW FACTORS SHOULD EQUAL ONE FOR ENCLOSURE
      SUMF=SUMF+F(I,J)
 200      CONTINUE
 100      CONTINUE
      RETURN
      END
```